Power Quality Programme Awareness: Framework for Developing Countries

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by

Saad Saleh Sultan

Electronics and Computer Engineering

School of Engineering and Design

Brunel University

London, UK

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وَقُل رَّبِّ زِدْنِى عِلْمًا

‘O lord! Increase me in knowledge.’

[*Surah Taha: Ayah 114*]

Abstract

In recent years, Power Quality Programmes (PQPs) have become one of the most recent services offered to electrical distribution companies, both private and state suppliers. This is due to the sudden increase in the number of concerns over power quality (PQ) problems. The aim of this research is to study the implementation of a PQP framework, and the obstacles and barriers faced by Libyan Distribution Networks (LDNs) in implementing a PQP. Firstly, to identify the most critical success factors that would have a major impact on PQP implementation in LDNs. Five Critical Success Factors (CSFs) for PQP were identified to examine the level of power quality in LDNs. They are PQ awareness, PQ disturbances, PQ management commitment, PQ employee's participation and training and PQ customers' satisfaction. It revealed that all five CSFs were significantly affected by the level of PQ awareness, and the suspension of PQP implementation.

An appropriate PQP framework was developed for the purpose of this study to guide LDNs as a case study in developing countries. The proposed PQP framework model was validated based on the identified CSFs, and the barriers and benefits of PQP, which were analysed using different techniques based on both SPSS and NVivo software. The PQP framework was developed from the findings based on the responses of 397 PQ survey participants, and supported by 44 face-to-face semi-structured interviews conducted with professionals and expert LDNs staff. Out of the 16 PQP barriers, 13 were statistically significant, which indicated that Libya distribution systems have already surmounted various barriers to implementing a PQP effectively.

The developed PQP framework consisted of three essential phases. Phase one is designed to increase the level of awareness, while phase two involves preparation for PQP, which contains seven crucial requirements. Phase three, which is the implementation, is designed to determine both the weaknesses and obstacles, and is designed to increase the awareness level. This framework encourages and guides the implementation teams to have an obvious and clear awareness and vision of how to prevent existing obstacles from reappearing in different forms, leading to long-term PQP improvements. There were 11 overall benefits of PQP implementation, which would have a positive impact on LDNs.

Keywords: Critical Success Factors, Power Quality Programme Barriers, Benefits, Libyan Distribution Networks, Power Quality Programme Framework and Roadmap.

Dedication

This thesis is dedicated to my magnificent parents, Saleh and Salima, my fabulous brothers, wonderful sisters, and to all my great family members' uncles, cousins and my best friends with love and gratitude for their prayers, and endless support.

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Author's Declaration

I, Saad Saleh Sultan, declare that the ideas, research work, analyses, findings and conclusions reported in my PhD thesis *Critical Factors Facing Implementation of Total Power Quality Programme Framework in Developing Countries: Case Study-Libyan Electrical Distribution Networks* are entirely my effort, except where otherwise acknowledged. Also, I certify that this thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work.

Publications from this research work

Conference Papers:

1. Saad. S. Sultan, M. K. Darwish, "Critical analysis of the barriers and benefits of implementing a power quality programme framework: Case Study Libyan distribution networks", presented in *47th International Universities' Power Engineering Conference (UPEC 2012)*, Brunel University, London, UK. 4 - 7 September 2012, published in IEEE pp. 1 – 6.

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5. Saad. S. Sultan "Statistical Evaluation of Power Quality Programme Framework in Libyan Distribution Networks", presented at *Brunel University Graduate School*, Research Student Poster Conference 13-14 March 2012.

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List of Symbols

α	Cronbach Alpha
β	Standardised Regression Weight
μs	Micro Second
AC	Alternative Current
DC	Direct Current
Df	Degree of Freedom
Eta squared	Effect Size
F	Variance between Groups
GWh	Gigawatt Hour
HV	High Voltage
Hz	Hertz
KHz	Kilohertz
KV	Kilo voltage
KWh	Kilowatt Hour
LD	Libyan Dinar
LV	Low Voltage
M	Mean Level
MHz	Megahertz
Min	Minute
Ms	Millisecond
MV	Medium Voltage

MW	Megawatt
MWh	Megawatt Hour
Ns	Nano Second
P	Significant Value
Post-Hoc	Different Between Groups
PU	per Unit
r	Pearson Correlation
R^2	The variance of the model explained (independent variables)
RMS	Root Mean Square
S	Second
S.D	Standard Deviation
SE	Standard Error
Sq	Square
T	Indicate the significant Contribution of Predictor Variables to The model
THD	Total Harmonic Distortion
V	Voltage
VIF	Variance inflation Factor

List of Abbreviations

ANOVA	Analysis of Variance
CEC	Commission of the European Communities
CEIDS	Consortium for Electric Infrastructure for a Digital Society
CNC	Computerized Numerical Control
CSFs	Critical Success Factors
DVRs	Dynamic Voltage Restorers
EDN3	Eastern distribution network
EEC	Electromagnetic of the European Communities
EFA	Exploratory Factor Analysis
EMC	Electromagnetic Compatibility
EN	European standard
EPRI	Electric Power Research Institution
EU	European Union
GECOL	General Electrical Company of Libya
GFCIs	Ground Fault Circuit Interrupters
GMMRP	Great Man-Made River Project
HVAC	Heating-Ventilation-Air Conditioning
IEC	International Electromagnetic Commission
IEEE	Institution of Electrical and Electronic Engineering
INSPEC	Information Services for the Physics and Engineering Communities
KEMA	Verification of Electrical Materials

KMO	Kaiser-Mayer-Olkin
LDNs	Libyan Distribution Networks
LPQI	Leonardo Power Quality Initiative
LSD	Least Significance Difference
MANOVA	Multivariate Analysis Of Variance
Mon	Monitoring Method
MVLR	Multivariable Linear Regression
NVivo	Qualitative Data Analysis Computer Software Package
PC	Personal Computers
PCA	Principal Component Analysis
PLC	Programmable Logic Controllers
P-P	Plot Regression Standardised Residuals
PQPBA	Power Quality Programme Barriers
PQPBN	Power Quality Programme Benefits
PQ	Power Quality
PQCCA	Power Quality Customers and Company Awareness
PQCS	Power Quality Customer Satisfaction
PQD	Power Quality Definition
PQDANs	Power Quality Disturbances Affecting Networks
PQDs	Power Quality Disturbances
PQEPT	Power Quality Employee Participation and Training
PQMC	Power Quality Management Commitment
PQP	Power Quality Programme

PQPS	Power Quality Physical Solutions
PQSs	Power Quality Surveys
QL	Qualitative Method
QN	Quantitative Method
RII	Relative Importance Index
SDN2	Southern distribution network
SPSS	Statistical Package for the Social Sciences
UK	United Kingdom
UNUCRD	United Nations Universal Consumer Rights Declaration
UPS	Uninterruptible Power Supplies
USA	United State of America
VCR	Video Cassette Recorders
VSC	Voltage Sag Compensators
VSD	Variable Speed Drives
WDN1	Western distribution network

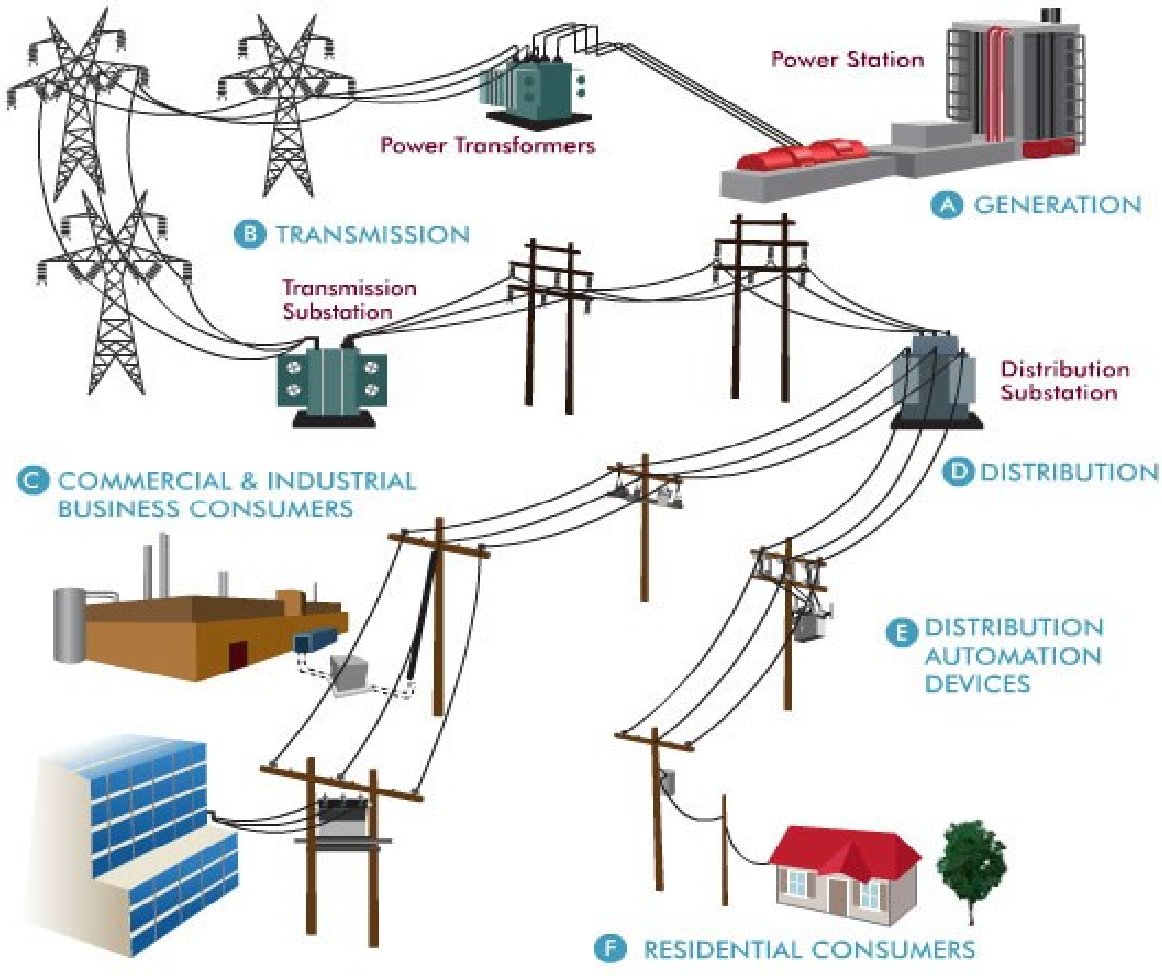
Chapter One: Introduction

1.1 Introduction

In recent years, PQPs have become one of the most recent services offered to distribution companies, both private and state suppliers. For any distribution system to satisfy its consumers, the utility must keep improving PQ in a way, which accommodates the increased demand for electricity [1][2]. This requires a PQP to be implemented to start tackling the difficulties facing the distribution utilities in sustaining a high standard of PQ. A PQP can help in reducing the huge number of complaints from end users, and the costs represented in the damage to their equipment [3]. It can also have a positive impact on the electrical distribution companies, improving their service and saving some of the significant resources spent. Therefore, distribution companies need to implement a PQ investigation programme, given all the facts indicating an increase in PQDs, particularly in the last two decades [4].

However, Electricity is being considered in the same way as any other product [5]. Ever since 1980, the idea has been that both "reliability and power quality are synonymous" [6]. This meant that the continuity of power supplied was at a standard level used to measure the quality of this product [7]. Therefore, over the last three decades, the quality of electricity was held at an acceptable level. This is because generation plants were close to the load centres [8], and distribution and transmission networks were designed to carry the electricity over short distances [9]. Hence, both the reliability and PQDs were not issues of concern as they are today [9][10]. However, since 1980, power quality issues have started causing disturbances in distribution systems worldwide [11]. As a result, both reliability and power quality have become significantly crucial issues for most distribution utilities worldwide. Thus, the distinction is made between power quality and reliability, each having its own characteristics. Reliability is represented in measurements for the disturbance lasting more than a minute, while power quality is represented in the measurement of disturbances lasting less than a minute [9]. Moreover, when the use of non-linear equipment expanded, replacing the linear, this distinction was considered in most distribution utilities due to their sensitivity to PQDs caused by non-linear tools

[6][12]. Figure 1.1 explains the typical diagram of the three power systems generators, transmission and distribution.



Source [13]

Figure 1.1: Diagram of the three power generation, transmission and distribution systems

On the other hand, figure 1.1 shows how PQP implementation is essential for the future of PQ, especially in urban, rural and remote areas in developing countries to cope with all expansions in generation and transmission systems, which force the distribution systems to suffer lack of power quality [14]. This is due to lack of designing the distribution networks to meet the end user expectation as well as the growth demand. Therefore, PQPs allow distribution utilities to improve the power supply by conducting such programmes regularly to reduce end users' complaints, and satisfy them in a way appropriate to their expectations. In addition, implementing a PQP can overcome barriers, including the lack of: a clear strategy, end user awareness, accommodation for economic growth, equipment standards, distribution network design, planning and infrastructure, resources, staff awareness, skills and experience, top management responsibility and commitment, training courses and support, and financial resources, as well as PQ measurement, consultants, standards, monitoring and databases. In addition, PQPs can increase the knowledge and skills of distribution utilities' staff by overcoming the complicated PQDs that most frequently occur by offering them education and training courses to raise PQ awareness.

In contrast, utilities in less developed countries are being pushed by the introduction of new technology from developed countries to improve and address their PQ issues. In response, some distribution companies have contracted third parties to solve PQ issues to their end users' satisfaction. This is due to the inability of their engineers and technicians, who lack the skills and experience, to solve these problems [15]. Indeed, government-controlled utilities are detached from the situation, with regard to PQ issues. The failure to implement PQPs by some distribution utilities in developing countries has resulted in them supplying free power to their customers.

Distribution utilities in less developed countries are not concerned about the quality of power they provide to their clients. They believe that PQ has matured to the point, where it will not be of any importance in the future. Moreover, their customers only want to be supplied with electricity, and are not concerned with quality [16]. Therefore, some managers from distribution companies have concluded that international electricity companies consider implementing PQP as a business, rather than concerning themselves with issues of power distribution systems [15].

In addition, government-controlled distribution utilities need support from public and private sector bodies in raising PQ awareness, so as to become part of their culture. The absence of PQ awareness will lead to significant effect on both utilities' and end users' equipment, costing them money. Therefore, there is a need for a "*PQ awareness programme*", which would be responsible for spreading PQP services across the distribution systems, and can provide those services to the utilities that need to improve PQ performance [1].

On the other hand, researches and concerns in power quality (PQ) gained significant momentum in the field of power electronics systems over the last two decades globally.

This sudden increase in the number of concerns over PQ problems is a result of the huge increase in the use of non-linear loads.

The purpose of this study is to present a statistical analysis of a PQ survey conducted in Libyan Distribution Networks (LDNs). It also explores the obstacles faced by LDNs in implementing a power quality programme (PQP) as well as to state the benefits, which would accrue by implementing a PQP; this would have a major impact on the distribution networks. In order to achieve these objectives, an extensive literature review was conducted, first, to identify the most Critical Success Factors (CSFs) facing implementing PQP. Five CSFs were identified in examining the level of PQ in LDNs. The test pointed out that all five factors were positively correlated, and revealed a low level of PQP implementation among LDNs.

1.2 Research Questions

1. What is the actual overall level of the PQDs, in terms of measurements, solutions and implementation regarding PQ awareness?

2. What is the current state of PQ awareness and efforts regarding PQP implementation in LDNs?

3. What are the most significant success factors of implementing a PQP regarding PQ awareness within LDNs in GECOL?

4. Are there any statistically significant differences between the level of PQ awareness regarding employee characteristics, in terms of position, education, responsibility and experience within LDNs, and the success factors derived from the literature needed for implementation of a PQP for satisfying future needs?
5. What are the difficulties and barriers facing LDNs in implementing PQP?

6. What type of PQP implementation model framework should be developed in order to guide LDNs in improving PQDs and what are the requirements involved in the PQP implementation?

7. How the PQP framework can be implemented, and what are the stages involved in the roadmap process and what are the outcomes gained after implementing PQP framework followed each process stage of the roadmap?

1.3 Research aim and objectives

The aim of this research is to develop a PQP framework for evaluating PQDs in developing countries case study LDNs in two ways. Firstly, to identify the most significant CSFs that would have a major impact on PQ improvement to facilitate PQP implementation. Secondly, to study the PQP implementation framework, and the obstacles and barriers faced by LDNs utilities in implementing a PQP. Therefore, this framework if adapted by the electrical distribution networks not only in developing countries but also in developed countries, which will encourage and guide implementation teams, to have an obvious and clear vision of how to prevent existing obstacles from reappearing in different forms, leading to long-term improvements. This can determine the PQ levels from perspectives of both end users and staff, and so create greater understanding and awareness.

In order to achieve the research aim, the following objectives are formulated to facilitate developing an appropriate PQP framework for LDNs;

1. To state the current situation of PQDs efforts in distribution networks in GECOL.
2. To determine the present level of knowledge and awareness regarding PQ for LDNs staff and to state the actual needs of the PQP, in terms of training courses, management planning, PQDs involvement and awareness.
3. To investigate the main reasons underlying PQP barriers leading to PQDs in LDNs.
4. To gain better understanding of the extent to which commercial, industrial, agriculture and domestic end users are aware of PQ problems.
5. To identify the most critically significant factors, that would have a major impact on PQDs and PQP implementation, in order to facilitate developing PQP

framework as guidelines through which LDNs could implement, maintain, and improve the power supply, in terms of quality, for customers.

6. To investigate the extent to which LDNs staff and end users could play a role in solving PQ problems with the rapid expansion in the economy, and advances in high technology of sensitive electronic equipment.

1.4 Study Motivations

Since 1980, PQ issues have been causing significant disturbance to the distribution systems and end users, becoming a global concern [5, 6, 17, 18]. This is due to lack of tackling the power quality programme barriers as well as low level of the critical success factors, which still existing in the electrical distribution utilities. Therefore, the end users always blame and point to the utility as delivering poor power quality [5][19]. However, despite previous PQP frameworks' contributions to understanding the barriers and benefits of implementing PQP and after the comprehensive literature review there was a need to develop a PQP framework to solve power quality disturbances for long term improvements due to the following factors:

- There is a lack of PQP implementation resulting from a lack of management strategy to cope with the expansion in generation and transmission systems.
- There is a lack of PQ standards to be followed by the electrical distribution utilities in any evaluation or comparison of PQD records.
- There is a lack of employee experience and skills arising from a lack of awareness of PQ, and so employees are not equipped to deal with PQ problems technically.
- There is a lack of end user awareness of the concept of PQ given the excessive use of non-linear loads and sensitive equipment.
- There is a lack of management planning in the proper design of distribution networks.
- There is a lack of control over the import of electronic equipment since 1990, due to competitive marketing and deregulation.

1.5 Research Contributions

The contributions to knowledge of this study can be highlighted from different dimensions including the following:

- This study is the first to investigate the barriers of PQP within Libyan distribution systems. It contributes by providing an insight into the overall efforts needed to implement PQP framework and the main reasons underlying its failure. It is also the first to explore the expected benefits, to be gained of implementing PQP. The findings are used to develop the PQP framework guideline to be implemented in LDNs. The findings also revealed the significant issues, which LDNs have to consider when planning to implement PQP.

- This study reveals poor implementation level of CSFs in LDNs, because they are not moving from the suggested strategies to realistic performance. This is mainly due to lack of PQP awareness. Therefore, this study alerts LDNs about the importance of implementing PQP, including the CSFs and barriers and the benefits would be gained to improve PQ.

- This study has ranked the critical success factor (CSFs) based on each significant factor affected the PQP implementation. The ranking of all five CSFs of PQP, in order is: PQ awareness, PQ disturbances, PQ management commitment, PQ employees' participation and training and PQ customer satisfaction.

- In this study, the PQP implementation framework model for Libyan distribution networks was investigated based on Thirty-Four sub-factors of the CSFs. These are distilled into five single factors (PQ awareness, PQ definition, PQ management commitment, PQ employee's participation and training and PQ customers' satisfaction). All the items were selected to measure their influence on PQP implementation in LDNs. These were Reliability and Availability, Satisfy Customers, Reduce Losses, Customer Awareness, Increase Efficiency, Customer Complaints, Customer Satisfaction, Customers' Needs, Improvement for Customers and Customer

Awareness, Identifies the Causes, Inaccurate Managerial Decision, Planning Good Strategy, Following the recommendations and studies, Ensure Security and Quality, International or National PQ Benchmarks, Survey or Feedback Techniques, Sufficient Training, Employees Suggestions, Employees Strategies, Appropriate Qualifications, Employees Involvement, Waste Use, Faulty Connection, Proper Design, Concept of PQ, Utility Faults, Illegal connection and Bad Distribution Networks Design.

- This study has investigated the implications of the barriers to PQP implementation in the context of LDNs. Four main factors of PQP barriers with total (16 factors) were determined, namely lack of awareness (lack of staff awareness, skills and experience, lack of end users' awareness, lack of customer cooperation, lack of long-term strategy and planning); lack of top management attention (lack of top management commitment, lack of network designing, lack of infrastructure for distribution networks, lack of continuing research and study, lack of top management responsibility); lack of resources (lack of training courses and support, lack of financial resources, lack of enough incentives); lack of power quality involvement (lack of PQ measurement, lack of PQ consultants, lack of PQ standards, lack of PQ databases). The obstacles were leading to poor PQP implementation in LDNs and need to be addressed before the preparation and implementation phases of PQP take place.

- The validation of the proposed PQP framework was done based on multiple level data collection, and an extensive literature review, as well as empirical tests performed before collecting the primary data. This helped the researcher to identify the areas of weakness, which were not clearly understandable and needed to be improved. The researcher personally has become aware regarding various disciplines, such as CSFs, barriers, evaluations, solutions, implementation of PQ to concentrate when implement PQP. This provides up-to-date information on this subject matter of PQP, which would be of assistance to the researchers, students, scholars and experts for investigation in this area.

- The main proposed PQP framework consists of three essential phases, awareness, preparation and implementation. The framework is designed to help LDNs to begin and continue with the implementation for a complete PQP. This framework is designed as a guide for PQP implementation in the LDNs environment. The PQP framework guideline is to increase staff awareness, knowledge and skills in each distribution network to improve PQDs. This involves motivating top management to be eager and enthusiastic to start implementation of the programme based on staff's level of knowledge and awareness after understanding the importance of PQP and its features respectively. The findings can be used as checklists between staff and the common PQP barriers, which can be understood and enhanced by top management to endorse its faster implementation and achieve its outcomes.

- The outcome of this study showed that the top management of GECOL do not give enough attention to their departments and staff, to set up long term strategy to link all the difficulties with both its objectives and strategies. PQP could be implemented faster and have positive feedback, if the concept of PQ is known and understood by staff, including top managers, engineers, and technicians, as well as end users. Therefore, top management must pay more attention to reach a high level of understanding, and so prepare clear objectives, along with a clear strategy for successful implementation of the PQP needed. This framework developed for implementing PQP in LDNs can be adapted and applied as tool internationally to assist and serve electrical distribution utilities having similar circumstances in both developed and under-developed countries.

- The findings have indicated that the process stages of the developed PQP framework need more assessment to consider the smooth changes after each phase. As a result, the author noted that the research results were found to have made substantial contributions for LDNs staff, in understanding the importance of implementing a PQP, derived from the comprehensive questions, objectives arising from the literature review, were included in both the survey and interviews.

- This study can benefit many electrical distribution utilities' staff, including top managers, engineers, and technicians, and also end users. From the top managers' perspective, this research helps them to understand the PQP barriers and difficulties that affect implementing PQP effectively to improve PQDs across their distribution networks. Moreover, for LDNs the developed framework stages will help them implement successful PQPs and encourage the involved departments to collaborate between the end user and their staff in order to raise the awareness level to improve PQDs. In addition, by increasing the end user PQ awareness, they will support the PQP implementation, which will benefit them with good PQ.

- This study concluded that implementing PQP for LDNs was found to have a positive impact on increasing end users' awareness, and satisfaction, improving PQ performance, reducing end users complaints, monitoring and measuring PQ disturbances, providing a PQ diagnosis system and database, reducing the huge losses through PQ cost, increasing top management awareness, increasing employees' skills and awareness, increasing PQ training courses and providing strategic planning. They are needed because LDNs have not yet implemented PQP due to the failure to establish PQ department.

1.6 Research Methodology

The methodology followed in this research is to achieve the research aim and to validate the PQP framework developed for LDNs. Choosing the appropriate methodology is critical in addressing specific research questions, in that collecting primary data for the entire framework relies on the type of methodology, strategy and approach. This study uses two methods, i.e. *"quantitative and qualitative"* as appropriate strategies to answer the research questions, and meet the objectives by gaining reliable and valid information. The researcher applied both research methods in this study, in the form of PQ surveys (quantitative) and semi-structured interviews (qualitative).

Two stages of data analysis were applied to answer the research questions and objectives. The first stage involved PQ survey questionnaire data collection, conducted during April-June 2010. The second stage involved interview survey data collection, conducted in late December 2010 and early January 2011 in LDNs. The total sample size used for pilot test was 42, comprising 2009/2010 MSc students in the School of Engineering and Design at Brunel University and 30 samples of LDNs staff.

The survey questionnaire was prepared based on main factors, derived from the extensive literature review and LDNs data. PQ survey was designed based on six factors, identified as CSFs for PQP implementation with total sub-factors comprising 34 items, where four factors were also identified as the main PQP barriers, with a total of 16 items to measure the level of PQP implementation using the survey questionnaire presented in Appendices A and B.

397 PQ survey respondents participated in assessing the current level of PQ and the implementation level of PQP from LDNs staff involved in PQ improvements, including head managers, middle managers, engineers, technicians and employees, who have between 6 to 15 years' experience. PQ survey responses were analysed using Statistical Package for the Social Sciences version 18.01 (SPSS). A five-point 'Likert' scale was the key instrument in the questionnaire, and each part had different structured responses with clear instructions. The respondents were asked to tick a suitable answer in the relevant category using a five-point 'Likert' scale. There were different techniques applied in this phase to choose the proper data analysis strategy, after the data is entered and coded for the completed surveys, in terms of completeness, accuracy and quality.

On the other hand, PQ survey interview was designed based on six factors with a total of 35 interview questions, which were formulated based on the main conclusion from the survey findings, and the updated literature review. 44 face-to-face semi-structured interviews were conducted with professionals, experts in LDNs, and staff in four departments, which are distribution, planning, training and customer departments, including head managers, engineers, technicians and employees, to state the difficulties and barriers facing LDNs in implementing PQP and to make the developed PQP framework more valid.

The qualitative data was coded by listening to tapes, translating and typing the text and reading transcripts, in order to identify what are the existing issues, concepts, beliefs, and themes regarding PQP. After the essential steps were conducted, then the data was transcribed and coded into NVivo 9.

1.7 Thesis Structure

This thesis consists of nine chapters, where each has its own contribution. They are presented as follows:

Chapter One: This chapter presents the thesis contents. It describes the background on the PQP and the need for its implementation in developing countries. It highlights the research problems, aims and objectives. It also explains the significance of the study, motivation of the study, and the contribution that was achieved. It briefly presented the research methodology and approaches followed in this study. Finally it establishes the thesis structure.

Chapter Two: This chapter outlined the history of PQ, sketched its background and the definitions of PQ concepts by researchers and experts worldwide. First, it extensively explained PQ disturbances as presented by previous scholars, in terms of characteristics and effects. Then a brief overview was given of PQ conditions used frequently to solve PQ technical problems. It also showed the cost of PQ to both industrial and commercial users and the significant losses caused by distribution utilities' neglecting PQ problems. Next, it identified the causes and obstacles that lead to PQ issues and also the obstacles facing the PQP implementation. In addition, this chapter focuses on experiences and examples from both developed and developing countries in solving PQ issues. The literature reviewed in this study has assisted the researcher in developing the research questions and designing the appropriate methodology to collect the data and answer these questions.

Chapter Three: This chapter presents the current level of power quality disturbances (PQDs) in the General Electrical Company of Libya (GECOL), and especially LDNs. It gives a brief view of the literature regarding power generation and transmission systems. It discusses the Libyan distribution system, including the classifications, the existing PQDs and the factors affecting the three distribution networks, such as those affecting infrastructure, including network design, economic growth, illegal connections, increased use of electronic equipment, and lack of PQ awareness. All these factors affect the PQP implementation in LDNs. It illustrates the research problem regarding PQ issues and introduces the PQP, and the requirement for its implementation in LDNs.

Chapter Four: This chapter consists of several sections, starting with evaluation of previous PQP frameworks, and offers a comprehensive and critical comparison between them and the PQP framework developed in this study along with main points relating to the PQP framework. This facilitates understanding the importance of implementing PQP in both developed and developing countries. It also justifies differences in the barriers and benefits of PQP in developed and developing countries, and why implementing PQP in developing countries is significant and explains its impact on LDNs. It states the key CSFs associated with PQP implementation in previous studies, from both the literature and the empirical survey findings, required to implement a PQP framework and support LDNs. It discusses the conceptual PQP framework developed for the purpose of this study, and its requirements and process stages.

Chapter Five: This chapter explains the methodology followed in this research, which is an essential element in achieving the research aim, to validate the PQP framework developed for LDNs. It provides perspectives on the research methods, including approaches, philosophies, design and strategies for this study. In this respect, the positivism and interpretivism philosophies were justified for their selection and how they are powerful when merged together to provide further explanation and exploration, regarding significant research problems in the PQP framework in LDNs. It indicates the data collection methods; both the quantitative method, as in PQ survey questionnaire, and the qualitative method, as in interview survey. These were used as primary data collection methods to understand and explore in-depth the barriers and difficulties of PQP framework implementation.

Chapter Six: This chapter presents the analysis of the quantitative data collected through the questionnaire survey designed for this research, with 397 PQ survey respondents. It presents the data analysis in two stages; Stage one examines the CSFs of PQP, while Stage two explores the level of PQPs implementation among LDNs, and shows the experience of those PQPs that LDNs implemented or tried to implement. The data analysis procedure was chosen based on the appropriate type of technique used for each item in the questionnaire related to each research question and objective by employ Statistical Package for Social Sciences (SPSS) version 18.

Chapter Seven: This chapter presents the second method of data analysis. 44 face-to-face semi-structured interviews were conducted with professionals, experts in LDNs and analysed using NVivo 9. Qualitative analysis was conducted using both content analysis and direct quotation to investigate the level of PQP implementation in LDNs. It was also used to explore and investigate the barriers and benefits of PQP within Libyan distribution systems.

Chapter Eight: This chapter presents the main findings of the study. It provides in-depth discussion of the outcomes related to the research questions, which were answered by the data analysis based on quantitative and qualitative surveys. It illustrated the implications of the CSFs and barriers of PQP and their influence on the LDNs environment. It highlights and examines empirically the CSFs, barriers and benefits of PQP along with developed PQP framework to be implemented in LDNs. It also presents the whole process of the developed PQP framework, and the roadmap of each phase respectively.

Chapter Nine: This chapter summarises the research findings, and provides the recommendations and requirements of PQP implementation and PQDs improvements, and research limitations. The future of PQP in LDNs and future research work were suggested to support the roadmap of PQP implementation in the LDNs context.

1.8 Summary

This chapter presents the thesis contents of the study conducted on Critical Factors Facing Implementation of Total Power Quality Programme Framework in Developing Countries: Case Study-Libyan Electrical Distribution Networks. It describes the background of the PQP and the need for its implementation in developing countries. It outlines the thesis including, the research problems, aims and objectives. It also provides the significance of the study, motivation of the study, and the contribution that was achieved. It explained briefly the research methodology and approaches followed in this study. Finally, it presents the thesis structure.

Chapter Two: Literature Review

2.1 Introduction

This chapter reviews and discusses the relevant literature regarding power quality programmes (PQPs) implemented in distribution utilities worldwide. It also explains the factors which lead to power quality disturbances (PQDs). In addition, this chapter focuses on experiences and examples from both developed and developing countries in solving PQ issues. The literature reviewed in this study has assisted the research in developing the research questions and designing the appropriate methodology to collect the data and answer these questions.

Section 2.2 describes the background of PQ since the concept first appeared. Section 2.3 discusses the definitions of PQ proposed by previous scholars, while Section 2.4 illustrates the general structure of PQ disturbances and their characteristics, causes and effects. Section 2.5 illustrates the PQ conditioning most used to mitigate technical disturbances and Section 2.6 describes the non-technical factors affecting PQ. Section 2.7 presents the Power Quality programmes (PQPs) implemented internationally, followed by Section 2.8 which presents the disadvantages of not implementing such PQPs. Section 2.9 discusses solutions for PQ issues arising from the implementation of PQPs and finally Section 2.10 summarizes the whole chapter.

2.2 Background to Power Quality (PQ)

Research into power quality has gained huge momentum in the field of power electronic systems over the last two decades. This is due to the sudden increase in the number of concerns raised over poor PQ and equally by the sudden increase in non-linear loads [13]. Kajihara mentioned the term PQ in 1968, indicating that it was the object of serious concern [20]. Bollen echoed that it was one of the most critical issues in industrial power system design "*together with safety and reliable service*" [4][8]. He also identified that many publications in the INSPEC database [21] used "voltage quality" with the same meaning between 1969 and 1984. The INSPEC database recorded that 91 publications had used the term PQ, while 64 used the term voltage quality. From 1985 to 1996, the number of publications using the term, PQ increased to 2051, with 210 recorded uses of 'voltage quality'. Nonetheless, according to Bollen, 'voltage quality' was used until 1970 to express the same meaning in both the Soviet Union [22] and the Scandinavian countries [23, 24]. However, the term 'voltage quality' was then replaced by 'PQ' [25].

2.3 Terminology and definitions of power quality (PQ)

The term, PQ, has been defined in several entirely different ways; hence, it means different things to different people depending on the standards, which are set by distribution utilities to reach, or meet, customers' expectations and satisfaction. The different concerns of those who define PQ are clearly stated, such as bus voltage, damage to load, load effects, load performance, powering and grounding of sensitive loads, electromagnetic compatibility, equipment life, load performance and productivity and quality of service or product. All the resulting PQ definitions are classified on the basis of system characteristics and standards set to address PQ disturbances, which should not impair either the utility's power supply system or sensitive end user equipment.

Gerry Heydt defines PQ as "*the measure, analysis and improvement of bus voltage, usually a load bus voltage to maintain that voltage to be sinusoidal at rated voltage and frequency*" [6]. This refers to voltage variation, which should not cause PQ disturbances to the end users' sensitive equipment and should be maintained within the input voltage standards for the system. Bollen defined PQ as "*the ability of a power system to operate loads without disturbing or damaging them, a property mainly concerned with voltage quality at points of common coupling*". He also sees it as "*the ability of loads to operate without disturbing or reducing the efficiency of the power system, a property mainly, but not exclusively, concerned with the quality of the current waveform*" [17]. This definition refers to the system's performance, for which the supply loads must operate within the international standards of both quality and reliability, without any disturbances.

Another definition of PQ which is formulated according to its effect on the equipment connected to the supply is as follows:

"*Power quality is the degree to which both the utilizations and delivery of electric power affect the performance of electrically powered equipment with an occurrence manifested in voltage, current or frequency deviation that results in failure or disoperation of the utility or the end user's electronic equipment*" [5, 18].

This definition brings in both the distribution companies and end users, since both are responsible for causing PQ problems [17][19, 26]. Therefore, they should cooperate to achieve an optimum level to mitigate PQ disturbances [27].

Moreover, PQ was defined by the Institution of Electrical and Electronic Engineering (IEEE) STD 1100 as "*the concept of powering and grounding sensitive equipment in a manner suitable to the operation of that equipment and compatible with the premise's wiring system and other connected equipment*" [28, 29]. This definition has been clearly used in the general sense by IEEE to cover all related problems under the term 'PQ'. This definition is appropriate and used extensively in IEEE guidelines, but even so there is disagreement about it, due to the different types of electronic equipment that are very sensitive to one of the many PQ disturbances.

Furthermore, the following IEC 61000 1-1 standard defines PQ in terms of EMC as follows: "*Electromagnetic compatibility is the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment*" [25].

The term 'PQ' can be referred to as "*a wide variety of electromagnetic phenomena that characterize voltage and current at a given time and at a given location on the power system*" [28, 29]. As a result, this definition can be associated with the reliability and quality of the power supplied in order to give a good quality of service to the end users. The supply quality or reliability refers to the combination of voltage quality and the non-technical problems experienced by the distribution networks and the end users connected to this network by the operator. Therefore, it is very important for the supply quality to be complementary to the consumption quality [30].

Moreover, Sankaran defines it as "*a set of electrical boundaries that allows a piece of equipment to function in its intended manner without significant loss of performance or life expectancy*" [31]. Both performance and life expectancy are essential for any electrical device; as a result, the electricity must be of good quality in order for good performance to result from a device, keeping it in good condition and extending its life. PQ is also defined as "*the poor quality of voltage or current or both*" [32]. Therefore, any changes in these three aspects will affect the performance and life expectancy of the device. Likewise, PQ is an important aspect of power systems and electric machinery, with obvious impacts on "*efficiency, security and reliability*" [13].

The European Community in 1989 defined power quality as "*life expectancy of a product which is manufactured, delivered and used at the same time*". Therefore, this product must comply with both the provisions and productions standards of the EMC Directive (89/336/EEC) in terms of quality [16][27].

In brief, the definition of PQ is a very significant factor to be considered before starting to mitigate a PQ disturbance or implement a PQ programme. Technically, the definition of PQ is associated with three main elements, i.e. voltage, current and frequency. These elements should not fall below power supply system standards and should be checked before distributing power to end users, otherwise customers will start to complain of poor PQ. Lack of awareness regarding the PQ concept could result in utilities still suffering from PQ problems caused by industrial, residential and commercial end users' sensitive equipment. Therefore, providing sufficient introduction and explanations for the most widespread PQ terms will help to identify the more common PQ disturbances. Subsequently, these are analysed, revised and compared to PQ standards and to PQ issues previously recorded. Moreover, those producing or using the power should basically understand what PQ means [7]. The reason is that as long as the concept of PQ is misunderstood by both the electrical companies and end users, then the severity of PQ issues will steadily increase, due to the fact that the demand for power will surely double and increase still further [33].

As a result, understanding PQ definitions and their features are very important for solving PQ issues. Developing and providing the requirements needed to improve PQ disturbances will help in implementing PQPs in the distribution system internationally, which will raise customer satisfaction to a high level. Therefore, EMC Directive (85/374/EEC) refers to PQ as "*the electricity service which should have the proper quality to satisfy the end user's requirements*". Hence, the product must be measured and evaluated in terms of the quality of power supplied, to ensure satisfies end users by being of the best quality and without any deficiencies [30].

In addition, the United Nations Universal Consumer Rights Declaration (UNUCRD) stated that "*goods that have any material, legal or economic deficiencies, which affect its quality, standard and technical specifications are deemed to be defective*" [34]. Therefore, in 1985, the Commission of the European Communities (directive 85/374) stated that utilities should assess the electricity which is distributed to the end user, as of poor or high quality and should classify its important characteristics clearly [27][35].

In response to this and in earlier definitions, PQ was linked with voltage variation, system performance, international standards of both quality and reliability, responsibilities between distribution companies and end users, the combination of the voltage quality and non-technical problems and performance and life expectancy for electrical and electronic devices. Therefore, regarding the criteria included in PQ definitions, Dugan, Mcgrranahan, Santoso and Beaty stated that PQ was "*similar to any other quality of goods or services and it is the performance and productivity of the end user's equipment*" [5]. If the power lacks adequate quality to meet the end users' needs and expectations, or includes one of the criteria mentioned in PQ definitions, then it is consequently lacking in quality [18]. Therefore, the priority of most electrical companies is now to meet both the end users' expectations and to maintain their systems. This depends on the level of understanding associated with PQ definitions; this will lead to responses to all the issues related to PQ definitions.

In response to this, those involved need to take PQ concept comprehensively into account and understand it very well, before determining the causes of a PQ disturbance. For example, it should be asked whether PQ issues are caused by a lack of awareness of PQ definition, whether among the distribution utilities staff, or end users, due to the increase in electronic equipment and lack of clear strategy. The distribution networks were never designed to perfectly accommodate both increases in electricity demand and economic growth. Moreover, the problem is aggravated by the lack of training courses to update employee skills and teach them to deal with problems, and indeed by the deregulation in power systems due to competition in the market, as well as the lack of clear polices and standards to follow.

2.4 Power Quality Disturbances (PQDs)

Power quality disturbances can be considered within a general framework identifying the main factors causing problems in both energy providers' distribution system grids and end users' sensitive equipment. Indeed, the most commonly occurring disturbances are short-duration voltage variations affecting power systems supplies [36]. Such disturbances are caused by a number of parameters, to be presented and discussed in subsequent sections.

These parameters are classified according to the slight differences identified in the typical spectral content of the disturbance, as well as its magnitude and duration [5].

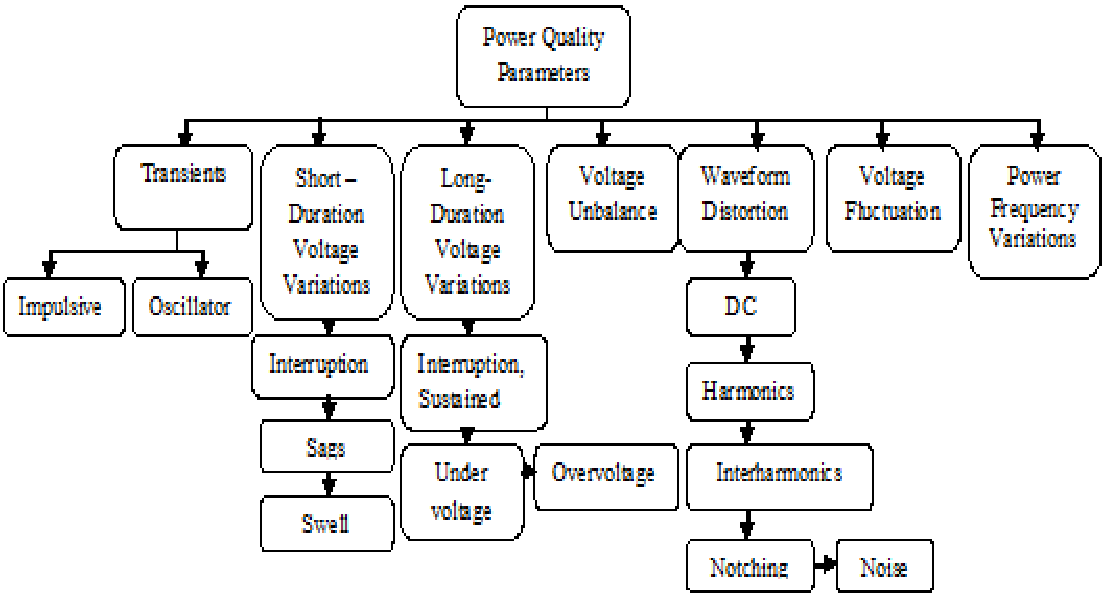


Figure 2.1: Classification framework for PQ Parameters

As can be seen, Figure 2.1 presents the most commonly occurring power quality disturbances. Each category is to be discussed, in terms of defining characteristics, and sensitivity to variations and root-mean-square (rms).

2.4.1 Transients

Transients occurring in a power system represent rapid events of short duration, which create undesirable distortions. The waveforms and characteristics of such transients are a product of the power generation mechanism and the parameters, i.e. resistance, capacitance, and inductance, of the distribution network [6][5]. There are two types of transients, namely oscillatory and impulsive.

2.4.1.1 Oscillatory Transients

An oscillatory transient is defined as a rapid change in frequency (non-power) occurring in steady state current or voltage, with accompanying negative and positive polarity change. It may also be described as the main frequency disturbance, with varying magnitude and duration [6]. Oscillatory transients may arise in power systems due to various reasons, including fluorescent and energization switching of capacitor banks [13][5].

2.4.1.2 Impulsive Transients

An impulsive transient is represented by a rapid change in frequency (non-power) occurring in steady state current or voltage, but without any polarity change, i.e. polarity remains unidirectional, whether negative or positive. For example, an impulsive transient may take the form of a voltage change from 0 V to a nominal 2000 V peak over 1.2µs, or a current surge, such as that due to lightning. Given the high frequencies in this event, circuit components can be used to quickly modify their shape [6][5].

2.4.2 Short-Duration Voltage Variations

The variation of voltage over a short duration may occur due to high current drawn by large loads, or poor connection because of loose wiring. Temporary voltage variations may take the form of drops (sags) or rises (swells) in voltage or even complete voltage loss (supply interruption) [6][5].

2.4.2.1 Interruption

Voltage loss or interruption may result from faults in the power system, failure of equipment, or malfunctioning controls, and is when load current or supply voltage drops to under 10% of its nominal value for duration of less than one minute. Interruptions are classed by duration of the event, where the voltage value drops below 10% of nominal. Typically, this is due to a utility system fault [6][5]. European standard EN-50160 considers interruptions to be short where they do not exceed 3 minutes, and long where they last for more than 3 minutes. The IEEE-1250 standard also based its classification on duration, where interruption was:

1. Instantaneous, if it lasted from 0.5 to 30 cycles.
2. Momentary, if it lasted from 30 cycles to 2 second.
3. Temporary, if it lasted from 2 seconds to 2 minutes.
4. Sustained, if it lasted for more than 2 minutes [13].

2.4.2.2 Voltage Sags

Among power quality problems, voltage sags are typically the commonest. These may be caused by large energy draws from the power system, which occur when heavy loads are energised, transformers fail, or large motors start up [6][5]. Voltage sag is defined as a 0.1 to 0.9 pu drop in rms current or voltage with supply frequency unaffected, and lasting from half a cycle to 1 minute. System faults are typically the cause of voltage sags. Different solutions, including constant voltage transformers, dynamic voltage restorers

(DVRs), and uninterruptible power supplies (UPS), can be used to protect sensitive loads from voltage sag [25].

2.4.2.3 Voltage Swell

Voltage swells represent a supply frequency or rms voltage rise of 1.1 to 1.8 pu lasting from half a cycle to 1 minute. System faults are typically the cause of voltage swells, yet on the other hand may result from temporary increases in voltage even without the existence of fault conditions. In addition, the variables implicated in voltage swells are the system impedance, fault location, large load grounding and switching off [6, 25][5].

2.4.3 Long- Duration Voltage Variation

The variation in voltage over a long duration includes departures in rms at power frequencies, and last for over one minute. Such variations may appear as an over-, or under-voltage, and are not caused by supply faults, but by load variations and switching operations in the system [6, 25][5].

2.4.3.1 Overvoltage

An over-voltage represents an rms ac voltage rise to above 110%, without affecting supply frequency, lasting more than one minute. In this respect, energizing a capacitor bank or switching a large load off, leads to system weakness in terms of regulating or controlling voltage at the desired level [6][5].

2.4.3.2 Under Voltage

An under-voltage represents an rms ac voltage drop to below 90%, without affecting supply frequency, lasting more than one minute. Switching events opposite to those causing an over-voltage are implicated in under-voltages. In this context, switching a large load on, or switching a capacitor bank off, as well as overloaded circuits, may result in an under-voltage event [6, 25][5].

2.4.3.3 Sustained Interruption

The most clearly recognised and most severe power quality event is the long or continued power interruption, where the voltage falls to zero and is not automatically resumed. In this respect, there is variation in defining the minimum duration of a sustained interruption, where the IEC defines this as being greater than three minutes, while the IEEE considers this to be greater than one minute. A sustained interruption may result from the occurrence of a fault in power supply system's affecting part, or all, of the distribution network. Moreover, a low voltage network without redundancy may also suffer sustained interruption [13][6][5].

2.4.4 Voltage Unbalance

A voltage unbalance is defined as the maximum deviation from the average of the 3-phase currents or voltages divided by the 3-phase current or voltage average. In this context, the main source of less than 2% voltage unbalance are phase loads in the 3-phase, as well as one blown fuse in one of the three phases of a capacitor bank, or non-transposed overhead transmission lines [6][5].

2.4.5 Waveform Distortion

Waveform distortion is represented by the deviation in the supply frequency from the ideal sine wave in the steady state, based on the spectral content. Waveform distortion comprises five types.

2.4.5.1 DC Offset

A dc offset indicates that within the ac system, a direct current or voltage is present. This may be caused by a disturbance affecting electronic power converters. A dc offset has a harmful effect since the direct current biases transformer cores in normal operation, resulting in added heating and reduced transformer life [6][5].

2.4.5.2 Harmonics

Harmonics comprise sinusoidal current or voltage frequencies that are integer multiples of the fundamental supply frequency of 50 or 60Hz. As such, the complete harmonic spectrum detailing the phase angles and magnitudes of the harmonic components clearly illustrates the harmonic distortion levels. Harmonic distortion may also be described by the total harmonic distortion (THD) as an effective measure. Furthermore, harmonic currents in some electric motors may lead to losses in the form of heat with associated loss of efficiency. Harmonics may also contribute to greater noise levels in transformers and motors. In addition, harmonic currents and voltages may lead to ground fault circuit interrupters tripping falsely (GFCIs) [13][6][5].

2.4.5.3 Interharmonics

In contrast to harmonics, interharmonics consist of voltage or current frequency components that are not integer multiples of the supply system operating frequency. Interharmonics may involve a wideband spectrum or discrete frequencies. Induction furnaces and static frequency converters are the main contributors to interharmonics.

These interharmonics may impact on power-line-carrier devices, and could result in flickering in fluorescent and arc lighting, as well as computers [6][5].

2.4.5.4 Notching

This is a voltage disturbance occurring periodically, and results from current commutation from one phase to another due to power electronics devices' normal mode of operation [6]. Given that notching is a constantly occurring phenomenon, it may be studied in the voltage harmonic spectrum, yet, it is considered to be a special case. In fact, due to the significantly high frequency components occurring in notching, typical harmonic analysis measurement equipment may not be able to adequately characterize it [6][5].

2.4.5.5 Noise

Undesirable signals composed of a wide band spectral content not exceeding 200 kHz is defined as noise. In an electrical supply system, various elements, such as switching power supply, power electronics devices, arcing equipment, and control circuits may generate noise. Noise may also be defined to be any undesirable power signal distortion, which is neither transients nor harmonics distortion. Noise issues may be resolved using appropriate components, such as line conditioners, filters, and isolation transformers [17][5].

2.4.6 Voltage Fluctuation

Fluctuations in the voltage represent variations in a series of continuing, fast, and random, changes in voltage, which typically go beyond 0.9 to 1.1 pu voltage range. The causes of voltage fluctuations may be arc welders and furnaces, as well as electrical distribution and transmission systems [13][6][5].

2.4.7 Power Frequency Variations

Power frequency variations in the electrical supply represent those deviations occurring in the fundamental frequency, normally 50 or 60 Hz. The fundamental frequency is based on utility generators' rotational speed. The fundamental frequency is set within strict limits under normal steady-state operation, but departures from these limits may be due to faults affecting the bulk transmission system. In addition, frequency variations may result from a loss of a large block of generation capacity, or in contrast disconnection of a large block of load. However, frequency variations are rare in present-day interconnected electrical power systems [6][5].

Table 2.1 gives the summary of the main sources of PQDs, with the effect of each category on the loads and sensitive equipments and an example of each PQ conditioning to mitigate the problems.

Table 2.1: Summary of Power Quality Problems

Causes	Sources	Effects	Example of power conditioning Solutions
Impulsive transients	-Lightning	-Destroys computer chips -and TV regulators	-Surge arresters
	-Electrostatic discharge		-Filters
	-Load switching		-Isolation transformers
	-Capacitor switching		
Oscillatory transients	-Line/cable switching	-Destroys computer chips and TV regulators	-Surge arresters
	-Load switching		-Filters
	-Capacitor switching		-Isolation transformers
Sags/Swells (RMS disturbances)	-Remote system faults	-Motors stalling and overheating	-Ferro resonant transformers
		-Computer failures	-Energy storage technologies
		-ASDs shutting down	-Uninterruptible power supply
Interruption (RMS disturbance)	-System protection	-Loss production	-Energy storage technologies
	-Breakers	-Shutting down of equipments	-UPS
	-Fuses		-Backup generators
	-Maintenance		
Under voltage/Overvoltage (steady-state variation)	-Motors starting	-Shorten lives of motors and lightning filaments	-Voltage regulators
	-Load variations		-Ferro resonant transformers
	-Load dropping		
Harmonics distortion (steady-state variation)	-Nonlinear loads	-Overheating transformers and motors	-Active or passive filters
	system resonance	-Fuses blow	-Transformers with cancellation of zero sequence
		-Relays trip	
		-Meters misoperate	
Voltage flicker (steady-state variation)	-Intermittent loads	-Lights flicker	-Static VAR system
	-Motor starting	-Irritation	
	-ARC furnaces		
Poor power factor	-Induction loads motors	-Network losses	-Capacitor bank active
	-Florescent lighting	-High KVA	-Power factor correction
	-Transformers	-Demand increased	
	-High intensity discharge	-Excessive power usage	
	-Arc Welder		

Source [6, 25]

2.5 Power Quality Surveys

PQ disturbances have led to significant costs to industrial, commercial and end users, as well as power distribution companies [37-42]. These increases in cost are due to damaged equipment which is not compatible with PQ standards, due to its sensitivity to power supply variation. These items of equipment vary according to the category of end user, whether domestic users ("TV, video cassette recorders (VCR), microwave ovens, personal computers (PC), heating-ventilation-air conditioning equipment (HVAC), dishwashers, dryers and so on") or commercial users ("workstations, PCs, copiers, printers, compact fluorescent lamps and lighting") or industrial users ("programmable logic controllers (PLC), automation and data processors, variable speed drives (VSD), soft starters, inverters and computerized numerical control (CNC) tools etc.)" [43]. Other factors, such as the lack of PQ awareness among top management, engineers and end users; increased power demand; deregulation; manufacturers' and customers' dissatisfaction have led both end users and distribution utilities to lose a huge amount of money [44]. Therefore, conducting more investigation surveys based on PQPs would reduce the cost of PQ maintenance to users [45-47].

2.5.1 Power Quality Surveys (PQSs) in different developed and developing countries

Power quality surveys (PQS) have become some of the most important methods used to measure and monitor PQDs. Most of the distribution utilities worldwide conduct such PQ surveys to identify the significant PQDs which damage end user equipment and incur significant losses. PQDs lead to inconvenience and dissatisfaction from end users when they receive sub-standard power services [43]. As a result, end users complain about poor PQ. Therefore, from the beginning of 1990, electrical companies started to conduct PQS when the level of customer complaints rose, due to the increase in sensitive non-linear equipment which was produced at the time and ever since.

The Electric Power Research institute EPRI conducted a five year monitoring programme of 24 utilities in the USA starting in 2001-2002; it identified the significant American end user complaints about PQDs, which were found to be voltage sags (dips) and swells (48%), transients, over-voltages (due to capacitor switching) and harmonics (22%). This was the result of distribution networks infrastructure which consisted of overhead lines [48, 49].

Moreover, in 2001, the European Copper Institute conducted PQS in 1,400 sites in 8 developed countries in Europe. The study results revealed that harmonic distortions, power supply reliability and voltage dips are the PQDs that end users complain most severely about [47].

In addition, another PQS campaign was conducted in 2004 among the EU-25 countries, including various end user applications by the Leonardo Power Quality Initiative (LPQI). The results found that most of the PQ complaints received from end users were due to voltage dips (23.6%), short interruptions (18.8%), long interruptions (12.5%), harmonics (5.4%), transients and surges (29%). As a result, these disturbances cost annually €151.7 billion yearly in the 25 countries of the European Union due to poor PQ. This affected the end users' sensitive equipment and the equipment installed by utilities for their distribution systems [50].

At the same time it should be noted that most of the end users surveyed in the EU-25 countries who suffered from significant PQDs were the industries. Their equipment was very susceptible to power supply variations, such as long and short interruptions. Voltage sag is categorised as a short interruption, the main PQ issue in industries such as *"semiconductor and continuous manufacturing, due to intensive use of motor driven systems and static converters",* whereas harmonics are observed to occur often in *"the commercial and telecom companies due to use of electronic equipment".* They are the most vulnerable to PQ disturbances [50]. Therefore, a great many case studies have been conducted all over the world to calculate the impact of poor PQ on its end users, but still only very rare surveys have been made to measure and analyse the technical and non-technical events which have led to the PQDs [43]. For example, the UK, a European country which faces most of the PQDs to end users and complains most to utilities, concentrates on voltage dips, harmonics and flicker [51].

Comprehensive power quality surveys were also conducted from 2002 to 2004 in Europe with a view to regulating power quality. In Norway, PQS was conducted in 2002 to estimate customer PQ losses due to poor PQ. The study indicated that the main PQDs to appear constantly are long and short interruptions including transients, overvoltage and voltage dips. These disturbances cost Norwegian customers, both domestic and industrial, approximately €107.6 million annually [52]. Moreover, in Sweden PQSs were conducted to investigate PQDs and estimate the cost associated with their effect on end users' sensitive equipment. The survey found that most of the customers who suffered from poor PQ were industrial customers who complained of due to significant short interruptions and voltage sags which cost them roughly €157 million annually [52].

In France most PQDs affected customers by damaging their susceptible devices (due to poor PQ) were interruptions and voltage quality. These disturbances cost French electrical utilities and both industrial and residential customer €37 million annually [52].
Furthermore, another PQS was conducted in 2004 of 256 Italian industrial companies to assess their PQ level. The survey results were similar to those which were conducted in Sweden and France. Long interruptions and voltage sags were the disturbances that occurred most often in these companies at a cost of €180 million annually [52].

Additional PQS were conducted during 2004-2005 by the Verification of Electrical Materials consulting PQ Company (KEMA) in the Netherlands. The project found that the main PQDs suffered were voltage flicker and under-voltage due to the state of the distribution networks' infrastructure and overhead lines. These disturbances affected residential users mostly (56%), damaging their sensitive tools, followed by commercial (12%), agricultural (11%) and industrial customers (10%) [53]. This study also highlights four reasons why distribution networks' infrastructure, consisting of overhead lines, causes PQ issues and the circumstances in which it does so, as follows [43][9];

- Natural phenomena due to disturbed weather, e.g. storms, lightning etc. and animal activity which causes system disturbances.
- Utility faults which cause system disturbances due to lack of maintenance in operation
- Illegal end user connections when connected to the same feeder or network
- The behaviour of customer's sensitive loads due to the poor PQ of the electric supply.

But the EPRI and Consortium for Electric Infrastructure for a Digital Society (CEIDS) institutes conducted a PQ survey in the USA to identify the equipment in the industrial sector that was most affected by poor PQ in 2000. This study highlighted that the devices most often damaged as result of lack of PQ are computers and microprocessor devices (43%), variable speed drives (13%), lighting equipment (8%), motors (5%), relays (1%) and other equipment (30%). As a result, the industry sector lost between $119 billion and $188 billion per year in this way [46].

In South Africa, a PQS was conducted by Eskom which asked approximately 330 large power suppliers and users to identify the most significant PQDs for user's equipment and causing economic losses in both the industrial and domestic sectors. The study revealed that the Eskom respondents lost approximately $350 million yearly as result of voltage sag and transients which caused most of the PQDs due to their frequency [54].

Another study conducted in South Africa by Johnson and Coney found that the most severe PQDs were voltage dips and transients, which concerned end users and always caused complaints. These disturbances are due to faulty design and the distribution network infrastructure which consists of overhead lines [55].

Hannan et al. (2010) conducted a PQS in Malaysia through 30 high-tech industries, including manufacturers, process engineering works and semiconductors to classify what they saw as the most severe PQDs. The study revealed that the main PQDs damaging their equipment was sag (50%), harmonics (43.3%), flicker (36.7%), voltage swell (26.7), transients (13.3%) and power interruptions (3.3%) [56]. As can be seen, these disturbances appear due to a lack of the following: education and awareness, laws and regulations, financial incentives for solving flicker problems, guidelines, training and research and development for the engineers in these industries.

Table 2.2 shows the cost to industrial, commercial and domestic customers of poor PQ in different countries of the world.

Table 2.2: Cost of Industrial and Customer Losses due to Poor PQ worldwide

Industrial Type	PQ Disturbances	Total Cost	Authors	Methodology
Large Brazilian Customer	Harmonics, Voltage Sag, Interruption	1.2 $ million annually	[37]	PQ Case Study
International's paper mill in Deferiet, New York	Voltage sag, Power Interruption	$1 million annually	[38]	PQ Case Study
Textile Industrial plant Italy	Voltage sag	235,600 $ million annually	[39]	PQ Case Study
plastics manufacturing facility	Voltage sag	1.7 $ million annually	[40]	PQ Case Study
Production Problems in a Plastics plant	Voltage sags Momentary interruptions	30$ million annually	[57]	PQ Case Study
Information Technology Equipment (ITE) Industry	Transients, Outages Voltage sags	4 $ million annually	[42]	PQ Case Study
Champion International Corporation's Deferiet Paper Mill in Deferiet, NY	Voltage sags	1 $ million annually	[41]	PQ Case Study
Semiconductor Industry China	Power Interruption	1.5 $ million annually	[58]	Presentation
DuPont International Company	Outage	75 $ million annually	[59]	PQ Case Study
Industrial Process Equipment Germany	Voltage sags, Power Interruption	€32 billion	[60]	Panel Discussion
Industrial and Commercial Power Systems	Voltage sags	2 $ million annually	[61]	PQ survey
Electrical Power Quality and Utilisation Industrial sectors 8 Developed Countries Austria, France, Italy, Poland, Portugal, Slovenia, Spain and United Kingdom	Voltage dips, Short interruptions, Long interruptions, Harmonics, Transients, and surges	€150 billion	[50]	Interviews and PQ Questionnaire
Massachusetts' industrial and Digital Economy Companies USA	Voltage Fluctuations, Voltage sags Outage	1.4 $ billion annually	[49]	PQ Case study and Interviews
industrial & digital economy companies USA	voltage dips, short interruptions	119$ to 188 $ billion Ann	[46]	PQ survey
The semiconductor industry in Taiwan	voltage dip	€ 1.7 million annually	[62]	PQ Case study
plastic extrusion industry Singapore	A short interruptions voltage dip	€ 3 million annually	[63]	PQ survey
steel industry Sweden	Voltage dip	€ 2.4 million annually	[45]	PQ survey
California businesses DE, CPM , and F&ES industries sectors	outages	18.8 $ billion annually	[64]	PQ survey
A glass factory in France	Outages, Harmonic Distortions, Power supply reliability, Voltage dips	€1 million annually	[47]	PQ survey
Cost to Customer of Power Quality Disturbances UK	Transients, Interruption	£ 200 million annually	[65]	Insurance Compensation
Industrial and Domestic sectors, 330 large power users , South Africa	Voltage sag and transients	$ 350 million annually	[54]	PQ questionnaire
domestic and industrial customers , Norway	Transient, overvoltage, voltage dips	€107.6 million annually	[52]	PQ survey
industrial customers, Sweden	short interruption and voltage sag	€157 million annually		PQ survey
industrial and residential customers, France	Long interruptions and voltage quality	€37 million annually		PQ survey
256 industrial companies, Italy	long interruption and voltage sag	€180 million annually		PQ survey

Table 2.2 summarises the comprehensive studies regarding the huge economic cost and losses affecting customers and electrical distribution by utilities worldwide. The significant level of PQDs is due to lack of power quality standards (PQSs) and regulations among the distribution utilities, which provide unique standards and regulations instead of adhering to international standards [66]. The distribution utilities are responsible for all PQDs associated with the power supply and they should take into account PQSs, when designing their systems and guarantee that PQSs must be included in the PQ contracts between themselves and their customers, by setting specific conditions in order to reduce the number of complaints from their end users [67] .

In response to this, the Institute of Electrical and Electronics Engineers (IEEE) and International Electromagnetic Commission (IEC) have started intensive programmes to establish PQSs in USA and Europe. Many electrical distribution utilities had considered them in their systems and adopted them in their power supply standards. Moreover, many manufactures and organizations have developed their equipment and systems on the basis of these standards in order to allow the power supply to operate without disturbing the end users and to enable the end users' loads to operate without damaging the power supply system [17].

At the same time, some distribution companies have also established their own PQ regulations based on their system characteristics and the limitations of these, where these standards can be applied. As a result of the huge number of end user complaints caused by inconvenient PQ variations which are not associated with the PQSs [19]. In this sense, designing an appropriate power supply system depends on the level of PQSs that the distribution utilities adopt and their investment in maintenance and operation to ensure that PQDs are under their control. Electrical distribution utilities need to provide PQSs; first, to evaluate their power supply system on a regular basis and second, to guarantee that the end users' sensitive equipment is compatible with their system regulations [5].

2.6 Non-Technical Factors Affecting Power Quality (PQ)

Since 1980, PQ issues have been causing significant disturbance to the distribution systems and end users, becoming a global concern [6][5][17][18][15][68-72]. The utilities started, as a result, to tackle these disturbances in the early 1990s [69][25], as essential concerns for both the utilities and their users [68][72][9][1][73][66]. Nowadays, these issues have driven both the electrical companies and the end users to pay more attention to better diagnosis and/or better understanding in their efforts to mitigate them [69][1][74]. The factors leading to these PQ issues are described below.

2.6.1 Deregulation

The rapid increase in PQ issues was due in part to deregulation, which for the electrical power industry began in 1980 [68][71][9][75][76][7]. Deregulation affected end user expectations, which saw complaints rising in the competitive conditions of the market [72][1][77]. As a result, the competitive market and the pressure of economic growth led the deregulated utilities to focus on the quantity and price, rather than the quality of electricity [27][70][1][78][2][79]. Hence, some of these distribution utilities made reductions in both maintenance and inspection programmes. This led to a consequent increase in the number of short-circuit faults in the networks, which caused both PQ interruption and voltage sag for end users [17]. Therefore, the lack of regular maintenance and investment in distribution systems has resulted in PQ issues [35].

Moreover, deregulation has affected PQ due to the weak regulation of the policies from power distribution companies [26][71][80]. GUL suggests that the distribution utilities which are privatized have concentrated on two main objectives, namely, commercial and technical quality to achieve customer satisfaction [71][81, 82]. Commercial quality maintains that there should be an agreement between end users and the company regarding PQ standards [83]. From the end users' perspective, the utility should consider both the link between its relations with the customer and customer satisfaction [82]. Technical quality is associated with the ability of the distribution system to satisfy the rising demand of consumers, by taking into account the economic cost and the average extent of interruptions [71][83].

2.6.2 Electronic Equipment

There has been a rapid increase in the high technology electronic equipment, such as sensitive computers, microprocessor systems, adjustable speed drives and induction heating, used by end users and in industrial applications [44]. These electronic devices are also among the critical issues which have brought significantly wide PQ variations to power supply [69, 70][75][2][84]. Moreover, over the last five decades, manufacturers have been forced to make electrical equipment, tools and sensitive components both smaller and more efficient to satisfy the economic aspect [31][72][1][10, 85]. However, such equipment was designed with a deficiency in performance quality, because it includes electronic control, which is more sensitive to PQ variation and disrupted power supply [86][79].

2.6.3 Increase Power Demand

The demand for electricity was another factor which caused poor PQ, due to inadequate network design which did not keep up with the increases brought about by economic growth [70][7][79]. Moreover, infrastructure is another cause of PQ problems, because it has not met and adapted to the rising popular demand. Thus, distribution networks are not designed on the basis of individual types of consumer and location [70][79][87]. This issue is found mainly in government-controlled distribution utilities in developing countries [15]. Therefore, in order to accommodate the demand, utilities must be equipped to adjust to "*the market and the technology innovations*" [87]. These innovations, which would ensure clear PQ, are "*power markets, renewable energy sources, distributed generation and electric energy storage*". Therefore, to avoid any PQ issues later, the utilities should be upgraded and their distribution networks should be designed "holistically", not based merely on the current level of demand for both consumers and power supplies; however, they must also be able to meet future demand [75].

2.6.4 Lack of Power Quality (PQ) Awareness

Lack of awareness of the concept of PQ was one more aspect which propagated the adverse PQ events [18][15][88]. This lack of PQ awareness is a result of the failure of customers to demand the deployment of PQ standards [15][72][79]. Furthermore, the industrial sector was found to contain some of the major causes of PQ problems [89]. Another study conducted by McNulty and Howe for Massachusetts distribution systems reveals that employees from both the industrial and the commercial sectors were the main causes for the PQ disturbances to California's power distribution utilities. This was due to accommodating heavy loads and the use of sensitive equipment [77, 78][85][49]. This has of course increased PQ problems and disturbances have become constant, partly because their importance has not been acknowledged [86]. A gap in terms of "*understanding and visibility*" was found between people who were familiar with PQ and those who were not concerned about it [73][68]. This revealing a lack of employee skills to deal with PQ problems which was highlighted as another main reason for the increase in such problems [26][90].

2.6.5 Customer Dissatisfaction

Although other causes of PQ issues have been of concern, end users' behaviour has been identified as one of the main factors leading to PQ events and impacting on the performance of distribution networks [74][91]. However, such user behaviour is the result of the complicated procedures that companies follow when consumers want power supply. This makes it difficult to connect them quickly. As a result, consumers have reacted negatively and connected to distribution networks in illegal ways; such connections have caused PQ both disturbance and commercial and technical losses. These losses can be ascribed in part to the negligence of the customer service department in responding to customer requests and complaints and resolving their problems satisfactorily [15][80]. Furthermore, McNulty and Howe conducted a PQP in Massachusetts to identify whether or not there had been any significant PQ issues [49]. The methods used in their study were based on the database of the Massachusetts distribution systems and interviews with Massachusetts customers in the industrial and digital economy sectors. They found that no PQP has so far been implemented to determine the nature of the relationship between the characteristics of the PQ indices and heavy complaints from users. As a result, both users and the utility lost approximately US$1.4 billion yearly. Consequently, the suppliers were silent about the importance of these complaints and did not step forward to reply to, or solve them [49][92].

Moreover, there was little cooperation from consumers, most of whom use sophisticated electronics equipment; they felt ignored when it came to providing good PQ. This may lead them to react negatively by connecting to the network illegally. Therefore, one of the responsibilities of the distribution systems is to become aware of the importance of strategic planning by taking appropriate action and making adequate preparations to introduce effective changes in the distribution systems. They should implement a PQP which satisfies their customers [93].

2.7 Power Quality Programmes (PQPs)

PQPs have become one of the most recent services among distribution companies, whether private or state suppliers [33][1][15][2]. A PQP can help to reduce the huge number of complaints received from customers and the costs representing the damage to their equipment [3]. It can also have a positive impact on the electrical companies, in the form of improvements to their service and savings in the significant resources spent. Nevertheless, PQ disturbances cannot be remedied unless the factors, such as lack of PQ awareness, clear strategy, increased power demand, deregulation, equipment manufacturers and customer dissatisfaction, are considered. Therefore, the distribution companies need to implement a PQ investigation programme, despite all the evidence of an increase in PQ, in particular in the last two decades, and an increase in the earlier factors which have raised the level of PQ and of customer satisfaction [33][4].

2.7.1 Examples of Power Quality Programmes (PQPs)

2.7.1.1 Power Quality Programmes (PQPs) in Developing Countries

Some utilities in developing countries have implemented PQPs and determined that PQ solutions are not as important as the free electricity being distributed [15]. With free electricity, the harm of PQ disturbances increases in step with the demand for power. It is suggested that only putting the utilities into private hands reduces the level of PQD; this is because private distribution companies will treat PQ as a product [27][16]. As a result, providing PQ solutions will improve the quality of power and customers' complaints will be considered appropriately, which will increase their satisfaction [15]. Moreover, providing high value PQ will attract more customers. However, this depends on providing a cost- effective service with relevant mitigation techniques to address PQ issues [9].

Managers from distribution companies concluded that some international electricity companies view this as a business, rather than concerning themselves with issues of power distribution [15]. Nonetheless, some utilities in less developed countries have stated that their priority is to diagnose the problems and then implement appropriate solutions to satisfy consumers rather than ignoring them; these measures mitigate the problem of delivering free power. However, customer complaints are still neglected by some utilities, because of a lack of PQ awareness among their employees. Therefore, Milanovic and Negnevitsky stress that a PQP will make significant contributions to customer satisfaction [78][79][4]. They suggest that this level of customer satisfaction can be used as part of the process to identify the level of PQ issues and, where improvements can be made, to further increase this satisfaction [94]. Moreover, some power distribution companies try to ascertain the critical factors for customer satisfaction. Accordingly, several less developed countries have compelled their utilities to implement PQPs and offer them as a mandatory service, in response to the high increase in customer complaints [80][88]. This is caused by a failure to demand PQ standards at a time when the use of sophisticated industrial and commercial equipment is increasing [69].

Negnevitsky, Milanovic and Green find that, with regard to PQ issues, government-controlled utilities are detached from the actual situation [36][15]. The failures to implement urgent PQPs by some utilities in developing countries have resulted in their supplying free power to their customers. According to these writers, distribution utilities in less developed countries are not worried about the quality of the power they provide to their clients, imagining that PQ has matured to the point where it will never be a problem; moreover, their customers are satisfied to have some kind of power supply and are indifferent as to its quality [15].

Yet utilities in less developed countries are being under pressure to improve and address their PQ issues owing to the introduction of new technology from developed countries. In response, some distribution companies have contracted out the solving of their PQ issues to a third party to satisfy their customers; this is due to the inability of their engineers and technicians, who lack the skills and experience to solve these problems [15]. These are among the factors which prevent utility companies in less developed countries from coping by themselves with the evaluation and solution of their PQ issues:

- Lack of PQ expertise among their staff, who have little understanding of PQ issues and are not knowledgeable about the ways to implement PQPs [35].
- Developing countries cannot afford to conduct PQ training courses and teach staff to measure and analyse PQ disturbances [35].
- Management is not committed to implementing good PQPs, due to lack of awareness. This has led to the lack of a long-term strategy for successful implementation [35][72].
- End users have no idea of the effect on the quality of the power supply of using high technology equipment [35][72].

Overall, some utilities in developing countries are not concerned over PQ issues, believing that they will not escalate [15]. However, even when PQPs are being implemented, they still do not generate the right solutions for PQ problems. Only when end users become aware of PQ definitions can the utilities diagnose the problems correctly. It would also be helpful to utilities to conduct intensive PQ training courses to make engineers and technicians aware of the issues.

Therefore, utilities need to take the chance to implement PQPs seriously, in order to deal with customer complaints and efficiently provide PQ to their consumers. Moreover, PQ issues will steadily continue to increase, considering that the demand for power will continue to rise significantly [33]. In response, several factors will need to be considered in running a PQP in less developed countries, such as:

- Customer type: distribution companies deal with a large number of commercial and industrial customers; hence, considering the type of customer type is required in implementing a PQP.
- Geographical location: significant PQ issues are caused by extreme and changeable seasonal weather, which needs to be considered when distribution companies implement a PQP [15][7].
- Awareness programmes: distribution companies need to address their customers regarding the deeper issues in PQ awareness programmes [15][7].
- Customer knowledge: distribution companies need to increase customers' knowledge of PQ issues, to enable them to be solved where possible at customer level [7].

2.7.1.2 Power Quality Programmes (PQPs) in Developed Countries

Some utilities in developed countries have implemented worldwide PQPs, which include the monitoring and measuring of PQ disturbances. PQPs are more successful in developed than developing countries, due to the rapid adoption of sophisticated technology, as well as the higher level of PQ awareness in the customers, who tend more to recognise its importance. Furthermore, as the use of sophisticated equipment increases, power suppliers in developed regions are trying to establish a high level of PQ standards in a short time, due to pressure from large industrial customers [1][4].

Schienbein and De Steese conducted a study to evaluate the features which led to reliability problems in the PQ and power supply in distribution utilities in USA. They identify three main factors driving the distribution companies to implement PQPs in this situation [70].

- The need to generate more power to meet consumer expectations when the growth in the rate of demand increased from 8% to 10% a year. This issue is particularly acute in developing countries, where two to three billion people currently have no access to electricity [70].
- Economic growth requires a high level of PQ, due to developments in digital equipment [70][79].
- Advances in high technology now affect equipment manufacturers, industries and end users; they all require a high level of PQ, due to the sensitivity of their equipment [79].

Furthermore, a study by Grebe, et al. (2012) conducted different power quality seminars regarding the implementation of PQPs around the USA. The main study results indicate that the significant challenge facing the distribution utilities and end users is the need to become familiar with PQ to deal with the relevant issues [95]. They conclude that, in order to deal with the problems associated with the implementation of PQP, the three following factors are essential:

❖ Education programmes for both end users and the employees representing customer services, to build a basic understanding of important PQ concerns. End users will learn about the importance of improving power quality and employees will be able to cope with the various PQ problems raised by end users and [95][96]. Moreover, full understanding of the scope of implementation of PQP will help to identify appropriate solutions and prevent future occurrences.

❖ Increasing power quality awareness has become one of the fundamental requirements for the successful implementation of PQP.

❖ Developing the infrastructure and capacity of distribution networks to accommodate and exceed the demand. This will prevent any situation arising from the failure of design to cope with economic growth.

In addition, Grebe, Mueller and Long also state that developing and implementing PQP involves various important requirements [95], such as the following:

➢ Structure of the distribution utilities to facilitate the programmes tasks.

- Funding with enough resources to reach the expected level of the implementation and surmount any existing barriers. This includes measurement equipment, incentives to encourage the staff and PQ training course facilities.
- Customer interaction; in so far as the end users understand the importance of improving PQ, they are required to learn from the programme team, which will provide them with the data needed, such as suitable types of equipment, methods of PQ measurement and cooperation.
- Training needs; staff at all levels, including top managers, middle managers, engineers, technicians and all other employees involved in PQP implementation should have enough training courses in PQ issues to improve their understanding of the implementation process.
- Equipment requirements; equipment for PQ measurement and monitoring is part of the PQP implementation; such equipment should be available at all levels to monitor the end users' sites. Moreover, a PQ database should be set up to share and view information about the power quality of the utility system; it should be reviewed and compared with the power quality data collected from the end users' site measurements.

In addition, Barnard, Van Voorhis and Moncrief conducted a study in 2000 regarding PQP in the USA, Asia, Africa, Australia, South America and Europe; the aim was to measure PQ issues across distribution systems and identify concerns for the future of PQPs from the perspective of domestic and international users [15]. This study revealed some significant features drawn from PQPs run in these areas, with the following outcomes:

The effect of PQ issues appeared quickly across distribution systems worldwide. More intensive programmes must now focus on the education of employees in both the industrial and semiconductor sectors and those who use their products [18][15][88]. Such programmes can reduce the impact of damage to the distribution systems and smooth out PQ disturbances. The study supports the view that both manufacturers and domestic end users are not fully knowledgeable about the risk of causing PQ issues with the sensitive electronic tools which they operate. Therefore, engineers must be knowledgeable enough to make both manufacturers and domestic users aware of PQ disturbances [31].

Barnard and Van Voorhis suggest that distribution companies should update their competence to include international industrial innovations, such as new technologies, in order to improve the setting up of PQPs to international standards [15]. But some authors believe PQ issues need to be solved because the level of awareness among end user has risen, due to the economic activity in the developed countries [77][1][78][2][79]. Finally some experts, they claim, emphasise that PQ issues will decline as customers' awareness increases and they learn to solve issues themselves [15]. Moreover, as the awareness level increases and they begin to recognize the concerns which affect the operation of their equipment, they will expect a high level of PQ in response to their demand [97].

Therefore, a PQ diagnosis system has been proposed which would offer adequate data for end users to remedy PQ disturbances themselves, as their awareness level increases [68][77][79]. This system would help determine PQ issues on the basis of both location and cause [68].

Nevertheless, the interviews conducted by Barnard and Van Voorhis in their study were only with professionals involved in PQP in the USA and elsewhere. Some respondents, however, unlike Barnard and Van Voorhis in their study [15], consider that the research programme should be extended to include interviews with end users [98], since one-sided views can never determine the right solution.

Moreover, Hannan, Hussain, Mohamed and Begum implemented a PQP in 26 industry sites in Malaysia to identify the factors leading to PQ flicker which represented 57.5% of all disturbances. Flicker causes serious damage to industrial equipment; it shortens its life and leads to low product quality [88][99]. The survey revealed that six main factors, in two main groups, caused PQ flicker in these industries, which should be tackled so as to raise the level of PQ awareness [88]. These groups were:

- Education, awareness, guidelines, training support and research and development play a very crucial role in raising the level of PQ awareness and in dealing with PQ problems in these industries. It would help distribution companies if they considered them in their policies [72][80].
- Financial incentives are another very important way of motivating employees to solve PQ issues.

2.7.2 Why implementing a Power Quality Programme (PQP) is Important

Some utilities describe PQ as interesting business and have started to implement different programmes for solving its problems [91]. Their target was to state the actual level of PQ differences and the main sources in the distribution systems. However, other electricity companies in a few developing countries believe that this is not an interesting subject to be engaged in. This is because it will not grow rapidly growth in the future [15]. However, some misunderstanding of the causes of these problems seems to have arisen, because the views of the electrical companies and their customers differ [5][19]. This highlights the need to implement PQPs and aid distribution companies to accommodate all the issues raised earlier and set a clear long-term strategy to raise the overall level of awareness.

2.8 Power Quality (PQ) Issues in Implementing Power Quality Programmes (PQPs)

Labricciosa conducted a study based on PQP to investigate the highlighting in 1996 of PQ issues in Canadian electrical distribution systems. The study reveals three main factors essential for solving PQ disturbances [18]:

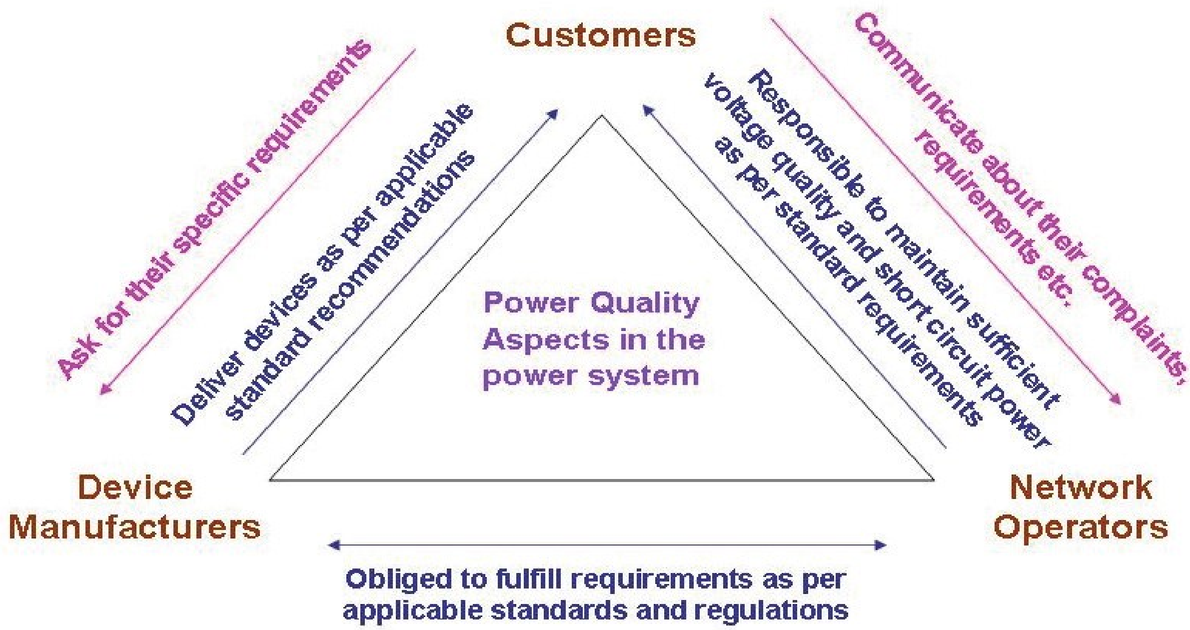
- PQ consultants should understand PQ issues by monitoring and analyzing the effective solutions to meet customer expectations, required as part of PQP.
- Power supply standards are one of the fundamental requirements for raising the level of PQ performance.
- PQ awareness of PQ issues among end users will reduce the susceptibility of the sensitive equipment that they use.

In addition, Schienbein and De Steese suggest that what is needed is new technology with less sensitive electronic equipment and changes in the structure, management and operation of distribution utilities, which would provide logical solutions for improving PQ and meeting customer expectations in the future [70].

Another study by Eberhard, based on a PQP implementation, presents five significant ways of improving PQ and resolving disturbances [78]. These need to be carefully considered to evaluate and improve PQ performance in the distribution networks worldwide.

- Better infrastructure for distribution networks
- Handling customer’s complaints in order to identify the underlying problems
- Including a PQ contract between the supplier and end users [78][82]
- Enabling sensitive electronics equipment to meet PQ standards
- Training courses to raise the education and awareness levels of engineers, enabling them to understand customer complaints

In response to these factors, Eberhard also states that the best PQ solutions can be implemented when PQ issues are shared between three main bodies. These are end users, distribution utilities and equipment manufacturers, who are all responsible for solving power problems, as shown in Figure 2.2 [27][78][97][100]. Moreover, according to Eberhard, these factors must be influenced and supported by top management to guarantee progress. The relevance of these points is that assessing the sources of PQ disturbances will help identify appropriate mitigation tools [78][80].



Source adapted from [78]

Figure 2.2: The relationship between three parties responsible for PQ in the network

However, Bhattacharyya, Myrzik and Kling suggest that the three parties – network operators, equipment manufacturers and customers – should be aware of and responsible for reducing the disturbances in PQ at the point of connection, which is liable to be under a regulatory standard regarding PQ [92].

Deshpande and Chitre emphasize the same factors as Eberhard. However, they suggest that the factors should come under government control, to force the utility companies to apply more measures associated with the concept of PQ across their institutions. This will increase the level of awareness and education of those involved, as they make more studies and measurements of the entire network [100]. Furthermore, Moncrief et al, agree that the customers, distribution network utility and equipment manufacturers should cooperate to identify PQ issues by implementing more education programmes. Therefore, four main steps should be taken to reduce the severity of the PQ problem [97]:

- End users should be aware which items of electronic equipment are most susceptible to PQ deviation and report these to the utilities.
- Equipment manufacturers should produce equipment less sensitive to PQ disturbance
- Distribution utilities, as a form of assistance, should provide a high quality power supply under PQ standards, establish PQ information for customers and diagnose and analyse customer complaints.
- PQ seminars and programmes should be conducted for both customers and utility employees to increase their knowledge.

Moreover, Radhakrishna recommends that four main elements are necessary for the distribution utilities to implement PQP and avoid PQ problems, in order to satisfy customer expectations [44]:

- Planning and designing the distribution network at an earlier stage is considered the best way to avoid PQ problems. This requires understanding the utilities' environment by developing PQ standards to be compatible with both changeable weather and the equipment specifications of the distribution networks, which should not be sensitive to variations in PQ.
- Proper teams should be formed to look into the causes and sources of PQ events, in order to analyse them and find the appropriate solutions.
- A PQ database should analyse customer complaints and revise and compare their characteristics.
- Susceptible equipment should be identified so as to include proper mitigation or equipment compatible with PQ standards in future.

Another study conducted by Bhattacharyya et al. (2007) also emphasised that end user satisfaction with PQ mainly depends on the relationship between customers and their utilities in terms of the commercial quality of the electricity distributed as a service. This relationship refers to the agreement between them in the PQ contract. To this end, this study suggests that the network operator should measure and guarantee that the PQ is limited by the PQ standards. This will affect the utility's reputation, for the end users will not trust the network operator if power supplies to them is of low quality. As a result, many distribution utilities around the world are obliged to respond to PQ complaints from end users and fulfil their expectations. However, end users also have a responsibility: to guarantee that the electronic equipment will perform effectively to PQ standard and not to cause any deviation in power supply from the abnormal operation of their components. Thus, the high standard to which the sensitive equipment operates will guarantee it for life, as well as reducing the financial losses resulting from the lack of standards for electronic devices. The money thus gained could be invested in improving the distribution networks [43]. Nonetheless, the following factors are highlighted to be taken into account in order to reduce the cost of PQ for both end users and utilities:

- Changing distribution networks infrastructure by placing PQ mitigation devices, etc.
- Compensation for the extra losses in network components due to PQ issues.
- Handling customers' PQ complaints by paying more attention to finding the problem
- Designing the distribution networks to facilitate any future PQ modifications and improvements
- Customers' cooperation in minimizing PQ disturbances at their installations
- Introducing a PQ contract scheme which insists on PQ standards between end user and utility.
- Implementing a PQ database to improve PQ performance in the network by conducting different PQ measurement programmes [43].

In any case, PQP requirements are not dependent on technical aspects, such as the type of equipment installed in the distribution system, but depend on other non-technical factors, of which strategic planning is one [75][97].

Strategic planning regarding PQ is considered one of the crucial requirements for the implementation of a PQP [72][93][101]. Strategic planning can eliminate the huge drain on financial resources which are currently spent on unnecessary consequences, such as the repair of damaged equipment, but instead focuses investment on improving PQ, resolving disturbances and finding appropriate solutions. Thus, the lack of clear strategic planning affects the consumer, since there are no incentives for them to cooperate with the utilities and implement a PQP.

2.8.1 Critical Success Factors of Implementing Power Quality Programmes (PQPs)

The key success factors are needed by top managers, engineers, technicians, and employees to effectively complete PQP implementation. These include end user satisfaction, employee participation, top management commitment, and staff and end user awareness. The success factors help the planning and implementation teams make the process of implementing each stage of the framework smooth, and obtain the required information to support improving PQDs. These factors are different from one electrical distribution utility to another due to differing situation, circumstances, and problems. They were discussed as following:

2.8.1.1 Management Commitment

A PQP was conducted to investigate PQ issues for satisfied residential and commercial customers. Dorr and Melhorn point out that management commitment is the first requirement. This should promise both "*Convenience and Completeness*" as vital variables to diagnose any PQ issues and implementing a PQP to satisfy residential and commercial customers [102]. Dorr and Melhorn find that the two elements must be considered aspects of management commitment, because the preparation, such as associated management planning, long term strategy and a high level of employee experience, are very significant factors in solving PQ problems.

Convenience means that there should be no obstacle to obtaining data to diagnose the problems. Completeness means that there should be an adequate and comprehensive system for solving them. Adequacy refers to the engineers' and technicians' skills needed for solving them. This approach to the solution has been agreed and is recommended [17, 18]. Thus, some utilities are being made responsible for providing a high standard of PQ to the end users, due to the increased use of sensitive equipment [17][103].

Comprehensiveness refers to the management commitment and ability to solve these problems [102]. It includes engineers, technicians, employees and the most important factor, the customers, to complete the requirements needed for a PQP. However, although both variables are important, there has still been no real evaluation so far of the factors surrounding PQ for residential sites and the implementing of a utility diagnostic system [103].

2.8.1.2 Power Quality (PQ) Database

PQ datasets have been highlighted as necessary monitoring tools for residential equipment [17][102][104]. This is because the demand for electricity and the electronic devices used by customers have increased [7][102-104]. As a result, PQ databases can be used to provide the equipment specifications and guidelines, identifying which are the most susceptible to PQ variations and informing manufacturers accordingly. Moreover, both technical guidelines and PQ standards can be provided as part of the implementation of a PQ database, in order to reach a high level of quality to satisfy customer requirements [26].

Moreover, the database can also be used for accurately analysing the causes of recorded disturbance and finding appropriate solutions based on set PQ standards [86][105]. Thus, to avoid any PQ issues, databases for electricity companies. These allow PQ data and information to be reviewed, revised, tested regularly and compared to PQ standards [19][75]. In this respect, both awareness and experience are required to analyse the data in order to tackle PQ problems [44]. Both these qualities can be enhanced by running regular training courses in ways to deal with dataset requirements. Therefore, one of the database requirements is to determine the characteristics of customer loads through predictive monitoring. But this type of monitoring might not provide the real measurement needed to solve the customer's PQ issues or even provide a clear picture of PQ disturbances. Furthermore, predictive monitoring is used in conjunction with engineering skills and awareness, since engineers refer to completeness as a very significant element which requires a high level of knowledge and experience [17][103].

In addition, Dorr and Melhorn identify the main factors for implementing a PQ database in order to satisfy residential and commercial customers:

- Training courses provided by the utility on PQ databases to increase the level of employee knowledge
- Management commitment to support staff and encourage them to implement the PQP and collect PQ data

- Proper teams to analyse PQ disturbances in immediate response to customer complaints by recording the PQ data captured and comparing it to PQ standards [17][102]

Moreover, the electricity companies can categorize the PQ dataset, taking into account the customers' perspective rather than the companies' in collecting the data [98]. It is also suggested that there should be more records on the most susceptible items of equipment [18] [44][73][85] [96]. This can help in identifying the severity of these disturbances and their sources. Identification would be based on the customer load characteristics that are crucial for the distribution utilities in dealing with PQ customer complaints [98][106]. This would avoid any disturbances in the same pattern and prevent them from recurring.

2.8.1.3 Design Distribution Network

Lee and Hoffman conducted a study to describe the aim of a holistic PQ supply and to identify the most critical factors in resolving PQ issues. They find that both climate change and infrastructure are the main reasons for PQ problems, in less developed countries in particular [70][7][87]. Infrastructure has not met, nor adapted to the growing demand of the population, i.e. the increased demand for electricity, in some distribution systems [27][87]. Therefore, in order to accommodate the demand, the power distribution system must be equipped to adjust to "*the market and the new technology innovations*" [27][80][87]. The utilities should upgrade and design the distribution networks "*holistically*", on the basis of the current level of demand for both consumers and power supplies [75]. They should take into account climate change in some rural areas when designing the distribution networks.

However, these writers emphasise that these upgrades and designs cannot be implemented unless structures and studies for all requirements are prepared logically [70]. A holistic programme is a major step in providing all these structures and studies. It includes network design based on management planning in solving technical problems, involving people's skills and experience and customer awareness according to PQPs implemented by the utility [101]. The most important element is that, if the power networks are designed with a clear strategy, then this can reduce the pressure of demand and the network will function effectively without any deviations in PQ [72][75]. It can provide awareness of the current state and also prepare the distribution systems for future development [87].

Moreover, more investment is needed in designing the grid, where the issues occurred would remove these obstacles to improve PQ [19][74][89][107]. However, if the distribution networks are not designed properly, this will lead to an increase in two different deviations [10]. These are an increase in the network losses caused by poor efficiency, poor operation and poor PQ, which are referred to as small deviations. Larger deviations can result in serious damage, causing the protective devices to trip or fail [19][108]. As a result, the components will break down regularly and their lifetime will shorten due to climate changes and lack of maintenance [19][99].

Another PQP was conducted by Meyer, Schegner, Winkler, Muhlwitz and Schulze to determine the most critical causes of PQ issues. They identify that ignoring both structure and the characteristics of end users and when designing networks are the main reasons for PQ disturbances in German power distribution networks [91]. These occurred mostly in rural areas, where the network was not properly designed due to geographical factors, such as large areas and unusual weather conditions [15][91]. As a result, power could be stolen through improper connections to satisfy the needs of users who had settled in rural areas, Therefore, any mismatch in either of these elements when designing distribution networks to diagnose PQ problems can give a different or wrong estimation of the real situation [19][75][108].

Distribution utilities need to apply high standards when designing distribution networks. Thus in order to achieve high level PQ the four main requirements to consider are: network structure, consumer structure, customer load characteristics and network size, [15][7][91]. The design should take into account the customer structure and reactions, even if there is a lack of background or experience regarding PQ [98]. This is especially the case in areas where PQ issues are inadequately measured [19]. The customer load characteristic is a function of three main requirements:

1. Proper network design based on each consumer load [7][106]
2. Accurate load forecast to predict and accommodate economic growth
3. Management planning and strategy to improve and reach a high level of PQ, based on points 1 and 2 [72][101].

In addition, when measuring PQ indices, both the network operation and planning sections should be connected to control systems and share PQ measurements data [26][15][91]. This connection is required to tackle customer complaints before and after the problems [19]. As a result, the writers recommend a careful focus when monitoring, calculating and analysing the data, otherwise a wrong conclusion might be formed about customer load characteristics [19][77].

Therefore, one of the solutions to PQ issues is to design the network to achieve an acceptable level of customer satisfaction which depends on those physical elements that increase the level of employee skills and awareness [10][109].

2.8.1.4 Power Quality (PQ) Awareness

Grady and Noyola conducted a PQP in the United States from the perspective of both end users and utilities. They reveal that lack of understanding of the PQ concept is another problem underlying PQ events.t the same time, too little understanding of the implications of PQ issues is a major obstacle which prevents a PQP from making improvements. As a result, efficiency, quality and equipment life are affected by poor PQ. Improving these depends on a high level of understanding of PQ features [66][77][80][99]. This creates a gap between people who are familiar with PQ and those who are not interested, in terms of "*understanding and visibility*" [44][73]. Consequently, the importance of PQ has in the last ten years become an essential issue both providers and customers to consider.

Manson and Targosz conducted a study in 8 developed European countries, namely Austria, France, Italy, Poland, Portugal, Slovenia, Spain and the United Kingdom, for an extrapolation of the overall wastage caused by poor PQ in EU-25. Addressing only the technical problems, this survey used interviews and questionnaires. It was pointed out that the industrial sectors suffer most from PQ problems in these countries [89]. As a result, PQ disturbances were a constant feature. This increase is due to the industrial sector not being aware of the importance of PQ and not taking effective action to prevent disturbances. These writers demonstrate that the increase in problems is due to a lack of employee awareness and skills to deal with such problems [47][89]. An effective solution refers to sufficient management commitment, whereby most of these issues can be avoided or eliminated. Therefore, these two factors have led to huge economic losses, exceeding €150 bn annually in Europe. This is also because measurement and maintenance of the existing networks are ignored, aggravating the disturbances and resulting in huge losses. All this results from poor PQ awareness [75][90]. Industrial sites were identified as the cause of PQ issues in Egypt also [10][109].

2.8.1.5 Customer Cooperation

Some responses to a questionnaire, administered ten years ago to EPRI customers, suppliers and customers in Texas, indicate that PQ satisfied customer's requirements to an acceptable level [73]. In other words, it was agreed that PQ had just begun to rise above previous results. This was due to the proliferation of sophisticated new technology [31][15].

Furthermore, some end users were interested in and endorsed whole programmes for solving PQ problems. The study conducted by Grady and Noyola shows that 57% of the respondents were getting help from a utility company, whilst another 39% were seeking assistance from other experts when suppliers were not helpful in either diagnosing or determining PQ issues [73][107][110, 111].

The method used by Grady and Noyola was useful in collecting data from the customers' and utilities' perception of PQ issues in different places. The study would have given necessary and sufficient results, if the interviews had been conducted to support the ideas and opinions gained from the questionnaires. The questionnaires highlighted the percentage of people who preferred to seek assistance from their utility and of those who preferred it from elsewhere. Therefore, had the end users been interviewed, more details would have been provided of whether the utility company could be trusted to provide satisfactory PQ solutions for them.

2.8.1.6 Training Courses

Remedying PQ disturbances requires training courses and programmes which run continuously. These programmes would give enough training and knowledge for end users and employees who lacked awareness of PQ [88]. During the pilot study, the companies provided relevant knowledge to users and engineers and as a result the level of PQ complaints fell [15][49]. However, when the companies cut back the training courses on PQ, the level of PQ complaints rose [49]. Therefore, the emphasis in conducting such programmes will be to raise awareness in the users and thus encourage employees in turn to find specific techniques for resolving PQ issues across the distribution systems. Therefore, utilities' educating the end users and engineers through workshops and seminars is crucial; such activities should promote familiarity with PQ definitions and disturbances. This would raise the awareness level which would support the attempts of the distribution companies to achieve high levels of PQ performance [44][71][80][94][97] [100].

To sum up, the present research has sought to make a comprehensive review of the literature in the relevant areas, such as PQ definitions, PQDs, PQP, non-technical factors and the success factors needed to improve PQ. This investigation is needed in order to identify and highlight the key outlines, patterns and areas of PQP which require further improvements, developments and research. The relevant literature was derived from different resources such as; journal papers, conference papers, posters, reports, surveys, books, archives, theses and dissertations. The main purpose of reviewing this literature was to guide the researcher to clear contributions, give better understanding of the current problems and, by implication, the areas requiring development so that sufficient attention is paid to neglected topics.

Consequently, this research develops its main contribution by examining the main factors drawn up to obtain the needed findings in terms of LDNs first by empirical study and second by collecting data in two ways: a PQ questionnaire and a series of semi-structured face to face interviews with LDNs staff. Table 2.3 presents a summary of PQ studies of different electrical distribution utilities in both developed and developing countries and some of their key factors.

Table 2.3: Summary of PQP studies in different distribution utilities across the world

No	Author	Purpose and aim of the study	Methodology			Finding/ Conclusion Suggestion	reference
			QN	QL	Mon		
1	Dorr and Melhorn (2000)	To monitor residential PQ which seeks to resolve the questions about power quality levels at residential customer power entrances by providing answers on large load management and application issues.	✓	✓	✓	They conclude that other significant factors associated with residential PQ monitoring, such as convenience and completeness, must be considered in monitoring residential sites to increase the residential electronic equipment which requires a PQ monitoring database common to residential appliance manufacturers and trade organizations.	[102]
2	Grady and Noyola, 1992	To study the impact of PQ problems on the business activities of industrial and commercial customers and the quantification of this impact, which is imperative for the successful implementation of a mitigation strategy in a PQP.	✓	✓		The findings of the study show that two thirds of all respondents endorsed the concept of adding an equipment-sensitivity rating to the nameplates of equipment more to characterize PQDs for end users than to measure utilities. It is also found that there is a gap in both understanding and visibility between end user and utility perspectives in power quality solutions and that some of them are not aware and willing to engage in PQPs.	[73]
3	Chung , et al. (2007)	To develop a PQ diagnosis system which measures PQDs at the end user's point of connection.	✓		✓	The study emphasised that the end users can gain sufficient PQ information to manage and improve PQ issues themselves subject to their utilities providing a power quality diagnosis system. It is also can help the distribution utilities to find the locations and causes of PQ issues by connecting to this system.	[68]
4	Lee and Hoffman (2009)	To describe a vision for a holistic distribution power supply and delivery chain regarding PQ within smart grid operation and planning.		✓		This study found that two challenges constrain the improvement of PQ. The first challenge is global climate change and the second challenge is the electric power system's infrastructure, if it is not prepared to adapt to market and technological innovations and it remains unable to meet all the demands placed upon it. This study suggested that holistic planning and a manageable plan must be available to provide all structural objectives in order to deliver good PQ to end users. They also recommended that without significant infrastructure upgrades, the electric power system will be unable to meet future energy needs and PQ will not improve.	[87]
5	Targosz and	To investigate the industrial sector's share of non-residential energy users in the consequences for European Industry of	✓	✓		The study provided numerous additional conclusions about the occurrence of PQ problems, their sources and the equipment	[89]

	Manson (2007)	poor power quality.				affected. It is astounded that the industrial sector, for which electrical power is critical, is not fully aware of PQ issues. It is also found irresponsible of the electrical power utilities to ignore the issues of PQ and their cost and losses. The study suggested that better design and greater investment in these systems would eradicate most, if not all, of these losses resulting from poor PQ.	
6	Forsten and Key(2005)	To develop the basis and guidelines for development of measurement metrics for each of the SQRA elements at the level of the electrical distribution systems.		✓	✓	The study emphasised that PQ is a critical element of electric power due to modern electrical devices. The strategic management of PQ performance will improve tools, resources and insights for utility decision makers to diagnose PQDs. It also will make it easier for utility top managers to cope with changes in the marketplace as well as the regulatory environment.	[75]
7	Salam and Nasri (2005)	To conduct a PQ survey in Egyptian industrial zones.		✓	✓	This study found that power quality has become a strategic issue for both electricity companies and industrial sites. It concludes that one of the mitigation tools is to use power conditioners such as UPS or voltage sag compensators (VSC).	[109]
8	Ortiz-Rivera (2004)	To study PQDs in commercial buildings in Puerto Rico and find the significant factors leading the issues to be compared to other studies conducted in other distribution utilities.		✓	✓	This study proved that PQDs affect Puerto Rico's commercial companies and customers, wasting a good deal of money and preventing any further improvement regarding PQ problems. This study suggested that if utility suppliers understand PQ definitions, it will lead to satisfying end users regarding PQ.	[11]
9	McGranaghan, et al.(1999)	To understand the existing levels of PQ provided to consumers and to determine the levels of PQ that can be reasonably expected.			✓	This study suggested that a basic understanding of PQ levels is needed before power distribution companies consider the strategic implications which must be met to satisfy end users, meet their expectations regarding PQ requirements and respond to their behaviour. It is also emphasised benchmarking the power quality levels at individual locations to provide a basis for the continuous evaluation of system performance and the effectiveness of measures to improve the performance of PQ as the loads of sensitive equipment increased.	[7]
10	Kottick (2008)	To present a statistical analysis of preliminary measurement results regarding A large majority of customer complaints of PQ.			✓	This study found that PQDs increased in recent years in the Israel Electric corps as a result of the growing dependency on a reliable and continuous supply of electricity which requires monitoring systems to tackle these issues.	[69]
11	McNulty	To determine whether or not there was a significant power	✓	✓		This study revealed that there has never been a PQP conducted	[49]

	and Howe (2002)	quality "problem" in Massachusetts and the extent to which renewable energy technologies could play a role in remedying PQDs.				to match the actual incidence of PQDs with actual customer PQ complaints. It is also indicated that there is clear evidence to link customer complaints regarding PQDs and the impact of these complaints on customer knowledge. This refers to the fact that when the utilities conducted a PQP to provide customer education, the level of PQD complaints from end users decreased and the converse was also true.	
12	Barnard & Van Voorhis (2000)	To Investigate utility-based power quality programmes: domestic and industrial rather than any type of quantitative data.		✓		This study found that if customers become more educated in the causes and effects of power quality issues, they will be better able to anticipate and handle power quality problems as their awareness level rises.	[15]
13	Meyer, et al.(2005)	To describe a method of power quality surveying in distribution networks by several performance indices.	✓		✓	This study revealed that a high level of automation in data management and analysis allows the efficient handling of measurement data without an increased need of manpower. As the appearance of PQDs relates to the power provider and consumer structure and consumer behaviour, the importance of methods for an overall PQ improvement requires consideration of end user structure and behaviour if it causes PQDs.	[91]
14	Orillaza, et al. (2006)	To present the development of models and a methodology for the segregation of PQ distribution system losses.	✓	✓		The study concluded that the developed models and methodology can allow the distribution utilities to precisely identify the occurrence of PQDs, due to technical loss. It can also help them in terms of preparing long term strategies for reducing and controlling all types of PQDs due to distribution losses.	[112]
15	Freeman , et al.(2009)	To examine PQDs in distribution systems based on the "local delivery" concept, considering the range of factors causing the issues.	✓		✓	This study emphasised that distribution utilities must move into more awareness programmes on ways to design and build more efficient energy delivery systems and improve PQ. As a result, due to poor design of the distribution network based on customer category and loads which tends to increase PQDs by not taking into account the conventional analysis when identifying the disturbances.	[74]
16	Howe (2007)	To provide information and tools to facilitate the implementing of PQP utilities by regulators and end users.		✓		The study suggested methods to determine the overall categories of PQ improvements. It mainly covers the relationship between designing the distribution networks, characterising the types of end user and providing full	[113]

						regulation of the power supply	
17	Deshpande and Chitre (2009)	To develop a system where knowledge regarding PQP must be shared as a team project by manufacturers, utilities, government and end users.		✓		The study indicated that the power supply should be of adequate quantity, low cost and high quality, while including PQ monitoring and increased levels of awareness. Adopting the PQP without any difficulties will be facilitated by conducting research, studies and measurements of existing networks and consumers.	[100]
18	Bruce (2007)	To provide power quality for the21st century needs effort and requires extensive education programmes to increase the level of understanding.		✓		This study emphasised that good understanding with comprehensive assessment of the current situation and the particular circumstances regarding the implementation of PQP will provide the best preparation.	[80]
19	Grebe, et al. (2012)	To conduct different power quality seminars regarding the implementation of PQP around the USA's distribution utilities.		✓		The main study results indicated that the significant challenge facing the distribution utilities and end users is the need to become familiar with power quality to deal with the relevant issues. This requires an education and awareness programme for both employees and end users and the development of the infrastructure of distribution networks to accommodate and remain ahead of the capacity demand.	[95]
20	Negnevitsky, et al. (1997)	To obtain a clear picture of the current problems of PQ supply in Tasmania via by conducting PQ monitoring and a questionnaire.	✓		✓	This study found that government-controlled utilities are detached from the real situation with regard to PQ issues and that customer complaints are still neglected. It stressed that a PQP will make significant contributions to customer satisfaction. They suggested that this level of customer satisfaction can be used as part of the process to identify the level of PQ issues and show where improvements could take place to further increase this satisfaction.	[36]
21	Hannan, et al. (2010)	To identify the factors leading to PQ flicker which represented 57.5% of all the PQ disturbances that occurred in industrial sites in Malaysia.	✓			The study revealed that education; awareness, guidelines and training support programmes would play very crucial roles in increasing the level of PQ awareness and dealing with PQ problems in these industries.	[88]
22	Eberhard (2011)	To allocate responsibility for resolving PQ issues in Croatian distribution utilities.		✓		This study stated that the best PQ solutions can be implemented when PQ issues are shared between three main bodies. These are end users, distribution utilities and equipment manufacturers, who are all responsible for solving them.	[78]

23	Winkler, et al. (2006)	To determine the most critical factors causing PQ issues in German utilities' distribution systems.	✓		✓	The study identified that ignoring both the end users characteristics and structure when designing the networks is the main root cause of PQ disturbances in power distribution networks in Germany.	[114]

(QN): Quantitative Method), (QL): Qualitative Method), (Mon: Monitoring Method) *Source:* developed for the purpose of this research

Table 2.3 summarises the previous studies conducted on PQP, showing that most of the researchers, authors and scholars are in consensus on the success factors when improving PQ. Electrical distribution utilities and their users lose significant amounts from the inadequacy of PQP frameworks, guidelines and models. This requires further developments by the distribution utilities to tackle the outstanding obstacles to improving PQ and implementing PQP. Moreover, PQP frameworks need to develop ways to minimise the severity and the cost of problems traceable to poor PQ which affect the end users' equipment and power supply systems.

2.9 Summary

This chapter outlined the history of PQ, sketched its background and the definitions of PQ concepts by researchers and experts worldwide. First, it extensively explained PQ disturbances as presented by previous scholars in terms of characteristics and effects. Then a brief overview was given of PQ conditions used frequently to solve PQ technical problems. It also showed the cost of PQ to both industrial and commercial users and the significant losses caused by distribution utilities' neglecting PQ problems. Next, it identified the causes and obstacles that lead to PQ issues and also the obstacles facing the implementation of PQP, before giving examples of PQPs conducted in both developed and developing countries.

This research finds critical areas which require a focus on non-technical factors, considered the priority for those, who want a high level of PQ to satisfy their customers. The critical areas of research are shown below.

- Most of the previous studies concentrated on theory and thus cannot be relied on to find the significant reasons beyond PQDs in LDNs.
- Few studies have concentrated on practical assessment which includes a PQ survey, PQ monitoring and face to face interviews, since these require more investigation and empirical testing.
- There is a need to understand the effect of the success factors on PQP implementation after defining their weaknesses and the outstanding issues beyond each stage of the roadmap developed for the purpose of this study.
- There are few cases of PQPs being tested empirically and still not enough to describe the implementation of PQP in developing countries and remedy PQDs.

> The reasons for this are the different circumstances of the electrical distribution companies, in terms of structure, design and regulations, the locations of these studies and the fear that studying them might not lead to clear contributions to knowledge.

Therefore, it may be said that the critical areas revealed in the present research and credibly claimed by researchers, authors and scholars require more attention from the electrical distribution companies and should not be ignored. Indeed they should be taken into account as the most important factors in implementing a PQP framework. In addition, the research finds a multidimensional approach to implement a PQP framework, based on the non-technical factors identified; such an approach will facilitate technical remedies for PQDs at each stage of the roadmap. The stages of the process are awareness of, preparation for and implementation. If these stages are completed in due sequence, it will be of most benefit to the PQ issues; this is perceived as the main requirement for any electrical company seeking to reach a high level of PQ and satisfy its end users. Moreover, successful elements in the PQP framework, if adopted as described by previous researchers, will support the distribution utilities in their simultaneous step forward to make changes in PQ.

This research seeks to conduct a more empirical investigation, based on the conclusions, recommendations and suggestions found in the previous studies, most of all in those from developing countries. These show a significant lack of PQP implementation and further research is required on the critical areas and non-technical factors identified. The proposed PQP framework and the success factors in implementing PQP are covered and discussed in detail in Chapters Three and Four (below). Finally, the chapter illustrates the benefits of implementing PQPs and shows how factors, such as management commitment, a PQ database, design distribution network, PQ awareness, customer satisfaction and training courses would raise the level of PQ which would in turn result in a higher level of customer satisfaction.

The following chapter (3) presents the current level of PQPs and the efforts to implement more in Libyan distribution networks.

Chapter Three: A Case Study of Three Libyan Distribution Networks: West, East, and South

3.1 Overview

This chapter presents the current level of power quality disturbances (PQDs) in the General Electrical Company of Libya (GECOL), and especially Libyan distribution networks (LDNs). This chapter also states the factors, such as those affecting infrastructure, including network design, economic growth, illegal connections, increased use of electronic equipment, and lack of power quality awareness. All these factors affect the implementation of power quality program (PQP) in LDNs. For any distribution system to satisfy its consumers, the utility must implement a PQP and keep improving power quality in a way that accommodates the increased demand for electricity and by tackling the earlier points to sustain a high standard of power quality [33][15][1][2].

This chapter also gives a brief view of the literature regarding power generation and transmission systems. Section 3.2 provides an overview of GECOL, while Section 3.2.1 sheds light on the generation systems. Sub-sections 3.2.1.1 and 3.2.1.2 discuss generated power and peak load. Section 3.2.2 describes Libyan transmission systems, and Section 3.2.3 presents the Libyan distribution system, including the classifications and the existing PQDs affecting the three distribution networks. Section 3.3 explains the non-technical factors causing PQDs in the LDNs. Section 3.4 illustrates the research problem regarding PQ issues in LDNs. Section 3.5 introduces the PQP, and the requirement for implementation in LDNs. Section 3.6 summarises the whole chapter.

3.2 The General Electrical Company of Libya (GECOL) Facts, Figures and Problems

GECOL was established in 1984 [115], and is based in an underdeveloped country, Libya. It is the only structured power utility company in the country, and is 100% owned by the Libyan government. GECOL is responsible for three main functions, which are the generation, transmission, and distribution of power all over the country [3][116]. Since it was established, its purpose is to deliver electricity to customers in all sectors, such as industrial, commercial, agricultural and residential.

3.2.1 Generation Systems

Generation systems in Libya consist of 62 generating units, where power is then supplied to customers through the transmission systems [115]. The generation systems consist of combine-cycle, gas-turbine, and steam plants. They also consist of diesel generators placed in some rural areas. The generation plants are located geographically in different areas of the Libyan coast, throughout the Libyan network, and are linked to the distribution networks through sub-transmissions networks. Figure 3.1 shows that the most common generation plants used until 2008 are gas-turbine plants, because these have positive impacts on the environment compared to others [115].

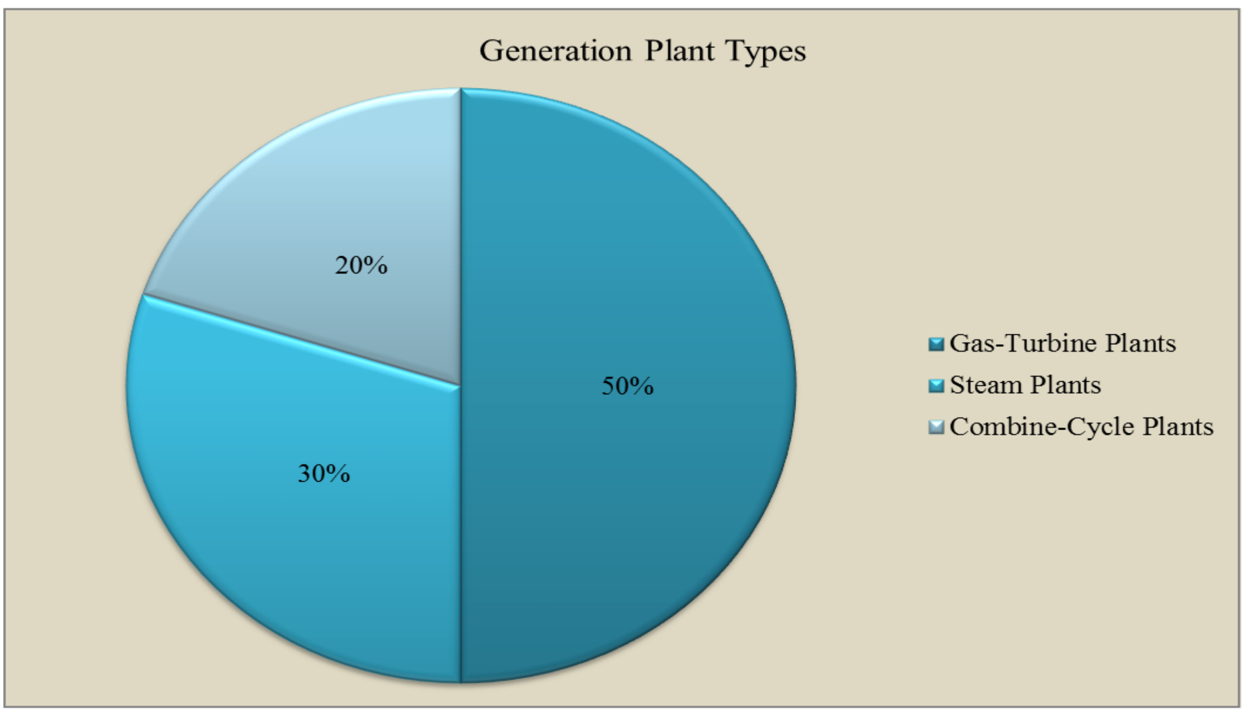


Figure 3.1: Types of generation plants used to generate power

The main fuels used to generate power are natural gases at 50%, heavy fuel oil at 30% and light fuel oil at 20% [117]. Figure 3.2 shows the most common fuel used to generate power during 2008.

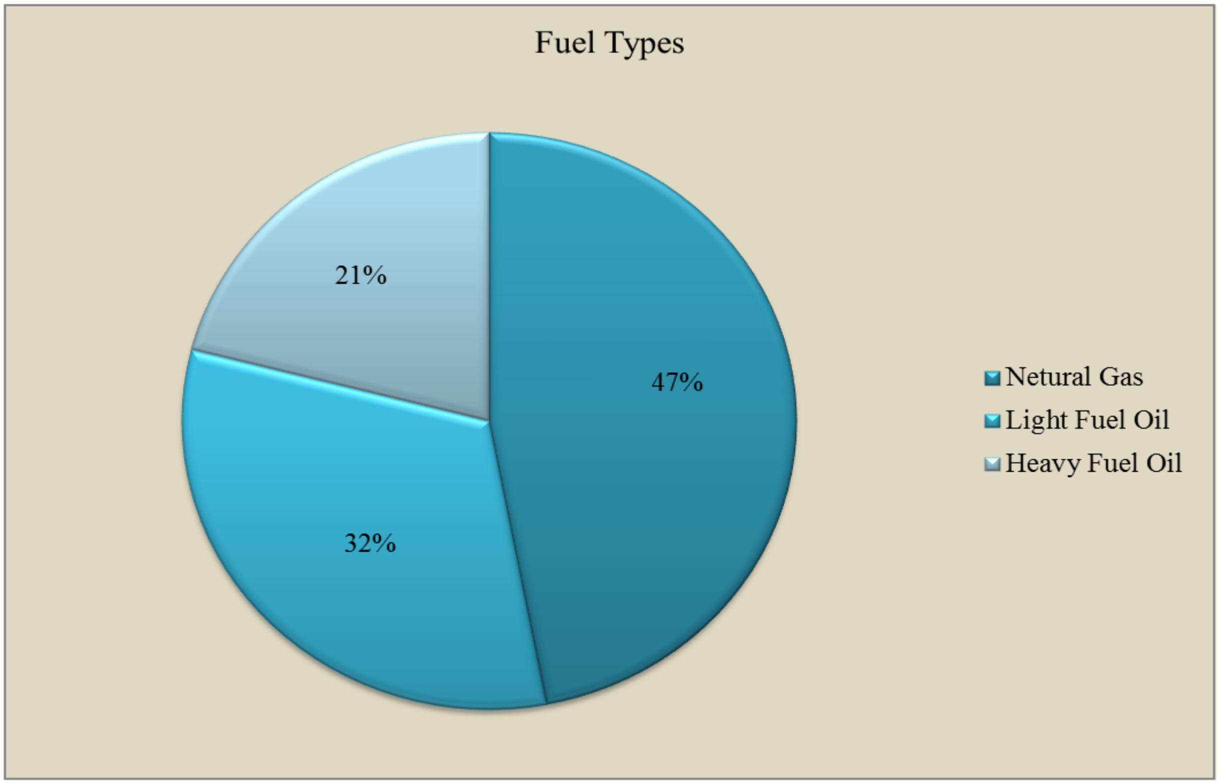


Figure 3.2: Types of fuels used to generate power

As can be seen in Figure 3.2, the most common fuel used to generate power in 2008 was natural gas representing 50% of all fuel used. The purpose of using this kind of fuel is to improve the rates of operational efficiency of power plants, and reduce the levels of greenhouse gas emissions and thermals [115]. Natural gas powered plants can also produce a high level of electrical power quality. Therefore, natural gas is the most used fuel for generation, rather than oil, which is being maximized for export only. Therefore, by 2016, gas will be the only fuel needed to produce power in all generation plants [118].

Generation plant capacity has expanded to meet the requirements of power for all users in the residential, agricultural, commercial and industrial sectors. This increase in generation capacity was driven by the need to keep up with the growing increase in demand and the expanding economy [119]. Therefore, GECOL planned to spend 5.3 billion LD over the next 10 years for new generation plants [120]. Nonetheless, a majority of GECOL's existing power plants are in poor condition, detracting from availability and efficiency, as shown in table 3.1. This explains the different types of generation plants that were built since 1976, and the fuels used to generate power [121, 122].

Table 3.1: The different types of generation plants and fuels used since 1976

The plant name		Type of fuel used	Number of units	Ability of each unit (MW)	Ability of each station (MW)	Year of operation
Steam plants						
Al-Khums		Heavy fuel oil /Gas	4	120	480	1980
West Tripoli		Heavy fuel oil	4	65	260	1976
		Heavy fuel oil	2	120	240	1980
Derna		Heavy fuel oil	2	65	130	1985
Tobruk		Heavy fuel oil	2	65	130	1985
The total generation for the steam plants			14		1,240	
Gas plants						
Abu Kammash		Light fuel oil	3	15	45	1982
Al-Khums		Gas/Light fuel oil	4	150	600	1995
South Tripoli		Light fuel oil	5	100	500	1994
Al-Zwetina		Gas/Light fuel oil	4	50	200	1994
Al-Kufra		Light fuel oil	2	25	50	1982
Al-Jabal Al-Gharbi		Gas/Light fuel oil	2	156	312	2005
			2	156	312	2006
The total power generation for Gas plants			22		2,019	
Combined-cycle plants						
Al-Zawiya	Gas	Light fuel oil	4	165	660	2000
			2	165	330	2005
	Steam	Heavy fuel oil	3	150	450	2007
North Benghazi	Gas	Gas/Light fuel oil	3	150	450	1995
			1	165	165	2002
	Steam	Heavy fuel oil	2	150	300	2007
The total power generation for simple-cycle			15		2,355	
Other generation plants						
Misrata Iron Industrial		Gas/ Heavy fuel oil	6	84.5	507	1990
Alsarir (The Great Man-Made River)		Light fuel oil /Gas	5	15	75	1990
The total of power generated			11		582	
The total overall of the generated power			62		6.196	

Table 3.1 shows the total number of generation plants, which have increased gradually since

1976 [123]. This increase is due to the fact that the demand for power has increased in parallel with the economic growth of the country over the last two decades [108]. As a result, GECOL has increased the capacity of power by building new generation plants in different geographical locations throughout the Libyan grids to satisfy user needs. In addition, the number of generation plants expected to be built within the next 10 years are 12 units by 2020 [108]. Geographically they will be distributed to mitigate the current problems faced by generation systems in GECOL [118].

3.2.1.1 Generated power

In 2008, generated power reached 28,666 GWh compared to 653 GWh, in 1970. The average increase each year ranged from 7% to 13%, as is clear in Figure 3.3 [115]. As a result, the demand for power has forced GECOL to significantly increase its capacity. However, GECOL has not implemented a PQP in parallel with these increases to solve PQDs raised in customer complaints [115][119][123][124][125][126][121].

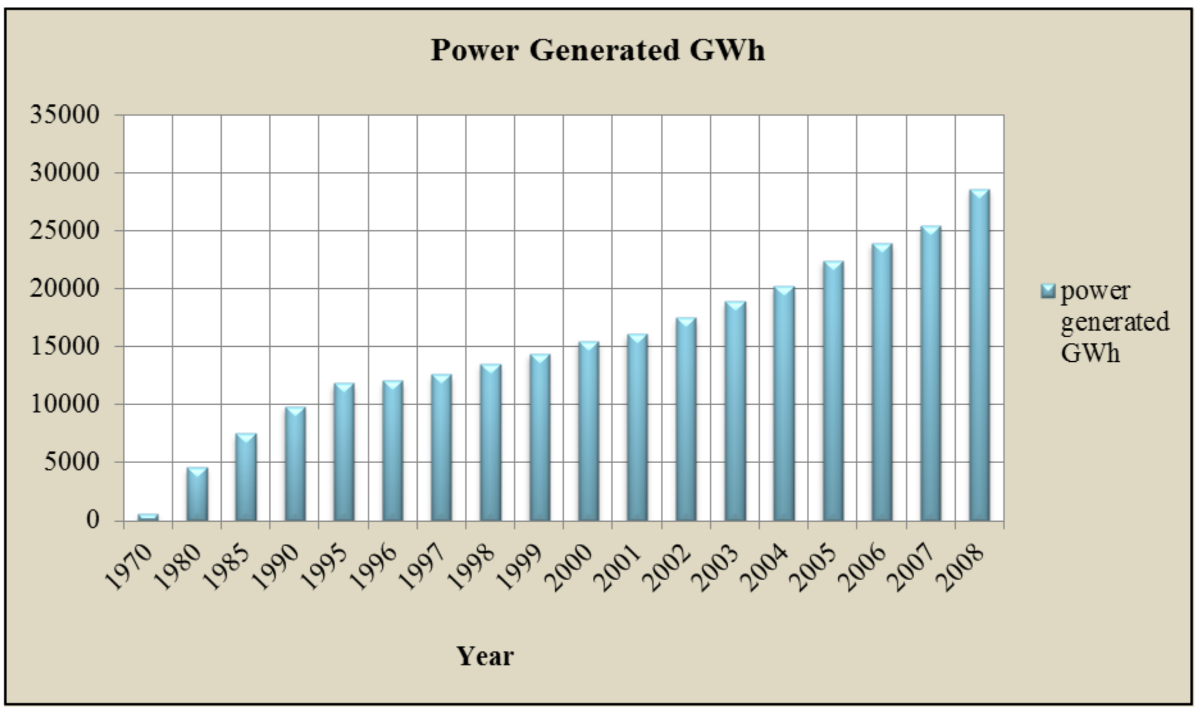


Figure 3.3: The power generated in GWh from 1970 to 2008

In addition, the average rate of consumption per capita is the same as in developed countries, and reached 4,602 kWh per capita in 2009. For comparison, it was 330 kWh in 1970, as shown in Figure 3.4 [115][119]. As a result, it seems that the increase in the average rate of consumption for each consumer from 1970 to 2008 has risen as the power generated increased in the same period [123]. This means that the average rate of each consumer's consumption also increased. As a result, the number of consumers using electrical or electronic equipment increased, in all sectors. It should also be noted that the increase in equipment also involved a change from linear to non-linear devices [12]. This was due to developments in high technology equipment over the last four decades [31]. Therefore, according to GECOL's annual reports, there was rapid economic growth represented in development, construction projects and residential demand. Nonetheless, there is still a lack in providing clean, secure and good quality electricity to all end users [119][126].

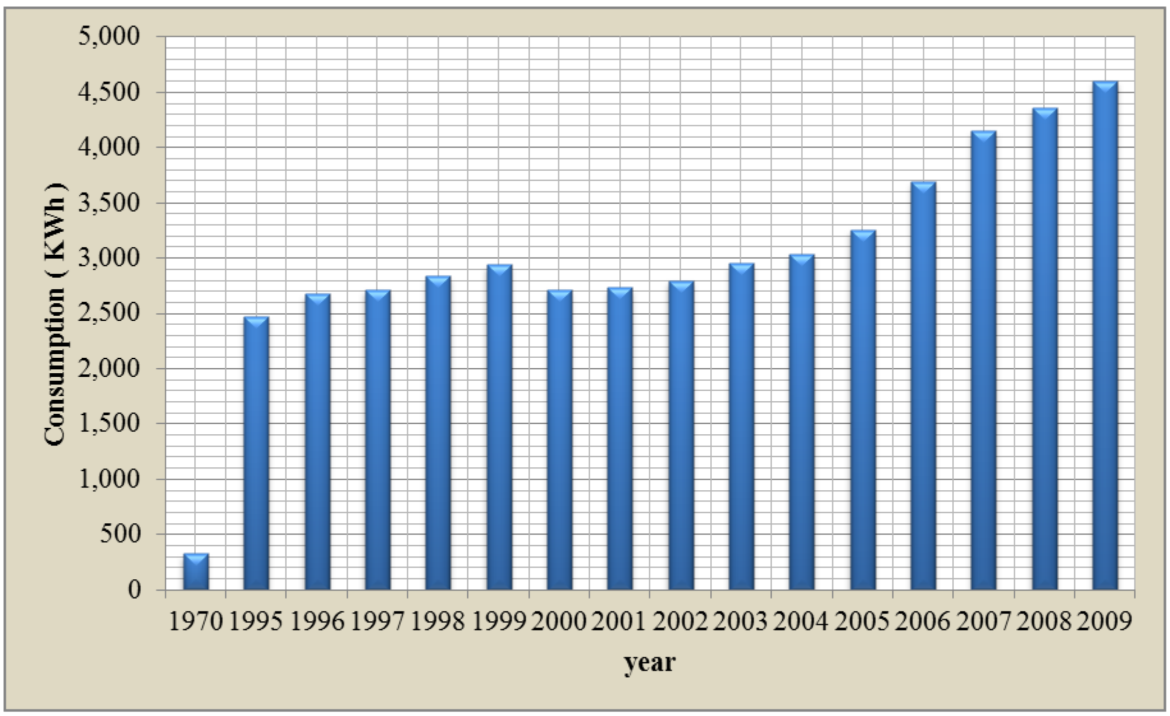


Figure 3.4: The consumption per capita in KWh from 1970 to 2009

3.2.1.2 Peak load

The peak load in the Libyan network has increased continuously, reaching 4,756 MW in 2008 compared with the peak load in 1970, which was only 150 MW. The average increase was approximately 7 to 13% annually [115]. In recent studies, the estimated peak load is expected to rise sharply to 12,621 MW by 2015. In 2020, it is predicted to approach 15,078 MW, and by 2025 will be around 18,417 MW, as shown in Figure 3.5 [108][127]. This rapid increase in peak load is due to the fact that many new infrastructure projects are planned in different places all over the country [118]. As a result, the peak load is expected to increase sharply to meet all the power needs.

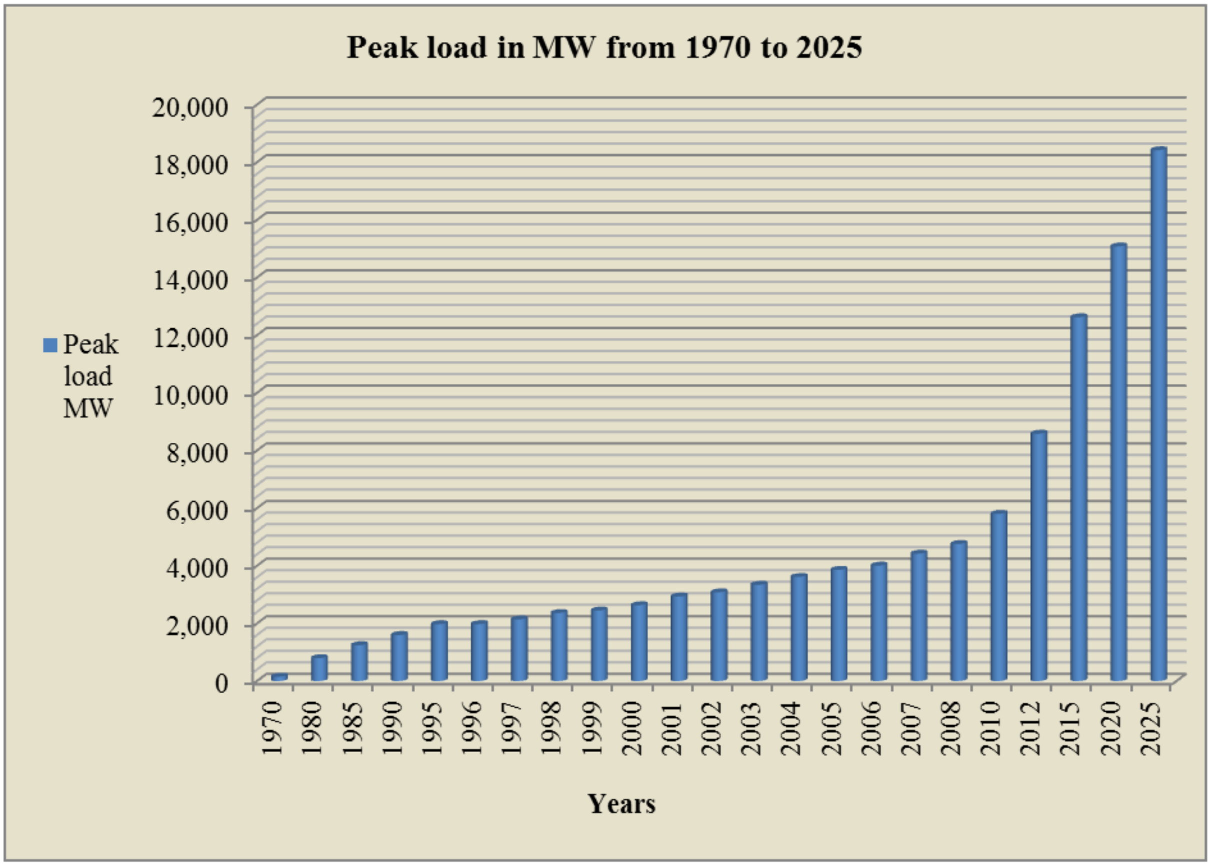


Figure 3.5: The peak load (MW) from 1970 to 2025

3.2.2 Libya Transmission Systems

These represent the electrical power transmission systems in GECOL. The rapid increases in generation systems have led transmission systems to increase as well [115][119][123][124][125][126][121].Power is transmitted from the generation systems through high voltage 220/400 kV transmission lines. Power is then distributed using medium voltage 66/30 kV sub-transmission lines to the distribution systems. The transmission networks convert energy through transfer stations to reduce the effort of distribution networks in various regions. The distribution of these networks' energy is not in adequate quantities to cover residential, commercial, industrial and agricultural consumers' needs. Therefore, efforts should always involve development of renewal and updates to networks, to keep pace with growth in power generation, and in order to transfer electrical energy to consumption centres. As a result, the GECOL transmission network has largely developed over the last 15 years to cover almost all parts of the country [115].

Since 2003, the transmission networks have been upgraded to 400 kV. The total lengths of transmission lines with a high voltage (HV) of 400 kV were 442 kilometres by the end of 2008. Approximately, 5200 kilometres of Libyan HV 400 kV lines are due to be added to the transmission networks, with the expected completion time at the end of 2016 [127]. The HV 220 kV lines extended to about 13,677 kilometres at the end of 2008. The total network lengths of sub-transmission lines of medium voltage (MV) of 66 kV are approximately 13,973 kilometres by 2008, and the total length of MV 30 kV lines was around 8,583 kilometres in 2008 [118]. Figure 3.6 shows the total length of transmission lines, which will statistically increase every year [115].

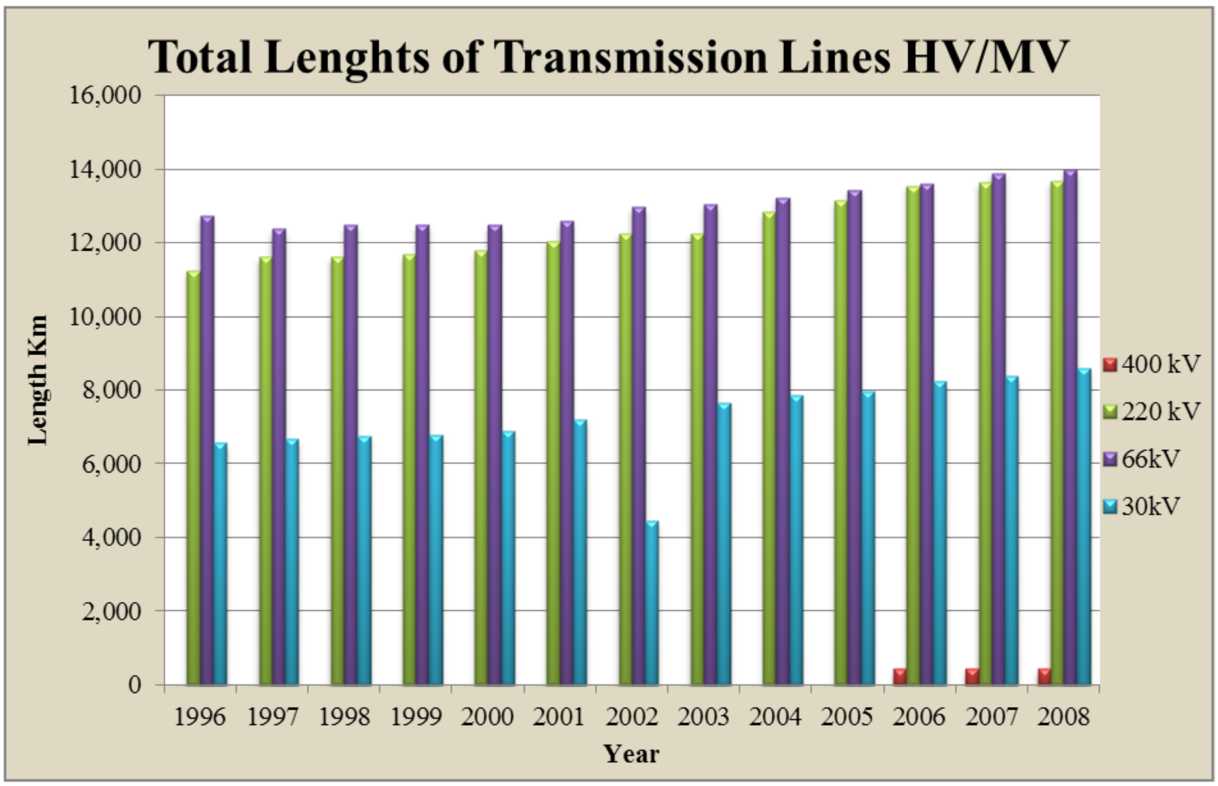


Figure 3.6: Bar chart illustrates the total HV/MV transmission lines

The expansion in generation systems has forced a rise in the capacity of transmission systems through building new lines to accommodate the power generated. These new lines are needed to deal with the current level of power generated, transferring it to the distribution system [118]. In response to this, the Libyan transmission system is completely interconnected and designed to ensure both reliability and security. However, Libyan transmission systems are not interconnected and designed to ensure power quality [115][118].

3.2.3 Libyan Distribution Systems

Distribution systems are the most important link connecting the consumers to the distribution networks and providing them with electric power. Distribution networks transfer the energy produced at the various power plants and deliver it to all points and centres of consumption [125]. Distribution systems in GECOL are based on five networks, which are the West, South-West, Central, East, and South-East Networks. The purpose of dividing the distribution system into five networks is to reduce the pressure on the distribution systems in order to deliver power to all consumers without any problems [115].

The total number of consumers connected legally by the distribution networks was 1,224,193 in 2008 as shown in Figure 3.7 [125]. This number is expected to increase due to the fact that average demand grows by 7% to 13% each year. One of the reasons for this growing demand on the Libyan distribution system is the country's economic growth [108]. However, the distribution networks' infrastructure was not designed to meet the increases in demand due to economic development and the rising population demand for electricity. Therefore, this significant lack of awareness and the large number of non-linear equipment utilised by end users are factors that have caused PQDs in the LDNs.

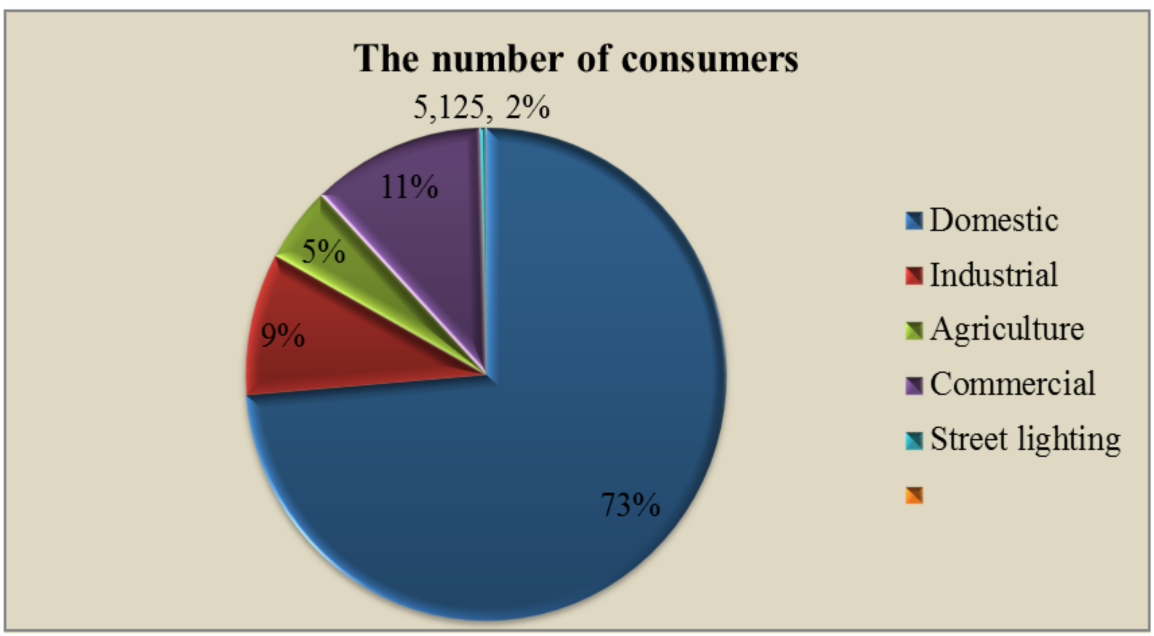


Figure 3.7: The number of power consumers connected to LDNs

In addition, Figure 3.8 shows that the total power consumption for all sectors connected to the

LDNs is 18,451,592 MWh [121]. It can be seen that the residential sector is where the majority of users are connected to the Libyan distribution system, followed by the commercial sector, and then the industrial sector. GECOL attaches great importance to the development and modernization of these networks. Therefore, the plan for the Libyan distribution system is to expand and address existing challenges, in order to ensure both reliability and availability. However, it seems that supply power quality is not being considered in the Libyan distribution system; this resulted from lack of awareness among GECOL top management [118].

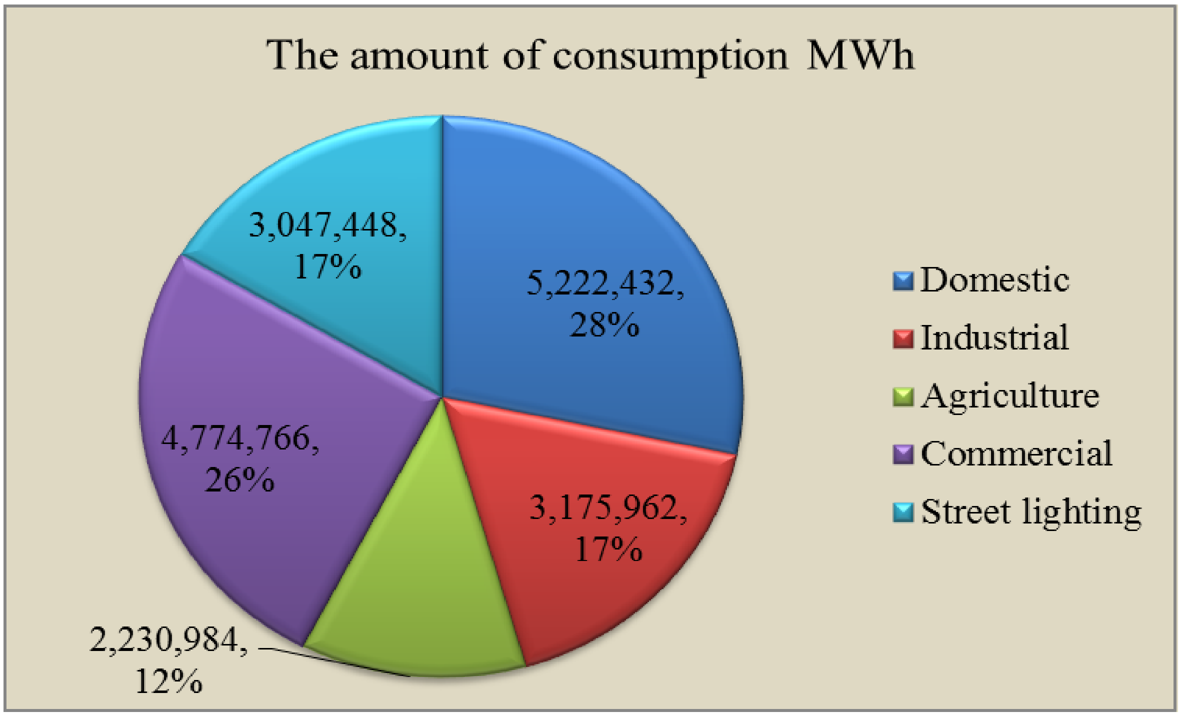
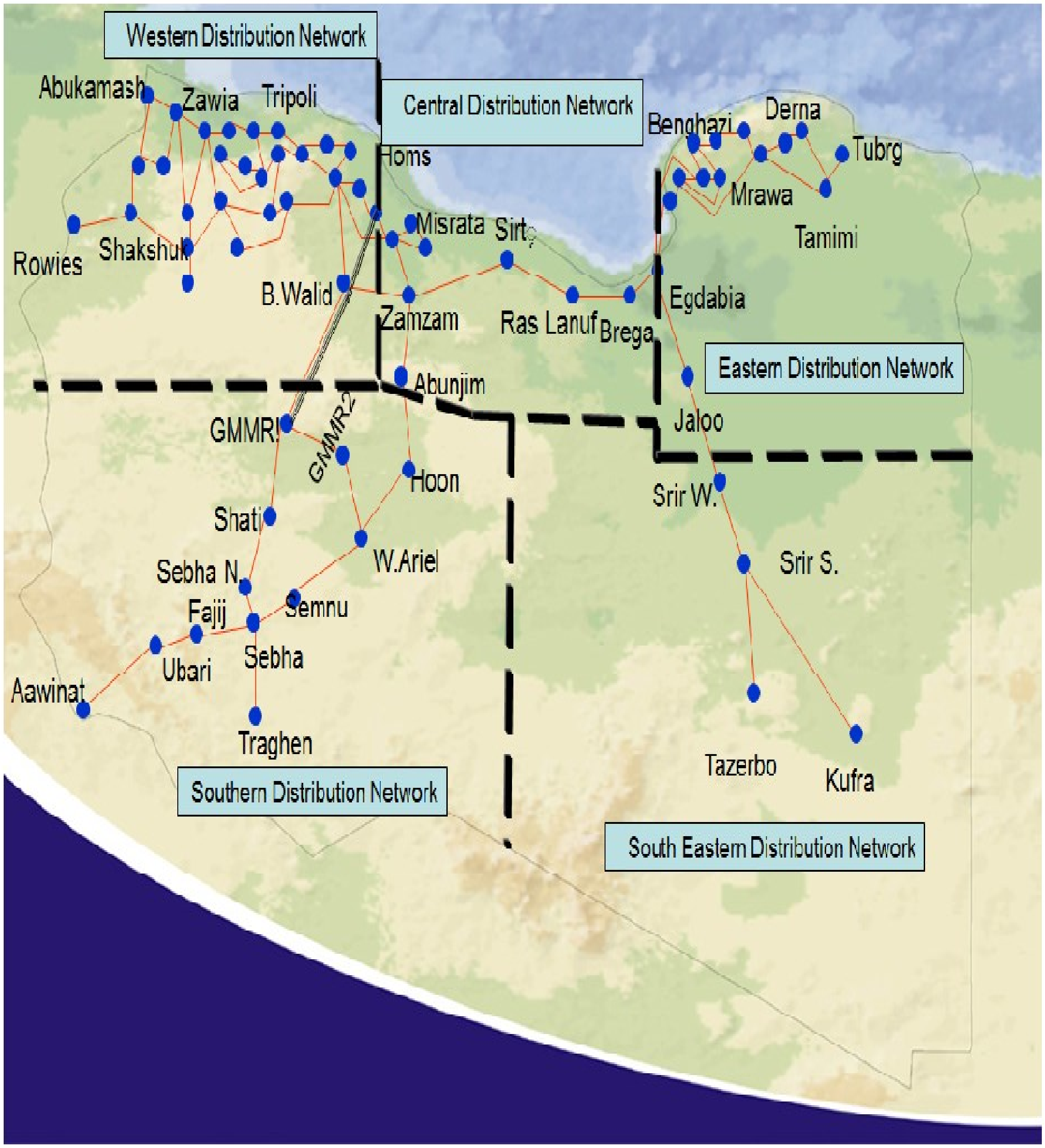


Figure 3.8: Power consumption by each sector type in MWh

Overall, this research will focus on three distribution networks only, as shown in Figure 3.9 [116]. The reason is that if all LDNs are included in this study, then it would be difficult to gain good results. The key purpose of this study is to investigate the main problems of power quality affecting the LDNs. Thus, the focus will be on the distribution networks that have suffered most from power quality issues, and have the most end users connected.



Sources [118]

Figure 3.9: The three distribution networks, Western, Southern and Easter

Most of the users connected to the western distribution network are residential and industrial users, while agricultural and residential users dominate in the southern distribution network, and industrial and agricultural users in the eastern distribution network as shown in Figure

3.10 [116]. Yet, each distribution network will be discussed and described separately. This will help in classifying the problems, and identifying the causes of these problems, with regards to the PQ definition adopted, in order to solve both technical and non-technical problems.

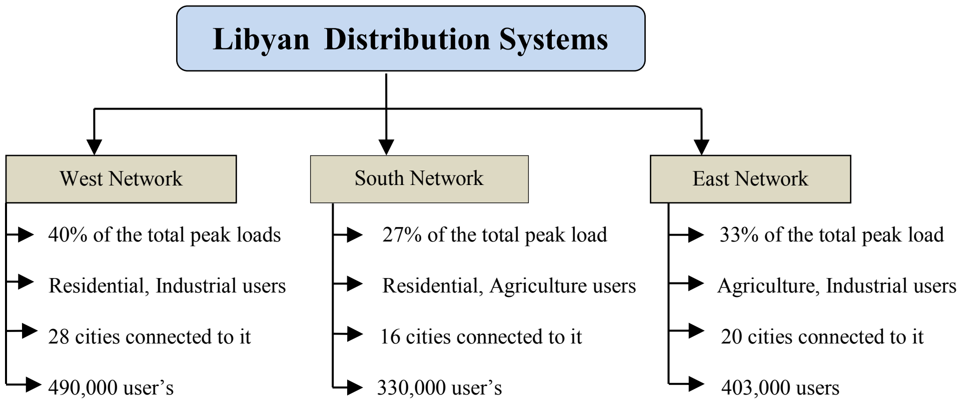


Figure 3.10: Classification of Libyan distribution networks (LDNs)

Figure 3.10 shows the classification of the three networks, western, southern and eastern. It clear that the western network is the largest, carrying 32% of the total peak load, and the east network follows with 25% of the total peak load, and then the south network, with 21% of the total peak load.

3.2.3.1 Western Network

The western distribution network is one of the largest networks in the Libyan distribution system. In 2008, approximately 32% of the total peak load was connected to this network, compared to the other distribution networks [116]. Around 28 cities are connected via different substations to the western distribution network, while the total number of consumers utilizing this network is 490,000. The majority of users supplied by this network are from the residential and industrial sectors [115].

3.2.3.1.1 Power Quality Problems (PQDs) in the Western Network

The most common power quality problem faced in this network is under voltage. Under voltage occurred when the network faced a blackout in 2003 [108]. This problem was caused on the 220/30 kV line by a short circuit in the transformer at the power production plant. This blackout had massive consequences on the network, in terms of power quality, which was followed by constant under voltage [128]. In addition, when the problem happened immediate losses occurred in about ten generation plants [120]. The total amount of loss in generated power in those plants amounted to 848 MW. This event happened due to three main factors:

- Lack of maintenance of the network caused PQDs due to old installed equipment.
- Lack of sufficient training for engineers, technicians, and top management to deal with such emergency cases.
- Lack an effective protection plan to protect the lines from trees, in terms of achieving good quality without any deficiencies.

Other power quality events, which occurred in this network, are voltage sag and swell, and poor power factor [108]. These problems occur, especially in the summer season, when the temperature is very high. As a result, heavy starting loads, such as huge numbers of air conditioning units, affect the network efficiency in terms of quality.

3.2.3.2 Eastern Network

The Eastern distribution network is another important network in the Libyan distribution system. In 2008, nearly 25% of the total peak demand was met by the eastern network [116]. This network connects 20 cities approximately, via a number of substations. 403,000 consumers or 32.9% of the total number are supplied by this network, where these users are mainly from the residential, agricultural, and industrial sectors. The rapid expansion in these sectors in this region due the huge growth in the economy has led to the highest rate of increase in demanded loads across the Libyan distribution system [127]. The most power quality problems faced by this network are voltage sag, poor power factor and over and under voltage [129].

3.2.3.3 Southern Distribution Network

The southern distribution network is the third important distribution network in the Libyan distribution system. The southern network in 2008 carried approximately 21% of the total peak load [116]. The number of cities connected to the southern distribution network is around 16, and the number of consumers supplied through this network is 330,000 (27% of the total). In terms of types of users supplied by this network, they are mainly from the residential and agriculture sectors. The Great Man-Made River Project (GMMRP) is one of the key projects, with power to its huge pumping plants supplied by the southern network. Moreover, many randomly scattered private houses and agriculture projects, which have also been connected to this network since 1999 [115][118][3].

3.2.3.3.1 Power Quality Problems in the Southern Network

The most common power quality problems that occurred in this network are voltage sags, power interruption and poor power factor [3]. These problems were due to a number of issues, such as illegal connections, economic growth, increase in electronic equipment, and infrastructure. These issues needed to be taken into account in the southern distribution network, to make a major impact on this network in terms of power quality [130].

3.3 Non-technical factors causing Power Quality Disturbances (PQDs) in LDNs

3.3.1 Infrastructure and Distribution Network Design

The lack of awareness regarding electricity infrastructure in the Libyan government and GECOL was the main factor leading to PQDs in the western distribution network. Thus, it can be said that the western distribution network was not designed to deal with the current demand for electricity, given the increases in the number of end users and their requirements [118]. For the same reason, the ad hoc nature of the infrastructure made it difficult for the western distribution network to accommodate citizens' needs, and connect them to the network to meet their requirements for electricity, since they are located in different areas.

On the other hand, the eastern distribution network covered most of the cities located in the mountain areas. As a result, obstacles, such as trees, animal contact, and changeable weather, such as rain and wind, were the cause of PQDs, and power interruptions for customers. Therefore, designing the network properly can help prevent disruption to the end users. The badly implemented network connections, brought on by the scattered private agriculture projects, and the lack of consideration for the high seasonal temperatures, i.e. in the summer, severely affected the ability of this network to deliver the electricity demanded [116].

Furthermore, the southern distribution network is fed on only one side by Al-Khums generation plant, as shown in Figure 3.9. As a result, the end users in this network are connected via different substations by transmission lines over a long distance, very far away from the generation source. For this reason, a 400 kV line was constructed and connected to this network to overcome the problems due to the long transmission distance. However, problems still persisted after the new line was introduced [118][126]. Moreover, heavy loads such as the GMMRP and private agriculture projects are connected to this network, and are the main cause of PQDs.

The purpose of the GMMRP is to deliver water from desert areas in the south of Libya to the north due to the lack of clean water for daily uses. In addition, citizens started private agriculture projects, as water can be found at less than 30m below ground. They started cultivating the desert without consideration for the LDNs, and the impact their activities would have on power quality. As a result, the southern network lacks sufficient efficiency and ability to provide good power quality to all sectors, including residential, GMMRP, and private agriculture projects. Therefore, the current situation of GMMRP's heavy induction loads, as well as the scattered private agriculture projects that appeared after the 1999 economic blockade, led to major PQDs in the southern distribution network [3][121][130, 131].

Thus, the network capacity and ability to provide all these users with good power quality is lacking [3]. The GMMRP pumping plants are driven far away from the generation systems by large induction motors. There is also the problem of large numbers of users operating air conditioning. As a result, the quality of the supply becomes low. Thus, the southern distribution network faced these difficulties since these projects were implemented without regard for the proper procedures. Hence, it is very important to consider the supply quality when designing the distribution network, especially in rural areas located far away from the transfer stations [15][91].

3.3.2 Economic growth

Economic growth is the main factor leading to power quality problems in the western distribution network. This is evident in the rapid urban growth with the construction of huge numbers of houses, flats, hospitals, schools, universities and industrial facilities, since 1999 [121]. These new development projects were needed to meet the annual population increases, yet with a lack of government strategy given the political, economic and trade blockade faced by Libya from 1990 to 1999 [131]. This blockade put the Libyan power distribution systems in a bad situation, whereby they could not build, renew, or upgrade any power infrastructure projects, such as distribution networks, due to the lack of resources. In these circumstances, citizens also built houses haphazardly, without any planning, which worsened the power quality situation. Moreover, the blockade critically destabilised the Libyan economy. Despite this, LDNs must have a clear strategy to avoid any PQDs, which might damage both the networks and customer equipment, especially once the blockade was lifted in 1999 [120].

3.3.3 Illegal connections

Electricity theft was another factor that led to power quality issues in the western distribution network, as consumers connected illegally to the network. For example, this led to PQDs affecting customers connected legally to the western distribution network. These customers then blamed the utility for supplying them with low quality power, and in addition, accused it of not cooperating or responding to their complaints. In contrast, the mentality of citizens is to obtain electricity for their needs, regardless of quality level [15].

In the eastern network, illegal connections are also implicated in causing PQDs, making it difficult to supply customers with a high level of power quality. Power quality issues are due to bad network design, which fails to account for increased customer demand for electricity. As a result of refusal of new connections by the utility, connecting illegally started due to the rapid growth of the economy over the last ten years, making it complicated to meet all end users' needs [120]. In addition, huge numbers of air conditioning units are connected to the southern distribution network, especially in summer, given the high temperature rises. Many end users operate their air conditioning using faulty, i.e. illegal, connections, which affects the network's efficiency, and ability to deliver good quality power.

3.3.4 Increase in the use of electronic equipment

Since 1999, when the blockade was lifted, many goods and products were imported into Libya, including a wide variety of electronic equipment. Likewise, most infrastructure projects were based on high technologies, consisting of sensitive tools and equipment. Therefore, non-linear equipments were rapidly adopted by customers in both the residential and industrial sectors in the western distribution network. Later, with the number of users increasing rapidly every month, across the country, so did the number of complaints due to damaging effects of their devices [123].

In addition, digital electronic equipments are one of the main causes of power quality issues in the eastern distribution network. It can be seen that the lack of understanding, or absence of an applied power quality definition, has brought significant disturbances for both end users and suppliers [130]. Furthermore, a large numbers of heavy loads are associated with water pumping using large induction motors. Despite new transfer stations being built, the problems still recurred, due to the sharp increase in the number of these projects, as well as the scattered new infrastructure projects.

3.3.5 Lack of power quality awareness

Lack of understanding of the PQ concept is one of the main elements causing PQ issues to customers, management and staff in the western distribution network. This led customer complaints to increase, as a result of problems not being properly addressed. Hence, the problems of power quality were aggravated, and started to increase across this distribution network. Moreover, it can be seen that head managers, engineers, technicians, and customers were not aware of the definition of PQ [123]. Therefore, the lack of awareness of the power quality concept in these three distribution networks is one of the main reasons causing problems, given the rapid expansion in using sensitive devices, without being aware of the adverse effects of such sensitivity. Moreover, this lack of awareness affected top management planning, where badly designed networks failed to meet economic growth and the associated rise in demand. This factor also affected employees trying to deal with PQDs, but lacking the skills to adequately address such problems [75].

3.4 Research Problem

Electricity is being considered in the same way as any other product [5]. Ever since 1980, the idea has been that both "reliability and power quality are synonymous" [6]. This meant that the continuity of power supplied was at a standard level used to measure the quality of this product [7]. Therefore, over the last three decades, the quality of electricity was held at an acceptable level. This is because generation plants were close to the load centres [8], and distribution and transmission networks were designed to carry the electricity over short distances [9]. Hence, both the reliability and PQDs were not issues of concern as they are today [9][10]. However, since 1980, power quality issues have started causing disturbances in distribution systems worldwide [11]. As a result, both reliability and power quality have become significantly crucial issues for most distribution utilities worldwide. Thus, the distinction is made between power quality and reliability, each having its own characteristics. Reliability is represented in measurements for the disturbance lasting more than a minute, while power quality is represented in the measurement of disturbances lasting less than a minute [9]. Moreover, when the use of non-linear equipment expanded, replacing the linear, this distinction was considered in most distribution utilities due to their sensitivity to PQDs caused by non-linear tools [6][12].

Similarly, the growth in demand and economic growth led GECOL to expand generation, transmission, and distribution network capacities, by building various new grids [31][10]. In other words, the demand for power has increased in the industrial sector, along with the residential sector. These complex combinations required utilities to initiate PQPs to make the network more efficient, due to the complex interconnections [31].

On the other hand, end users always blame and point to the utility as delivering poor power quality [5][19]. Therefore, power quality issues have become concerns raised across utilities. Moreover, power quality as a product, should be considered from the perspective of meeting client requirements [7][8][9]. For this reason, Libyan distribution systems are forced to solve these power quality problems due the huge number of complaints received from customers [3], and also due to the huge cost in money lost by both the utility and end users [45][46][47].

In this context, the Libyan distribution system is similar to other systems, yet has its own characteristics. It is designed to deliver secure and good quality power to customers through different levels of substations. Therefore, the system's design characteristic may be considered in reducing the impacts of power quality problems. The basic concept is to separate the technical problems, leading to poor power quality, from the non-technical ones [78]. This will help in identifying and classifying the problems for better mitigation. Yet, there are few studies conducted concerning the investigation of the technical and non-technical factors caused poor PQ to the distribution network utilities, which if conducted can lead to improve PQ and measure PQDs [43].

The rapid growth in the Libyan economy began after 1999 [121]. Before that time, and from 1991 to 1999, Libya was under a political, economic, and trade blockade [131]. Therefore, the increase in peak load was not as rapid, as it is nowadays. Moreover, with the huge increase in peak load, expected in the next ten years, the power quality in LDNs is not expected to rise at the same rate as availability and reliability. For example, Libyan distribution systems have increased the peak load to reach 4,756 MW by 2008 [115]. However, this peak load is expected to rise to 18,417 MW by 2025 [118]. Meanwhile, there are serious power quality problems, which still affect end users' equipment and the distribution networks [118]. This means that LDNs must be expanded and designed properly to accommodate the current, as well as the future level of consumer demand.

However, since GECOL was established in 1984, it has planned to expand generation, transmission, and distribution systems to meet the demand for power by consumers [115][119][123][124][125][126][121]. This increase is focused on the power generated by increasing the number of generation plants [118]. It also focused on increasing the transmission network by building a high voltage 400 kV line in 2003, which is expected to reach approximately 5200 kilometres in 2016 [115].

However, the peak demand has rapidly increased in line with the above. This means that the average rate of each consumer's consumption also increased. As a result, the number of consumers using electrical or electronic equipment increased, in all sectors. It should also be noted that the increase in equipment also involved a change from linear to non-linear devices [12]. This was due to developments in high technology equipment over the last four decades [31]. The design of such equipment led to a lack of performance efficiency, which caused significant power quality issues that affected all end user equipment connected to the same distribution network.

On the one hand, the level of power delivered was not at its worst level, this is mainly because sensitive equipments were not yet introduced widely before 1999. In addition, the current growth in the Libyan economy is based mainly on high technology digital equipment, introduced in the industrial, commercial, residential, and trade sectors, which are very susceptible to power quality variations. Therefore, in recent years, the widespread use of electronic equipments have led to power quality problems in LDNs, becoming one of the major issues of concern for industrial, commercial, agricultural, and residential users, which have been intensively imported since 1999, and caused damage to end-users' equipment.

On the other hand, PQDs caused by industrial, agricultural, commercial, and residential sector users, were due to lack of awareness of power quality issues arising from sensitive equipment used intensively in those sectors since 1999 [121]. PQDs were also due to bad design of the network, where massive economic projects were built, without considering network capacity, due to lack of management planning. It is also due to lack of employee experience as a result of absence of power quality phenomena in the past, and the lack of power quality training to diagnose problems in the utility distribution network equipment, or customer sites. Therefore, LDNs have lost LD 464 million annually due to poor power quality and the failure to implement PQP [120].

For this reason, the essential future challenge for Libyan distribution systems comprises two main reciprocally decisive goals; as economic development is advancing constantly, there should be a clear strategy, which would support the increased demands of the future. Therefore, it is highly recommended that the rapid growth in the electrical power distributed through LDNs remains under management control [91]. According to the actual, current level of LDNs, and the problems faced in terms of power quality, it is imperative for Libyan distribution systems to ensure that any added changes would be to improve power quality in the networks, and so ensure sustainable development into the future.

There have been serious concerns about the power quality level in GECOL, in general, and the Libyan distribution system, specifically [91]. Such concerns are based on the fact that as the economy expands, more power is needed to be distributed to the above sectors, especially during the summer and winter seasons, when most customers complain about bad power quality affecting their electrical and electronic equipment.

In response, three different aspects need to be considered across the Libyan distribution system to resolve power quality problems:

- There is a need to know to what extent end users, staff, and LDNs are aware of the power quality definition. This can determine the power quality levels from both perspectives of end users and LDNs, to create a greater understanding or awareness.
- It is very important to classify the causes of power quality issues into two categories, namely technical and non-technical problems.
- Once the level of power quality is determined, both in terms of awareness and category, then PQP model framework can be developed, to be used as a guideline. This

framework will guide both the LDNs, including management and staff, to implement a PQP. It would help them to deal with problems, and consider a further strategy. It will also help end users become aware of the impact of these problems, and become familiar in dealing with them, and introducing the right diagnosis of disturbances to the utilities.

Hence, it is suggested that new criteria for non-technical problems could produce better solutions to power quality issues. These criteria are management planning, training programmes, and customer cooperation and awareness. All these criteria can be phrased under one framework called Power Quality Physical Solutions (PQPS).

Management planning can help in designing the distribution systems based on population capacity rather than on availability of electricity. Training programmes can involve both technicians and engineers to gain better knowledge, and increase their skills in diagnosing the problems, rather than temporarily solving these problems without involving themselves in understanding the main reasons underlying these events. Customer awareness can help in assessing how far end users are familiar with power quality phenomena caused by their equipment to avoid any problems in the future.

Essentially, improving the power supply, and reaching a high level of power quality, will guarantee that customer equipment will be capable of functioning satisfactorily as expected, and prevent any failure occurring due to small power quality disturbances [30]. The satisfactory functioning of customer equipment is subject to power quality standards, and contractual terms between the customer and distribution utility; guidelines regarding power quality, and manufacturer equipment standards, are such that equipment should not be susceptible to power supply variations [78][80]. These conditions should be taken into account as essential requirements to protect end user devices from being affected by power supply deviations, and so a high level of power quality is required.

Therefore, Libyan distribution systems should accommodate the various types of customers [116]. Each user type can be determined easily, to diagnose and resolve any issues leading to PQDs [91]. In this respect, customer categorisation can be of assistance in resolving PQDs, if the LDNs adopt it not only in urban areas, but also in rural areas. In Libya, many villages and remote areas with small populations suffer bad power quality. This is because the geographical area of Libya is around 1.7 million square kilometres, which makes it very difficult to deliver clean, secure, and good quality electricity [125][14]. For this reason, Libyan customers in rural areas are among those suffering from lack of power quality. In addition, many cities, villages and remote areas with small populations are located far away from each other. As can be seen in the southern distribution network, it is very difficult to supply them with a high level of power quality [14]. Therefore, the Libyan distribution utility must consider the concept of power quality when designing its distribution networks. This will prevent any small or large deviations appearing, as a result of bad planning of the grids, which can only lead to end users connecting illegally to satisfy their needs [75].

Hence, without solving the non-technical problems, technical problems will only be aggravated. Therefore, paying more attention, and concentrating on these problems, will lead to resolving power quality events, and distribution networks efficiency will be improved. However, this does not mean that the technical problems will disappear, but will appear less significant as the non-technical problems are being considered and tackled.

3.5 Proposed Power Quality Program (PQP)

LDNs are among those systems facing bad power quality in under-developed countries. Statistical data shows that LDNs seem to pretend that users do not experience PQDs. Meanwhile, no PQ measurements were conducted by the LDNs in the last two decades, as appears from their annual reports, and also from the pilot study conducted for this research [115][119][123][124][125][126][121]. In addition, no PQ department was established to address all the issues related to PQDs. This absence of a PQ department is due to lack of awareness on the part of top management regarding the importance of PQ. Most distribution utilities worldwide have started implementing PQPs to solve PQDs and satisfy their customers [33][15][1][2].

In response, LDNs have not implemented a PQP in line with the expansion in generation, transmission, and distribution systems. This can solve the earlier issues arising from a lack of strategy. This is because the geographical expanse of Libya (1.7 million sq. km), with many remote cities, villages and areas with small populations, make it difficult to deliver clean, secure, and good quality electricity [125]. For this reason, there should be a PQP based on raising the level of awareness of all end users, particularly as the economic level increases, to avoid the serious effects of using equipment without sufficient knowledge of its sensitivity to PQDs. This would reduce the impact and increase the awareness of PQ issues in the above sectors, thus contributing to competitiveness of a rapidly developing economy [1].

Consequently, from the extensive literature review presented in chapter two and this chapter, regarding PQP implementation, LDNs have not implemented one. These were not considered in the development of all the projects, both those under execution and those new projects forming part of the company strategy for 2025 [47, 48]. LDNs have not implemented any of these programmes to solve PQDs. PQPs consider and ensure power quality is improved in distribution systems, and will assure the reliability and availability of the service, to satisfy customer's needs, reduce the losses in the network, make customers aware of PQ importance, and increase network efficiency.

Accordingly, from GECOL archives or annual reports, LDNs have not planned or implemented any PQP in line with all the increases mentioned earlier, ever since the company was established in 1984. The absence of such programmes prevents determining whether power quality issues are caused by technical or non-technical problems, such as lack of management strategy, lack of employee experience, lack of customer's awareness, or simply caused by the generation and transmission systems. Therefore, the increase in generated power in the last two decades, along with the average consumption of each consumer, have shown that distribution networks were not designed to accommodate the increases in both generation and transmission capacity. Therefore, PQPs should be implemented in LDNs, and influenced by the following factors to avoid any major consequences:

- Securing and guaranteeing power supply quality by expanding capacity to meet the growing demand in all networks, and to support economic growth.
- Increasing and maintaining the level of security, efficiency, adequacy, and quality of supply.
- Improving power quality by reducing technical disturbances and non-technical issues.
- Reducing management complexity regarding PQP implementation.

In addition, a PQP can guide LDNs to avoid the issues mentioned earlier, and resolve PQDs. Therefore, requirements must be taken into account by LDNs management, which ought to consider them equally to achieve a high level of power quality [120].

- Customer cooperation to aid the distribution utility meets their expectations regarding power quality issues. Therefore, employees should be encouraged to satisfy the customers' needs due to the fact that power quality events face its systems due to growing demand and illegal connection.

- Top management commitment at LDNs, which should have a clear long-term strategy in planning distribution networks to accommodate current and future power demand in expanding generation and transmission networks, and avoiding PQDs.
- Improve top management planning and experts' experience, skills and awareness to tackle PQDs.
- Conduct research and studies to formulate recommendations for improving power quality for customers by identifying the existing issues facing power quality improvement.
- A clear strategy with regards to training programmes for staff to accommodate and understand PQ phenomena, and share knowledge with employees involved in PQP implementation, to increase their awareness and skills, regarding PQ definition, maintenance, repair, and diagnosis.
- A power quality awareness programme, which allows the end users to be aware of the risk of using sensitive equipment, and also provide sufficient knowledge to be familiar with the impact of PQ on their equipment, and the consequences of a faulty, illegal connection.
- PQD measurement should be performed by the LDNs to encourage their employees to satisfy customer needs, using PQ complaints to identify patterns, and prevent the same power quality problems from recurring in the future by monitoring, recording, analyzing, and comparing them to PQ standards.

In addition, the proposed PQP framework encourages and guides implementation teams to have an obvious and clear vision of how to prevent existing obstacles from reappearing in different forms, leading to improvements in the long-term. The progress on this framework, in moving through from one phase to another, depends on the level of awareness, knowledge, and skills gained respectively as each phase is completed.

In response to these elements, a PQ survey was conducted at three LDNs, west, east and south, to investigate and determine why LDNs have not implemented a PQP to evaluate the power supply before delivery to its customers. At the same time, the survey focused on the future of PQDs at LDNs, in line with any increases that they are expecting. The survey was prepared based on main factors, which were derived from the literature review and the LDNs data as shown in tables 4.5 and 4.6 [123]. In response, PQ survey was designed to answer the first two research questions:

What is the actual overall level of the PQDs, in terms of measurements, solutions and implementation regarding PQ awareness?

What is the current state of PQ awareness and efforts regarding the implementation of PQP in LDNs?

The results of the power quality survey are presented in details in chapter six.

3.6 Summary

This chapter has discussed the current situation of LDNs, regarding power quality problems. In terms of PQP implementation, it is imperative for Libyan distribution systems to ensure that any changes would improve its networks, which need to be responsive to sustainable development for the future in terms of power quality. Thus, the essential future challenge for Libyan distribution systems contains two main equally decisive goals, where economic development has been progressing constantly since 1999; there should be a clear strategy to support the rising demands for the future. Therefore, the increased generated power capacity achieved in the last two decades, as well as the average increase in consumer demand, have not been accommodated by the distribution networks, which were not designed for such increases in both generation and transmission capacity. In this context, the peak load is expected to reach 18,417 MW by 2025.

In response to this, and to achieve a high level of power quality, Libyan distribution systems need to implement a PQP to improve power quality issues, and ensure the reliability and availability of the service, satisfy customer's needs, reduce the losses in the network, make customers aware of the importance of power quality, and increase network efficiency. Furthermore, implementing a PQP is influenced by raising a critical aspect, represented by the awareness level among the head managers. They are the ones responsible for improving the main factors, such as infrastructure, in terms of network design, economic growth, illegal connection, the increasing variety and quantity of electronic equipment, and lack of power quality awareness.

The next chapter (4) presents the proposed conceptual PQP framework developed for LDNs.

Chapter Four: Power Quality Programme (PQP) Frameworks

4.1 Introduction

This chapter aims to present a Power Quality Programme (PQP) framework, which was developed for implementation in an underdeveloped country such as Libya, with the aim of improving and solving Power Quality Disturbances (PQDs). It also seeks to explore the obstacles faced by distribution utilities in implementing a PQP, as well as presenting the benefits gained, which have a major impact on the distribution networks. In order to achieve these objectives and develop an appropriate PQP framework for Libyan Distribution Networks (LDNs), the design was based on two resources. First, an extensive literature review to understand the barriers and benefits of implementing a PQP; and second, the findings from both a pilot and full field study, consisting of a Power Quality (PQ) survey questionnaire, and face-to-face interviews conducted in Libyan distribution systems departments. The main purpose of the PQP framework developed is to guide LDNs, which have not previously implemented PQP, to improve PQDs. This is mainly because there is no PQ department established yet, to influence the measurement of PQDs.

However, despite previous PQP frameworks' contributions to understanding the barriers and benefits of implementing PQP, they are not sufficient to explain the particular circumstances of PQ issues in LDNs. Therefore, after the comprehensive literature review, and the findings from the field study, and in order to gain full understanding of the LDNs case, there was a need to develop a PQP framework, because:

- There is a lack of PQP implementation resulting from a lack of management strategy to cope with the expansion in generation and transmission systems.
- There is a lack of PQ standards to be followed by the company in any evaluation or comparison of PQD records in the Libyan distribution systems.
- There is a lack of employee experience and skills arising from a lack of awareness of PQ, and so employees are not equipped to deal with PQ problems technically.

- There is a lack of end user awareness of the concept of PQ given the excessive use of non-linear loads and sensitive equipment.
- There is a lack of management planning in the proper design of distribution networks.
- There is a lack of control over the import of electronic equipment since 1999, due to competitive marketing and deregulation.

This chapter consists of several sections, starting with an explanation of the evolution of, and main points relating to, the PQP framework. This facilitates understanding the importance of implementing PQP in both developed and developing countries. Section 4.2 discusses differences in the barriers and benefits of PQP in developed and developing countries, and why implementing PQP in developing countries is significant. In section 4.3, the researcher also justifies barriers to implement a PQP in developed and developing countries, and its impact on LDNs. Section 4.4 shows the benefits of implementing PQP in developed and developing countries and the change that LDNs will achieve, after implementing each stage of the proposed framework.

Moreover, in section 4.5, the researcher evaluates previous PQP frameworks, and offers a comprehensive and critical comparison between them and the PQP framework developed in this study. Section 4.6 builds the conceptual PQP framework, while Section 4.7 explains the factors and requirements of the PQP framework implementation process. Section 4.8 states the key success factors, from both the literature and the empirical survey findings, required to implement a PQP framework and support LDNs. The criteria governing key success factors consider most of the critical factors associated with PQP implementation in previous studies. Section 4.9 illustrates the roadmap for the developed PQP framework and the process stages. Finally section 4.10 summarises the whole chapter.

4.2 Power Quality Programmes (PQPs)

PQPs have become some of the most recent services offered to distribution companies, both private and state suppliers [33][15]. For any distribution system to satisfy its consumers, the utility must keep improving PQ in a way, which accommodates the increased demand for electricity [1, 2]. This requires a PQP to be implemented to start tackling the difficulties facing the distribution utilities in sustaining a high standard of PQ. A PQP can help in reducing the huge number of complaints from end users, and the costs represented in the damage to their equipment [3]. It can also have a positive impact on the electrical distribution companies, improving their service and saving some of the significant resources spent. Therefore, distribution companies need to implement a PQ investigation programme, given all the facts indicating an increase in PQDs, particularly in the last two decades [4].

Without establishing a clear vision of the barriers to achieving high PQ, such as the lack of: a clear strategy, customer awareness, accommodating economic growth, equipment standards, network design, PQP resources, staff awareness, top management responsibility and PQ standards, together with an excessive increase in electronic equipment, then any efforts to improve PQ will be wasted in both time and resources. Accordingly, several less developed countries have compelled their utilities to implement PQPs, which are offered as a mandatory service, in response to the large increase in customer complaints [80][88]. This is caused by the increase in sophisticated industrial and commercial equipment, with customers failing to demand PQ standards to be applied [69].

PQPs are particularly successful in developed countries rather than developing countries, due to the rapid adoption of sophisticated technology, as well as the higher level of PQ awareness among most end users, in recognizing its importance. Furthermore, power suppliers in developed regions are trying to establish a high level of PQ standards in a short time, due to pressure from large industrial customers, as the use of sophisticated equipment increases [4].

In contrast, utilities in less developed countries are being pushed by the introduction of new technology from developed countries to improve and address their PQ issues. In response, some distribution companies have contracted third parties to solve PQ issues to their end users' satisfaction. This is due to the inability of their engineers and technicians, who lack the skills and experience, to solve these problems [15]. Indeed, government-controlled utilities are detached from the situation, with regard to PQ issues. The failure to implement PQPs by some distribution utilities in developing countries has resulted in them supplying free power to their customers.

Distribution utilities in less developed countries are not concerned about the quality of power they provide to their clients. They believe that PQ has matured to the point, where it will not be of any importance in the future. Moreover, their customers only want to be supplied with electricity, and are not concerned with quality [16]. Therefore, some managers from distribution companies have concluded that international electricity companies consider implementing PQP as a business, rather than concerning themselves with issues of power distribution systems [15].

4.2.1 Why Developing Countries?

The implementation of PQPs is essential for the future of PQ, especially in urban, rural and remote areas in developing countries [14]. PQPs allow distribution utilities to improve the power supply by conducting such programmes regularly to reduce end users' complaints, and satisfy them in a way appropriate to their expectations. Implementing a PQP can overcome barriers, including the lack of: a clear strategy, end user awareness, accommodation for economic growth, equipment standards, distribution network design, planning and infrastructure, resources, staff awareness, skills and experience, top management responsibility and commitment, training courses and support, and financial resources, as well as PQ measurement, consultants, standards, monitoring and databases.

In addition, PQPs can increase the knowledge and skills of distribution utilities' staff by overcoming the complicated PQDs that most frequently occur by offering them education and training courses to raise PQ awareness. Therefore, lack of knowledge and understanding still exists, and so top management is required to support and encourage PQP implementation by providing learning opportunities in the form of courses, conferences, seminars, and commercial campaigns to inform engineers, technicians and end users about the benefits that can be gained after implementing a PQP.

There is enormous similarity in PQP implementation between developed and developing countries, in terms of common difficulties. In this context, developed countries have pioneered and established PQP programmes that demonstrate solutions, and achieve results. On the other hand, PQP programmes are not very well known, or widespread in developing countries, due to lack of: PQ awareness among top management, engineers and technicians, financial resources, clear strategy, training courses and support, and PQ monitoring and databases [132].

PQP implementation will require effort from top management, staff and end users. In addition, government-controlled distribution utilities need support from public and private sector bodies in raising PQ awareness, so as to become part of their culture. The absence of PQ awareness will lead to significant effect on both utilities' and end users' equipment, costing them money.

Therefore, there is a need for a "*PQ awareness programme*", which would be responsible for spreading PQP services across the distribution systems, and can provide those services to the utilities that need to improve PQ performance [1].

4.2.2 Developed and Developing Countries

There are different types of barriers to PQPs in developing countries compared to developed countries. It is important to distinguish between these types of PQP barriers. This creates very wide variation in PQP implementation between developing and developed countries. Therefore, the distinction based only on developed and developing country is not adequate, and improvement in resolving PQDs should be performed on a regular basis. For example, some distribution utilities may not have enough resources, such as PQ analyser, team, database and standards, to conduct PQ measurement on a regular basis, or more highly less developed countries may be more similar to a developed country and nevertheless might lack distribution network infrastructure, skilled and experienced engineers and technicians, enough equipment and facilities to conduct PQ training courses to support the PQP. Therefore, there are many parameters used to distinguish between developed and developing countries, such as "awareness and knowledge", "experience and skills" and "long term strategy" [72][93][101].

For the purpose of this research, LDNs are among those systems facing poor PQ in an under-developed country. Unfortunately, statistical data shows that in the last two decades, LDNs have not implemented a PQP [118][133]. This is mainly because there is no established PQ department, to influence the measurement of PQDs. This absence of a PQ department is due to lack of awareness on the part of top management regarding the importance of PQ. As a result, LDNs have faced very significant difficulties in implementing a PQP [130][14].

4.2.3 Differences PQPs barriers and benefits in developed and developing countries

This section will explore the differences between the barriers to PQPs in developed countries and developing countries. It will also state the benefits to be gained by implementing a PQP, and which would have a major impact on distribution utilities globally. The barriers to implementing PQP are different in developed and developing countries due to some circumstances. This is mainly due to the variation in the lack of PQ awareness; PQ awareness is higher in developed countries, which is increased due to different programmes of concern about PQ issues. It is also due to highly sophisticated equipment used in different applications, which are very sensitive to power supply variations and require a high level of PQ.

On the other hand, developing countries suffer from a lack of PQ awareness, which prevents the distribution utilities from implementing PQPs effectively. The absence of PQ awareness is due to top management, who do not recognise the importance of PQ, and the severity of effect on the end users' equipment [130].

In addition, developed countries have also started tackling some factors, such as distribution networks infrastructure to provide a high level of PQ to end users and meet their expectations by reducing the number of complaints. However, in developing countries, where the infrastructure of the distribution networks is poor, and PQPs are not implemented to lead to the expected level of PQ, due to complex mixing of end users, such as agricultural, industrial, commercial and residential users connected to one distribution network [27][87]. Therefore, PQDs cannot be easily solved.

The deployment of PQPs in developing countries is necessary, where end users complaints can be tackled. This results from a lack of PQ awareness, distribution networks infrastructure, top management responsibility, and sufficient resources. This is why they are not able to implement PQPs successfully. However, the need to implement PQP in developing countries is crucial and imperative because of the valuable outcome, which will help the distribution utilities provide a good level of PQ and satisfy end users. Therefore, PQPs can be successfully implemented, not only in urban areas, but also in rural areas in developed countries due to striving by end users to be supplied by a good level of PQ, as well as the availability of enough resources, awareness, and infrastructure.

The implementation of PQP is facing almost the same barriers in developed and developing countries; these barriers vary between technical problems (PQ database, PQ monitoring and measurements, PQ standards and PQ consultants) and staff problems (lack of staff awareness, skills, knowledge and experience). Electrical distribution utilities worldwide are making attempts to solve PQDs, and overcome PQP barriers, including top management addressing the lack of commitment on its part, lack of good network design, lack of distribution networks infrastructure, lack of research and studies, and lack of top management responsibility. It also includes the lack of resources, such as training courses, and support, financial resources, incentives, and regular maintenance.

However, there should be more multidisciplinary efforts and co-operation from head managers, middle managers, engineers, technicians, employees, end users and government bodies, in order to implement PQPs successfully in both developed and developing countries.

Although faced by some barriers, PQP also has very significant benefits, which are described in the next section. In order to classify the barriers facing the implementation of a PQP, and also the expected benefits from implementing such a programme, a literature review has been carried out, and is summarized in two sections, namely PQP barriers and PQP benefits.

4.3 Barriers to Implementing a PQP in Developed and Developing Countries

Since 1980, PQ issues have been causing real and significant disturbances to distribution systems and end users worldwide, and have become a global concern [6][17][18][5][68][70-72]. The lack of awareness of PQ could result in utilities still suffering from PQ problems caused by end users' sensitive equipment in the industrial, agricultural, residential and commercial sectors [1]. Therefore, providing a sufficient introduction, definitions and explanations for the most widespread PQ terms, will help in identifying the more common PQ disturbances that occur. Moreover, those overseeing or using power, in particular in less developed countries, should understand what PQ means.

The reason is that as long as the concept of PQ is misunderstood by both the staff of the electrical distribution utilities and the end users, then the severity of PQ issues will increase every day, as the demand for power increases and even doubles [33].

Several authors and researchers have determined different aspects of barriers according to their experience and their studies on PQP implementation. They reported more or less the same barriers as the previous studies in Chapters Two and Three. The common conclusion from their studies is that each electrical distribution utility has a set of significant barriers to which it must pay attention, and that the implementation process of PQP is beyond tackling the existing difficulties, and moving forward to overcome each barrier respectively.

Ferracci conducted a study based on statistical surveys in the UK, which revealed that a strategic issue for electricity companies has led to eight major categories of PQP barriers [35];

- Staff awareness regarding PQ issues
- Enough resources
- PQ training courses
- Management committed to implementing good PQP
- Long-term strategy
- End users' awareness
- PQ standards
- Regular maintenance.

Meyer et al., in 2005, conducted an empirical study on two distribution system operators in Germany. The main focus of the study was on the critical PQDs needed to implement effective PQP. The study found eight barriers to PQP implementation;

1. Distribution network design, structure and size
2. Distribution networks operations and planning
3. End users' load characteristics and structure
4. Inadequate background, experience, skills and awareness among employees, regarding PQ to solve customer complaints
5. PQ standards
6. PQ measurement
7. Lack of PQ data
8. Management planning and strategy [91].

Howe and McNulty conducted a study in a Massachusetts distribution system in the USA based on 16 in-depth interviews with large Massachusetts business customers. The study revealed that three barriers were perceived as being critical for the successful implementation of PQP;

1. PQ standards
2. Lack of cooperation by end users, i.e. illegal connection made by end users
3. Lack of top management responsibility and commitment regarding end users'

complaints [49].

Another study conducted by Dorr and Melhorn sponsored by EPRI in the USA was based on 9 telephone interviews, which pointed out nine components of PQP implementation barriers [102];

1. Top management commitment
2. Management support
3. Top management encouragement
4. Engineers' and technicians' skills
5. Engineers' and technicians' knowledge
6. Engineers' and technicians' experience
7. Proper teams to analyse PQ disturbances
8. Training courses
9. PQ database.

Barnard and Van Voorhis conducted a comprehensive empirical study in the USA, Asia, Africa, Australia, South America and Europe based on 70 face-to-face in-depth interviews with PQ managers and engineers. This revealed two barriers to PQP implementation, namely a lack of PQ awareness among end users, and lack of PQ training courses for engineers and technicians [15]. A further study in the USA revealed two barriers believed to hinder the successful implementation of PQP, i.e. the lack of a utilities distribution structure, and lack of a suitable management and operations structure [70].

A study conducted in Malaysia by Hannan et al. (2010) was based on 26 samples of high-technology industries to assess PQDs (flicker severity) as the most common PQ problem in Malaysia. The results indicated that six barriers to implementing a PQP were [88]:

1. Education programmes
2. PQ awareness and guidelines
3. Training courses and support
4. Continuing research and development
5. Financial incentives to encourage staff to resolve PQ issues.
6. PQ standards and policy

A survey was conducted by Targosz and Manson in eight developed European countries, namely Austria, France, Italy, Poland, Portugal, Slovenia, Spain and the UK, based on 16 industrial sectors. It was found that the commonest PQDs were power interruptions, dips, surges, transients and short interruptions. This is because there are four main barriers to PQP implementation;

1. End users' awareness
2. Employee awareness and skills
3. Management commitment
4. PQ measurements and maintenance

These factors have led to huge economic losses in Europe, exceeding €150bn annually [90].

Another survey conducted by De Keulenaer in France found that the main difficulties encountered during the implementation of PQP are;

1. PQ awareness among top management, engineers and end users
2. Network design, due to increased power demand
3. PQ standards
4. PQ measurement [47].

Labricciosa conducted a case study of PQ enhancement in an electrical distribution system in Canada, which revealed that three main factors impede the wider spread of PQPs;

1. PQ consultants
2. PQ standards
3. PQ awareness on the part of end users [18].

Hulshorst et al. conducted a survey in the Netherlands in 2007. The main focus of the study was on premium PQ contracts, labelling to improve PQ and how the distribution utilities can implement PQPs. The study found five significant difficulties in implementing a PQP, namely;

1. Distribution networks infrastructure
2. Failure to handle end users' complaints so as to identify the underlying problems
3. PQ contracts between suppliers and end users
4. Increasingly sensitive electronic equipment

5. PQ training courses to raise the education and levels of awareness of engineers to understand consumer complaints better [82].

Aniruddh conducted a study in India to evaluate PQP management [79]. The study found three barriers to PQP implementation in less developed countries;

1. Lack of proper design in the distribution networks' infrastructure
2. Lack of PQ standards
3. Lack of PQ awareness

Another case study was conducted by Deshpande and Chitre in India for critical factors of implementing total PQ management in a large distribution system [100]. The contribution of this study found two major barriers to PQP implementation;

1. Lack of PQ measurement
2. Lack of PQ awareness and skills among employees.

In addition, Radhakrishna conducted a PQ survey also in India to identify the external and the technical perspectives in electrical PQ. The survey found four significant barriers to PQP;

1. Lack of planning in designing the distribution network
2. Lack of proper PQ teams
3. Lack of PQ monitoring and databases to analyse customer complaints
4. Lack of PQ standards [44]

In Pakistan, a study conducted by Qureshi et al. in 2007 assessed PQDs in the power system and compared these with standards in developed countries [66]. The study revealed that the major obstacles to the implementation of a PQP were;

1. Lack of understanding PQ disturbances
2. Lack of PQ awareness
3. Lack of PQ standards

A study conducted by Moncrief et al. in 1999 in the USA to guide architects and engineers regarding PQ Applications. The study found that five main barriers were perceived as being critical for the success of PQP implementation [97];

1. Lack of end users' awareness programmes regarding PQ
2. Lack of PQ equipment standards

3. Lack of PQ awareness among employees
4. Lack of PQ monitoring and databases regarding end users' complaints as a form of assistance to the utilities
5. Lack of PQ measurements [97].

Abreu and Castellano carry out PQ site survey for the regulated electricity market in Venezuela [26]. The survey revealed that PQDs will be improved if the electricity utility company in Venezuela tackled the three barriers encountered during the implementation of PQP, comprising;

1. Lack of PQ monitoring and datasets
2. Lack of PQ standards
3. Lack of PQ employee awareness and experience.

Gomes et al. conducted an empirical study, in 2002, to evaluate PQ management issues in the Brazilian transmission system. The study revealed that PQDs such as flicker, harmonic distortion and voltage sag occurred due to the absence of a PQP [101]. The main barriers to PQP implementation in the Brazilian transmission system were;

1. Lack of distribution network infrastructure
2. Lack of studies and research
3. Lack of distribution network design
4. Lack of management planning
5. Lack of technician and engineer skills and experience
6. Lack of end user awareness
7. Lack of a clear strategy
8. Lack of PQ standards.

Table 4.1: The differences and similarities regarding PQP discerned by the above researchers

Item No	Barriers	Countries	Authors	References
BA1	Staff awareness, skills, knowledge and experience	USA, Europe, India, Venezuela, Brazil, Germany, Pakistan, Austria, France, Italy, Poland, Portugal, Slovenia, Spain and UK,	Ferracci (2001), Meyer, et al., (2005), Dorr and Melhorn (2000), Targosz and Manson (2007), De Keulenaer (2003), Abreu and Castellano (2006) , Gomes, et al.(2002)	[90],[47],[101],[35, 91, 102],[26]
BA2	End user awareness	USA, Asia, Africa, Australia, South America and Europe, Canada, Brazil, Austria, France, Italy, Poland, Portugal, Slovenia, Spain, UK	Barnard and Van Voorhis (2000), Targosz and Manson (2007), Gomes, et al.(2002), De Keulenaer (2003), Schienbein and DeSteese (2002)	[15],[90],[47],[101],[70]
BA3	Customer co-operation	USA, Massachusetts	Howe and McNulty (2002), Dorr and Melhorn (2000),	[49],[102]
BA4	Long-term strategy and planning	USA, Brazil, Germany, UK	Moncrief, et al.(1999), Gomes, et al.(2002), Meyer, et al.(2005), Ferracci (2001),	[101],[35, 91, 102],[97]
BA5	Top management commitment	USA, Massachusetts, Austria, France, Italy, Poland, Portugal, Slovenia, Spain and UK,	Howe and McNulty (2002), Targosz and Manson (2007), De Keulenaer (2003)	[90], [49], [47]
BA6	Network designing	USA, European, India, Brazil, Germany	Targosz and Manson (2007), Gomes, et al. (2002), Schienbein and DeSteese (2002), Radhakrishna (2008), Meyer, et al.(2005)	[90],[101],[70],[91],[44]
BA7	Distribution networks infrastructure	Netherlands, Brazil	Gomes, et al.(2002), Hulshorst, et al.(2007)	[101],[82]
BA8	Conducting research and studies	Malaysia, Brazil	Hannan, et al.(2010), Gomes, et al.(2002),	[88],[101]
BA9	Top management responsibility	USA, Netherlands	Dorr and Melhorn (2000), Hulshorst, et al.(2007)	[82, 102]
BA10	Training courses, and support	Malaysia, USA, Asia, Africa, Australia, South America, Europe, Netherlands, UK	Hannan, et al.(2010) ,Hulshorst, et al.(2007) Aniruddh (2003) , Deshpande and Chitre (2009), Radhakrishna (2008)	[44, 79, 82, 100]
BA11	Enough resources	Malaysia, USA, UK, India, Venezuela, Brazil, India	Hannan, et al.(2010) , Abreu and Castellano (2006),Radhakrishna (2008), Gomes, et al.(2002), Ferracci (2001)	[88],[101],[35],[44],[26]
BA12	Financial incentives	USA, UK, India, Venezuela, Brazil	Howe and McNulty (2002), Abreu and Castellano (2006), Radhakrishna (2008) , Gomes, et al.(2002), Ferracci (2001)	[49],[101],[35],[44],[26]
BA13	Regular maintenance	UK, Austria, France, Italy, Poland, Portugal, Slovenia, Spain	Targosz and Manson (2007), De Keulenaer (2003), Ferracci (2001)	[47],[35]

BA14	PQ standards	USA, European, Canada, India, Venezuela, Germany, UK	Targosz and Manson (2007), Labricciosa (1996), Ferracci (2001), Radhakrishna (2008) , Abreu and Castellano (2006) , Meyer, et al.(2005)	[90],[18],[35, 91, 102],[44], [26]
BA15	PQ measurement	India, USA, Germany, Austria, France, Italy, Poland, Portugal, Slovenia, Spain, UK,	Targosz and Manson (2007), Moncrief, et al.(1999) , Radhakrishna (2008) , De Keulenaer (2003) , Meyer, et al.(2005)	[90],[47],[91],[44], [97]
BA16	PQ consultants	Canada, India, USA, Venezuela, Pakistan	De Keulenaer (2003), Labricciosa (1996), Radhakrishna (2008) , Qureshi, et al.(2007), Moncrief, et al.(1999) , Abreu and Castellano (2006)	[47],[18],[26, 44, 66, 97]
BA17	PQ monitoring and database	India, USA, Venezuela, Pakistan	Radhakrishna (2008), Qureshi, et al.(2007) , Moncrief, et al.(1999), Abreu and Castellano (2006)	[26, 44, 66, 97]

4.4 Benefits of Implementing PQP in Developed and Developing Countries

An effectively implemented PQP will lead to substantial benefits. Tackling the barriers to a high level of PQ and end users' satisfaction requires both patience and discipline by top management and staff of distribution utilities. Moreover, they need to appraise their level of knowledge in the past regarding PQ issues, and what existing problems they still face. This would help them to learn how to avoid these obstacles, by raising their awareness of PQ [80]. It is very essential to allusion that the previous studies, which focused on the outcomes and the results of implementing PQPs in the electrical distribution network utilities as explained in table 4.2 below. Thus, such benefits, which derived from the literature and the studies conducted regarding PQP implementation will enable in building suitable PQP framework for LDNs by considering the limitations mentioned by the researchers. The outcomes and the consequences of the previous studies are detailed in the next sections.

A study conducted by Eberhard stressed that the expected benefits of PQP implementation in Croatia would make significant contributions to customer satisfaction [78]. He suggested that this level of customer satisfaction could be used as part of the process to identify the level of PQ issues, and where improvements could be made to increase this satisfaction. Moreover, Barnard and Van Voorhis found that the main benefits of PQP implementation in the USA are increasing end users' awareness and satisfaction, and also improving the situation regarding PQDs [15]. Furthermore, Labricciosa, in his case study of PQ enhancement in an electrical distribution system in Canada, stated that successful PQP implementation will result in reduced end user complaints, and will solve PQDs through PQ measurement programmes conducted on a regular basis [18].

Another study conducted by Aniruddh in India found that one of the main benefits of implementing PQP is providing PQ diagnostic systems and databases, which offer adequate data for end users to tackle PQ disturbances themselves, as their level of awareness increased [79]. Janjic et al. conducted a study in Serbia in 2011. The main results of the study indicated that when PQP was implemented successfully, the distribution utilities gained the benefits of strategic planning by taking appropriate action, and making adequate preparations to introduce effective changes in the distribution systems regarding PQ, and in so doing, satisfying their customers [93].

In addition, a study by Ronghua and Suan in Singapore found that increasing end users' satisfaction and reducing PQ cost are the most valuable benefits of implementing PQP [63]. Aqureshi and Paracha conducted an empirical study of PQ management techniques and methods in a power system in Pakistan [72]. The results indicated that the great benefits of PQP implementation are;

1. Reducing the pressure of demand by designing the distribution networks based on economic growth and accommodating the end users' needs.
2. Improving network performance regarding PQDs.
3. Increasing top management awareness of developing the distribution systems for future requirements of PQ improvements.
4. Stopping illegal connection by end users, once their complaints are addressed.

PQ problem surveys were conducted by Salam and Nasri in industrial zones in Egypt [109]. The main survey found that the significant benefits of PQP implementation are to:

1. Increase customer satisfaction
2. Raise the level of employee skills and awareness to tackle PQ issues.

Gul conducted a study to assess PQ and electricity consumer's rights in the restructured electricity market in Turkey [71]. The main findings indicated that the most valuable benefits of implementing PQP are;

1. Measuring PQ disturbances
2. Increasing PQ training courses
3. Providing enough knowledge
4. Widening employees' experience and skills
5. Educating end users and engineers
6. Reducing the huge losses for end users and utilities.

The benefits of PQP revealed by the above researchers and studies can be summarized as follows; increasing end users' awareness and, satisfaction, improving PQ performance, reducing end users' complaints, monitoring and measuring PQ disturbances, providing PQ diagnosis systems and databases, providing strategic planning, reducing PQ cost, improving network performance, increasing top management awareness, raising the level of employee skills, experience, knowledge and awareness, increasing PQ training courses, and reducing the huge losses for end users and utilities. The 11 PQP expected benefits are listed in table 4.2.

Table 4.2: List of PQP benefits

Item No	PQP Benefits	Countries	Author	References
BN1	Increasing end user awareness	USA, India, Turkey	Barnard and Van Voorhis (2000), Aniruddh (2003), Gul (2008)	[15],[71],[79]
BN2	Increasing the end users' satisfaction	Croatia, USA, Serbia, Singapore, Egypt	Eberhard (2011), Barnard and Van Voorhis (2000), Janjic, et al.(2011), Ronghua and Suan (2002), Salam and Nasri (2005)	[15],[63],[93], [78], [109]
BN3	Improving PQ disturbances	USA, Canada, Pakistan	Barnard and Van Voorhis (2000), Labricciosa (1996), Aqureshi and Paracha (2007),	[15],[72];[18]
BN4	Reducing the end users' complaints	Canada, Pakistan	Aqureshi and Paracha (2007), Labricciosa (1996)	[72], [18]

BN5	Monitor and measuring PQ disturbances	India, Turkey	Aniruddh (2003), Gul (2008)	[71], [79]
BN6	Providing a PQ diagnostic system and database	India	Aniruddh (2003)	[79]
BN7	Reducing the huge losses of PQ cost	Singapore, Turkey	Ronghua and Suan (2002), Gul (2008)	[63], [71]
BN8	Increasing top management awareness	Pakistan	Aqureshi and Paracha (2007)	[72]
BN9	Increasing employee skills and awareness	Egypt, Turkey	Salam and Nasri (2005), Gul (2008)	[71],[109]
BN10	Increasing PQ training courses	Turkey	Gul (2008)	[71]
BN11	Providing strategic planning	Serbia	Janjic, et al.(2011)	[93]

In LDNs, empirical research is required to categorize and underline the barriers and benefits of PQP in the context of a distribution utility, which has not implemented PQPs in the last two decades. The knowledge and results obtained from this study will guide LDNs implementing PQP, including all departments and staff, who are directly responsible for remedying PQDs, in tackling any PQ problems by setting up clear and long-term strategies, with crucial objectives and barriers. Therefore, the implementation of PQP requires great attention from top management to help the distribution networks achieve their goal of offering and providing a PQP in practice [103].

4.5 Evaluation of Current PQP Frameworks

From the comprehensive literature review of chapter two and chapter three and sections 4.3 to 4.7 detailed in this study, it is clear that there should be PQ framework guidelines to support the Libyan distribution system in implementing PQP. Therefore, considering previous PQP frameworks is important, in order to view and defines the critical factors needed to assess PQP framework requirements in LDNs. This section will describe the basis of framework forms and tools conducted to identify the weaknesses, which could be developed and improved as appropriate for LDNs' circumstances.

Howe's 2007 PQP framework aims to provide information and tools that will enable utilities, regulators, and end users to optimize investment in technologies for both the power supply system and the end user equipment, in order to reduce the overall costs associated with PQ variations in the USA [113].

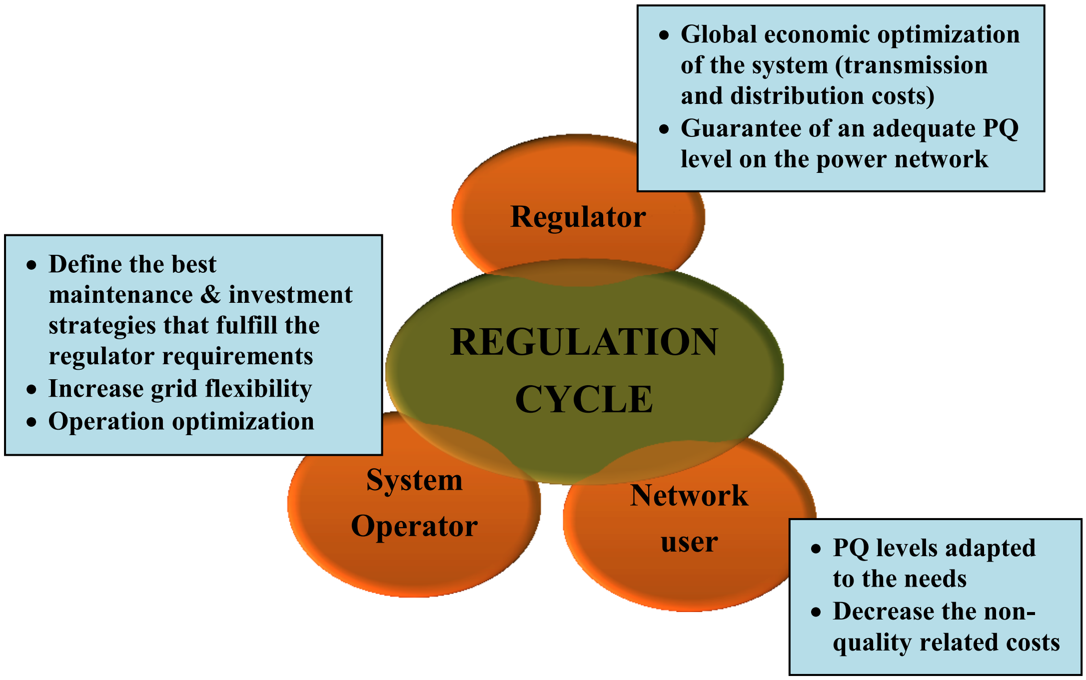
Deshpande and Chitre's 2009 framework aims to develop a system where knowledge must be shared as teamwork between manufacturers, utilities, government and end users regarding PQP. It highlights the key aspects that are needed for successful implementation of PQP requirements [100].

Bruce's 2007 framework aims to provide PQ for 21st century needs. He requires that implementing a PQP should be a coordinated endeavour between government, utilities, regulators, and standards bodies, such as IEEE and ICE. These efforts require extensive education programmes to increase the understanding of all people involved in improving power supply quality [80].

4.5.1 The description of the frameworks

Howe's 2007 study took place in the USA. The study found three main factors, which are responsible for PQP implementation framework [113]:

- System Operator: serves to delineate the best strategies to maintain, improve and increase the distribution networks to fulfill the regulator requirements and end user capacities in terms of PQ.
- Network user: indicates that PQ should meet end users' expectations, while on the part of the end users, they should minimize using non-linear loads, which are very sensitive to power supply variation.
- Regulator: refers to sufficient and high PQ standards at all levels of the distribution networks.



Source adapted from [113]

Figure 4.1: Framework for achieving optimum system and end user investment for PQP

Howe stated that there are three important requirements of the framework, seeking to successfully regulate, plan and design the distribution utilities at all levels, in order to develop and improve PQP:

1. Characterize distribution network installed equipment to cope with the new technologies, and for any future improvements of the networks that will allow solving PQ variations. It includes designing the distribution system, customer service technologies and end user equipment technologies with connection to the supply system for PQ data management.
2. Adapting international regulatory structures and contracts between the utilities and end users to achieve desired levels of PQ.
3. Develop the methodology and tools to optimize PQPs

- Distribution system level analysis (e.g. customer characteristics)
- Individual facility level analysis (e.g. industrial, commercial, agricultural and residential

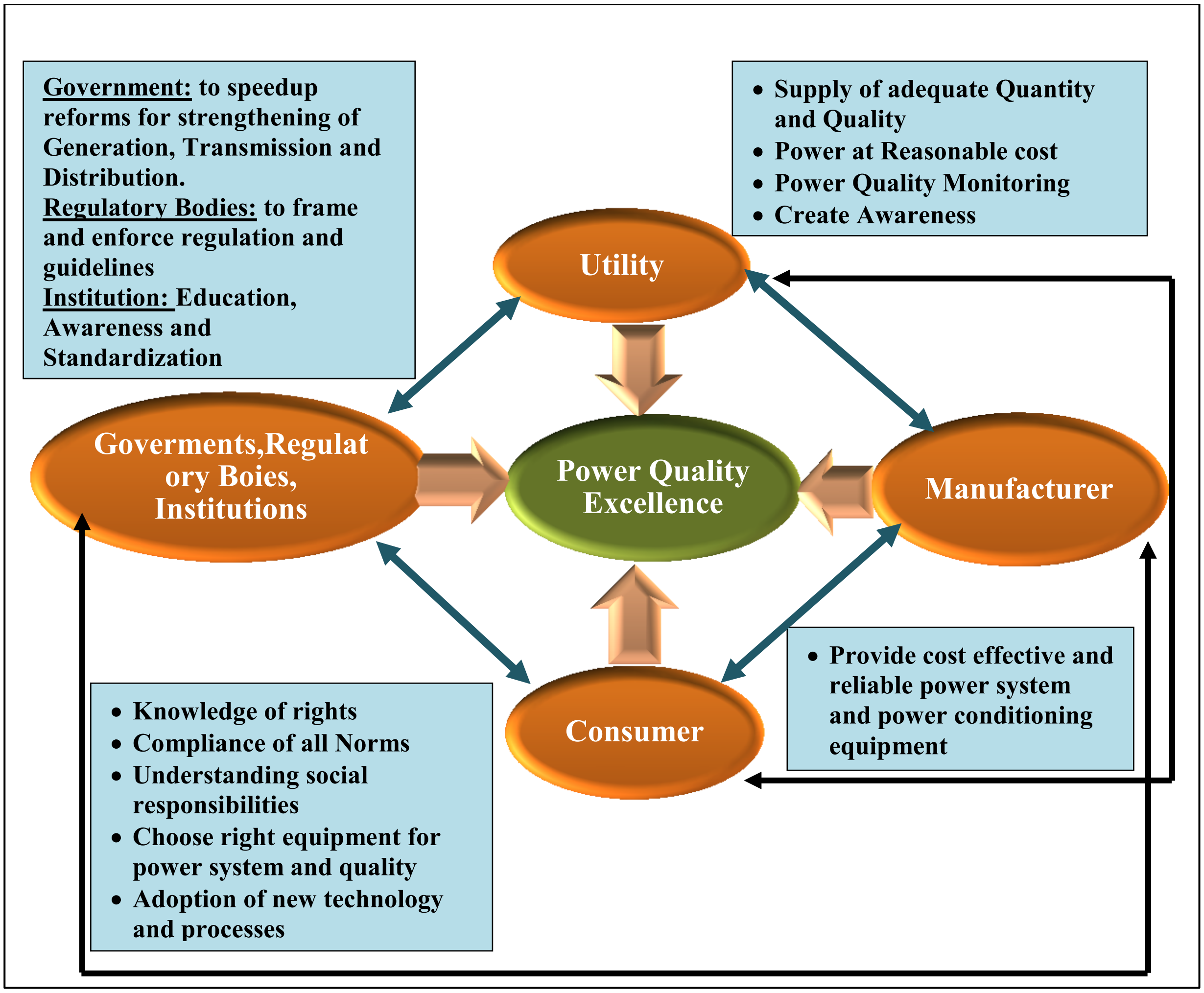
for considering future designs).

Howe's framework involved suggesting methods to determine the overall categories of PQ improvements. It mainly covers the relationship between designing the distribution networks, characterisation of end user types, and providing full regulation of the power supply. It did not study the lack of PQ awareness and barriers facing PQP issues in depth. However, engineer and technician skills and ability to perform in this programme were not clarified. Moreover, the study did not provide enough information about the roadmap for the mitigation system.

Deshpande and Chitre's study took place in India, and their framework contains four major requirements involved in developing PQP implementation together with relative elements of each factor. They emphasized that these issues must be considered before assessment of any PQ problems to improve and sustain PQ in a typical distribution network [100].

The four requirements of the framework are:

- Utility requirements: indicates that the power supply should be of adequate quantity, low cost, and high quality, while including PQ monitoring and increased levels of awareness. Adopting the PQP without any difficulties will be facilitated by conducting researches, studies and measurements on existing networks and consumers.
- Consumer requirements: refers to consumers being knowledgeable about their rights regarding supply PQ, considering all conditions in the contract, understanding legal actions against illegal connections, selecting the best devices to meet power supply and quality standards, and be aware of new technology and sensitive equipment. This factor is influenced by how widespread the level of awareness is, which can be a bridge between the end users and the utility.
- Manufacturer requirements: refers to providing the equipment installed in power distribution systems and PQ mitigation tools, which should be highly reliable and effective without any disturbances.
- Government requirements: refers to accommodating rapid reforms of generation, transmission and distribution systems, facilitate and impose regulation, laws, and guidelines, and establish institutions to increase education, and awareness, and provide standardization of systems equipment.



Source adapted from [100]

Figure 4.2: Framework for highlighting the key aspects for excellent PQ Bridge

Deshpande and Chitre's framework can evaluate the PQP implementation in distribution utilities with no previous attempts at a PQP. This is mainly because it is based on multiple requirements, including awareness, standardization and guidelines, which will assist and identify the significant elements of PQP achievement needed. However, Deshpande and Chitre have emphasised that all the requirements should take into account power supply infrastructure and a feasibility analysis of the entire networks.

Bruce's study conducted in the USA consists of three principal concerns together with three recommendations relating to the impacts of these concerns on PQP implementation.

The three major issues are:

- Reducing the high costs of PQ mitigation equipment. This refers to encouraging a wide range and number of users to install and apply these devices at their sites, as costs decrease. According to Bruce's framework, making cost effective mitigation tools using advanced technologies to improve PQDs is important, and must be coordinated among device manufacturers, power suppliers, end users and power standards agencies.

- Applying policies and regulations to encourage investment in PQPs. This refers to the failure of providing differentiated policies and regulations regarding PQ distributed to consumers with varying requirements.
- Developing PQ codes and standards. This refers to the absence of electrical standards; organizations and institutes have not provided a wide range of PQ standards based on the consumer's requirements at every level of the distribution networks. Providing differentiated PQ standards is crucial to assist and educate all the parties involved in PQ problems to guarantee widespread awareness, in terms of PQ compliance and the capability of power suppliers to meet end users' expectations.

All the mentioned issues contribute to diminishing barriers to improved PQ. They also allow minimizing the losses in the networks due to poor PQ caused by sensitive devices used by residential, agricultural, commercial and industrial consumers, which will reduce the large amounts of money wasted, estimated to be in the billions, and impacting on the economy. The three main recommendations are:

1. PQ solutions must be designed to accommodate different types of consumer needs. This refers to the distribution utilities and customer service departments needing to work together to conduct studies on end users' point of connection and analyze the PQ delivered.
2. Government leadership refers to the responsibilities shared between government bodies and distribution utilities to identify the highest economic loss areas requiring PQ solutions, along with the end users willing to be involved in PQ improvement.
3. Carrying out regular PQPs to provide PQ education. Refers to end users becoming aware, understanding and highly knowledgeable about PQ imperfections in to their facilities [80].

Considering these problems and recommendations before conducting any PQP will require the electrical distribution utilities to provide a clear strategy in terms of planning objectives. Good understanding with comprehensive assessment of the current situation and the particular circumstances regarding the implementation of PQP will provide the best preparation needed.

This entails that top management, engineers, technician, employees, and different categories of consumers, especially in developing countries, to bear their responsibilities and deal with the PQP implementation. Table 4.3 briefly explained the influence of the frameworks on this study.

Table 4.3: The influence of the frameworks on this study

Framework	Main Issues considered
Howe (2007)	• The aim of the study was to provide information and tools that will enable utilities, regulators, and end users to implement a PQP. • To optimize investment in technologies for both the power supply system and end user equipment. • To reduce the overall costs associated with PQ variations in the USA. • To provide sufficiently high PQ standards at all levels to meet end users' expectations. • To develop the best strategies to maintain, improve and increase the distribution networks to fulfill regulatory requirements and end user capacities. • Characterize distribution network installed equipment to cope with new technologies, and allow for future improvements. • Adopting international regulatory structures and contracts between the utilities and end users. • Develop methodology and tools for optimize PQPs.
Deshpande and Chitre (2009)	• The aim of the study was to develop a system, where knowledge must be shared in a team effort between manufacturers, utilities, government and end users regarding the PQP • To improve and sustain PQ in a typical distribution network by regular monitoring • Increase the level of awareness regarding new technology and sensitive equipment • Adopting PQP without difficulties by conducting researches, studies and measurements on existing networks and consumers. • Considering all conditions in contracts by understanding the legal actions to be taken against illegal connections causing PQDs. • To facilitate and impose regulation, laws, and guidelines, and establish institutions to increase education and awareness, and provide standardization of systems equipment.
Bruce (2007)	• The aim of the study was to provide PQ for 21st century needs; efforts require extensive education programmes to increase the level of understanding. • To allocate the areas those cost most in PQ, and apply solutions along with end users. • The failure in providing differentiated policies and regulations regarding PQ distributed to consumers with varying requirements to install and apply these devices at their sites. • The absences of the electrical standards organizations and institutes have not provided wide range of PQ standards based on the consumer's requirements.

The factors mentioned by these three frameworks were significantly considered to be empirically tested and interpreted to measure the validation of PQP framework implementation in LDNs. Therefore, 540 copies of the PQP questionnaire were sent to LDNs staff including head mangers, engineering, technician and employees, followed by 44 face-to-face semi structure interviews for the same categories to make the framework more valid. Nonetheless, these factors included in the frameworks would be very enough to assess PQDs if comprehensively explained their effect on PQP implementation as some previous studies in literature review revealed their importance and their impact on improving PQDs and PQP implementation. Moreover, the authors of these studies did not conduct reliable and comprehensive qualitative and quantitative investigations to illuminate whether these factors would have direct impact on PQ improvement or to indicate the method they used to influence these factors on PQP implementation.

4.6 The Conceptual framework for PQP

In order to implement a PQP framework successfully, it should be simple, logical and should fit with the current level of LDNs [134, 135]. The PQP framework roadmap for this study was developed based on extensive literature reviews, as presented in Chapters 2 and 3, including documents, papers, reports and archives [136]. The framework was also developed based on the research results gained from primary data, collected using both quantitative and qualitative data methods. This study considers some PQP frameworks mentioned earlier in Chapters 2 and 3. However, there were some limitations which needed to be improved and developed to fit the Libyan case.

A framework was defined by Aalbregtse as *"a clear picture of the leadership goal for the institution and should present key characteristics of the to-be style of business operations"* [137]. Therefore, there were some reasonable factors why a framework is vital, and needs to be developed in some organisations, companies and institutions as follows:

- To demonstrate the key critical factors of what needed to be achieved in terms of vision, strategy of companies.
- To alarm the top management to tackle substantial critical issues, which repeatedly occur and are not being addressed?
- To present the entire weaknesses and strengths into the organization.
- The most important is to sustain smooth improvements and to support the

implementation of each stage, which significantly needed to address.

Moreover, there are other PQP frameworks in the literature reviewed. However, the above mentioned frameworks were the most significant, which influenced the main objectives of this study as they include several factors that have a direct relation to this research.

Howe's framework applied to the USA. It aimed to provide information and tools to allow utilities, regulators, and end users to implement PQP [113]. It mainly refers to the relationship between designing the distribution networks, characterisation of end user types, and providing full regulation of the power supply, which was neglected in the Deshpande and Chitre framework. The Deshpande and Chitre framework also aims to develop a system, where knowledge must be shared as a team effort between manufacturers, utilities, government, and end users regarding PQP in developing countries [100]. Bruce's framework aims to provide PQ for 21st century needs, and require efforts and extensive education programmes to increase both the understanding and the level of awareness for both electrical utilities staff, and encourage large numbers of end users to install and apply the mitigation devices for PQ improvement at their sites, as costs fall [80]. Howe's framework influenced this study, because it considers information and tools that will allow utilities, regulators, and end users to implement PQP. However, it did not study the lack of PQ awareness and barriers facing PQP in depth, including management and staff levels of awareness. Deshpande and Chitre's framework also influenced this study, in that it considered comprehensive factors involving manufacturers, utilities, government and end users to impose regulation, laws and guidelines, and establish institutions to increase education, awareness and provide standardization. The study has emphasised that all the requirements should take into account power supply infrastructure, and conduct a feasibility analysis of the entire networks. Furthermore, Bruce's framework influenced this study, because it consists of three principal concerns together along with three recommendations to address the impacts of these concerns on PQP implementation.

Therefore, existing frameworks significantly influenced the one developed to address the current level of PQ in the Libyan distribution system, as the factors and components proposed in them are reflected in the Libyan distribution utilities that require the PQP framework. Additionally, the three mentioned frameworks give a comprehensive picture of the requirements and the improvements on PQ, and the factors needed in implementing a PQP framework. However, they are not sufficient to explain the particular circumstances of PQ issues encountered in Libyan distribution systems. As it can be seen from Table 4.3, the mentioned frameworks and other work in the literature were conceptually focused on theoretical with lacking of conducting more empirical studies concentration, which are very necessary to make their assumptions more valid in order to support the theoretical expectations. This led the researcher to develop a PQP framework for improving PQ in LDNs as a contribution of this research. Thus, from the literature review presented in Chapters 2 and 3, the relevant components of PQP frameworks were considered respectively. These were used to build a suitable framework required to collect data from Libyan distribution systems staff. This statement leads to build the following research questions:

> *What type of PQP implementation model framework should be developed in order to guide LDNs in improving PQDs and what are the requirements involved in the implementation of PQP?*

The proposed framework for the PQP considers every aspect, and includes levels of awareness, top management commitment, internal resources, and internal and external PQ involvement in distribution utilities. Existing frameworks, as explained earlier, are not sufficient in order to draw the main points for implementing the framework. This is because they focused only on the requirements, and not the implementation stages and the process for each factor. Therefore, implementation teams were not moving from the suggested strategies to realistic performances. As a result, implementation teams needed to be aware of the factors in the proposed framework, with the related significant requirements needed to reach the expected level of the implementation. Accordingly, this gap will continue if the PQP is not implemented. Therefore, one of the main challenges in implementing PQP is to link all the difficulties with both objectives and strategies. Hence, the implementation difficulties should be assessed regularly, to identify the hidden reasons associated with poor implementation. Thus, without adequate knowledge, awareness, planning, design, preparation, training, PQ standards, and clear strategy, and also most importantly top management support for the programme, PQDs will never be resolved, and their severity will affect all consumers.

In response to the research question, this research contributes by developing a framework for evaluating PQDs in two ways. Firstly, by identifying the most significant factors, that would have a major impact on PQ improvement in the Libyan distribution grids, and facilitate PQP implementation. Secondly, this framework encourages and guides implementation teams to have an obvious and clear vision of how to prevent existing obstacles from reappearing in different forms, leading to improvements in the long-term. The progress on this framework, in moving through from one phase to another, depends on the level of awareness, knowledge, and skills gained respectively as each phase is completed. From his point of view, the researcher believes that the PQP model framework implementation consists of four main factors, which are awareness, resources, management attention and PQ involvement. These are described in Figure 4.3 as follows:

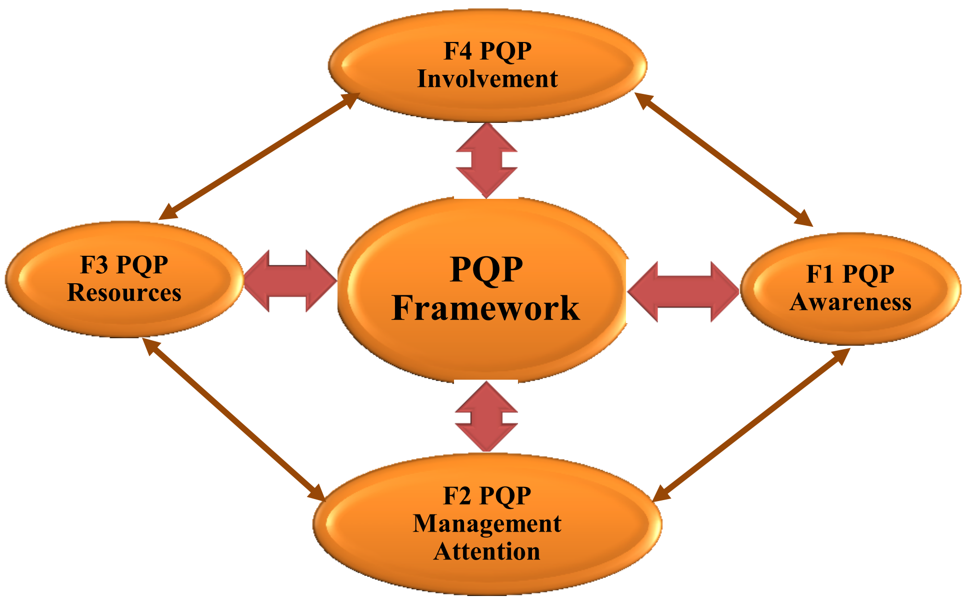


Figure 4.3: PQP framework Model developed for the purpose of this study.

4.6.1 PQP Awareness

This is very important, because of its influence on top management attention and PQ involvement, which leads to preparing sufficient resources. Most PQ frameworks presented in Chapters 2 and 3, and the section on PQP barriers, indicated that reaching a high level of PQ was influenced by how high the level of awareness is, among the planning and implementation teams, top management and end users. For this reason, carrying out education and awareness programmes on a regular basis is one of the keys requirements for PQP implementation [100].

4.6.2 PQP Management Attention

This is a crucial factor that affects the preparation and implementation process. In Chapters 2 and 3, it was clear that top management's responsibility and level of awareness are among the success factors for any company to implement PQP successfully. Top management sets out a clear strategy for all participants involved in improving PQ problems, with the purpose of improving the distribution networks [102].

Hence, top management support is considered to be one of the key factors, which would help overcome any difficulties, and includes awareness and attention in conducting some studies, making the administration structure uncomplicated, and providing more training courses, regarding the implementation of PQP. Moreover, top management, as well as the planning and implementation teams, should understand the complete process to achieve successful implementation of PQP, as endorsed by top management. Thus, time should be spent on planning, preparation, and providing a clear picture of what the company needs from such a programme, to eliminate any obstacle or confusion that might face the implementation objectives in the future. This includes strategy, studies, accommodating the growth in economic, infrastructure, PQ standards, end users' cooperation, and training courses. Therefore, an obvious vision will enable top management to provide significant guidance on requirements for both planning and implementation teams, which are in turn influenced by the strategy teams in each department.

4.6.3 PQP Resources

As there are a variety of requirements needed for framework implementation, there should also be a variety of sufficient resources. These are quite essential aspects for any distribution utility to cope with the current situation by improving existing equipment, and upgrading networks for better PQ performance. Furthermore, the resources needed for maintenance of existing networks, new projects, and running training courses regarding PQP [75]. It includes practical, technical, psychological and cultural materials, and incentives to encourage and support planning teams [88][95].

4.6.4 PQP Involvement

This factor goes beyond the first three factors, which should be prepared logically in order to resolve PQDs. After providing all the technical and non-technical elements, this factor provides teams with PQ measurements to monitor, analyse, revise, and compare to PQ standards. Hence, a PQ database can be built in order to satisfy the end users and meet their expectations [86][105]. As a result, minimizing the outstanding barriers will lead to obtaining accurate feedback, as stated by both the planning and implementation teams.

This framework supports the distribution utilities to evaluate PQ programme against the planned requirements of planning teams. Firstly, by increasing the level of awareness and then by providing all the requirements for the implementation teams to support the proper teams, which will conducted the PQ measurements by supplying the appropriate tools and equipment that can solve PQDs. This framework also concentrates on the external factors, which are identified as significant from the previous frameworks and studies associated with PQ improvements. Table 4.4 shows PQP framework factors along with sub-factors.

Table 4.4: The key factors to assessing the PQP framework

Key factor	Sub-factor	References
PQP Awareness	Staff awareness, skills, knowledge and experience	[88]; [90]; [47]; [101]; [26, 35, 66, 79, 91, 97, 100, 102]
	End users awareness	[35]; [79]; [66]; [97]
	Customer cooperation	[49]; [91]
	Long-term strategy and planning	[101]; [35]; [91]
PQP Top management attention	Top management commitment	[90]; [35]; [102]
	Network designing	[47]; [101];[70];[91]; [79]; [44]
	Distribution networks infrastructure	[101]; [87]; [70]; [82]; [79]; [108]
	Conducting research and studies	[88]; [101]
	Top management responsibility	[49]; [82]
PQP Resources	Training courses, and support	[15]; [88]; [35]; [102]; [82]
	Sufficient resources	[35]
	Financial incentives	[80]; [88]; [72]; [95]; [97]
PQP involvement	PQ measurement	[90]; [47];[91]; [100]; [97]
	PQ consultants	[18];[102]; [44]
	PQ standards	[88]; [49]; [47]; [101];[18];[35]; [91]; [79]; [44]; [66]; [26]
	PQ monitoring and database	[91]; [102]; [44]; [97]; [26]
	Regular maintenance	[35]; [120]

Source: developed for the purpose of this research

4.7 The requirements of PQP framework implementation process

The implementation of PQP and tackling existing obstacles required the distribution utilities to develop significant requirements, which facilitate the framework stages process [87]. Lee and Hoffman have emphasised that these requirements must come under strategic planning.

Therefore, top management identifies the most significant factors, which lead to the major prior requirements influencing the PQP framework, to be justified and evaluated as needs in holistic programmes in the PQ framework [75]. PQP programme requirements are explained below as following:

4.7.1 PQP Awareness

The rapid growth of PQDs and the significant necessity to implement PQP has emphasised the need for a PQ awareness programme in the distribution utilities. This overcomes the lack of PQ awareness, and underlines the importance of improving PQ, and so clarifies the reasons why PQP implementation is crucial [66]. PQ awareness enables the distribution utilities to give more explanations and apply initiatives for PQDs improvements as this level will does so. These definitions for both staff and end users allow them to understand, and realise the importance of PQP implementation and its benefits [73].

PQP benefits include increasing end user awareness and satisfaction, improving PQ performance, reducing end users' complaints, monitoring and measuring PQ disturbances, providing PQ diagnosis systems and databases, reducing the huge losses through PQ costs, increasing top management awareness, increasing the employees' skills and awareness, increasing PQ training courses and providing strategic planning. These benefits will be gained during the implementation process after each stage.

Yet providing education programmes to raise the level of awareness of PQ among staff and end users requires significant attention from distribution utilities. Nonetheless, end user awareness regarding PQ would not be increased unless technical PQ training courses are given to technical staff, so as to be familiar with PQ features. Technical staff are responsible, in another way, for making the end users aware of PQDs from the technical side [89]. McNulty and Howe highlighted that the lack of employee skills in dealing with PQ problems was as another main reason for the increase in such problems [26][90]. Furthermore, one of the essential PQP framework requirements is to spend more time and resources on education and awareness programmes through different means, e.g. seminars, TV, radio, newspapers, posters, leaflets and Internet. Without paying enough attention to enhance PQ awareness, the implementation of PQP will not be achieved as expected. Thus, as long as an appropriate PQ awareness programme is widely implemented, then solving PQDs would be possible [103].

The lack of PQ awareness and other potential difficulties might lead to delay in PQP implementation. Tackling these is influenced by top management having clear vision and awareness of them. It is also vital for both planning and implementation teams to take advantage of their knowledge, skills and awareness of these potential difficulties, in order to overcome any issues occur suddenly during PQP implementation as it explained in sections 7.3.4 and 7.4.8. Figure 4.4 showed the cycle of the PQP awareness, which required for LDNs.

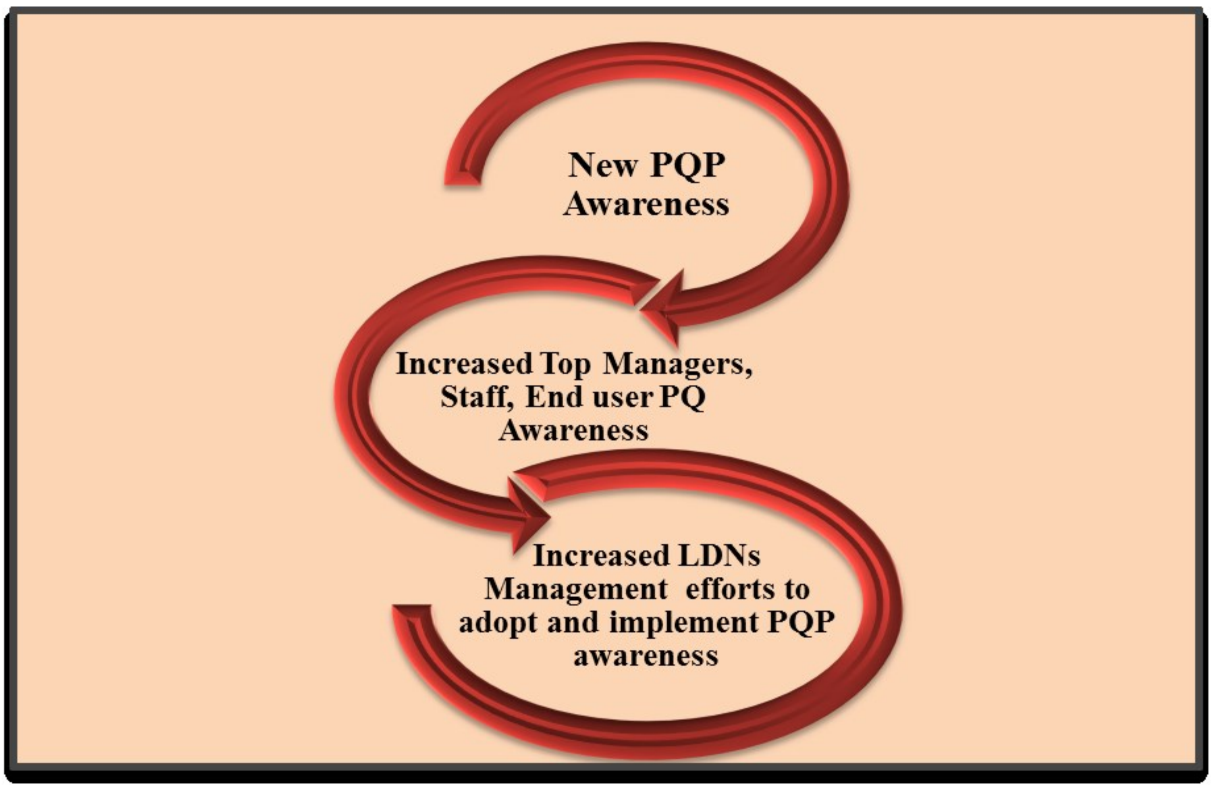


Figure 4.4: PQP Awareness Cycle

4.7.2 Top Management Leadership in PQPs

Leadership or top management involved in PQP is the first and most significant factor in assessing how well distribution systems bear their commitment to support the implementation of PQP. Therefore, top management's commitment is to understand PQ definitions, as well as the difficulties and benefits of implementing PQP. Therefore, without clear direction, vision, goals, objectives, intention, purpose, and effectiveness, given the significant barriers, then any efforts at improving PQ issues will be wasted in both time and resources [17]. Top management needs to identify most projects as top priorities. As a result, they must bear the commitment and involvement to prepare the most crucial resources that contribute to all staff being involved in PQ improvement from all departments, which have direct relation to solving PQ issues. Moreover, to help the achievement of completing PQP implementation by tackling the top priority issues faced by the implementation team. This requires providing the professional teams, including strategic planning and implementation teams, with enough training regarding PQP to gain appropriate and sufficient skills, experience, and knowledge to make a smooth transition in each stage. Therefore, lack of top management support and involvement is seen as a serious issue, which leads to failure in completing the implementation process, and overcoming the critical outstanding barriers to the PQP [44].

4.7.3 PQP planning team

The planning team is one more essential factor in implementing the PQP, as they carry out the studies and researches, which affect the preparation and assessment of the PQP framework and processes. As mentioned earlier in Chapters 2 and 3, top management needs to understand each stage of the framework, and receive the feedback from the strategic team, to cope with each level of the process, including the barriers and difficulties facing the planning team. With this information, top management will be able to determine that what are the top priority factors, which need to be focused on at each phase, until a high level of PQ is achieved. Accordingly, the planning team might face some critical issues, which can be tackled by raising the level of awareness, and by providing extensive PQ education programmes and seminars to be able to tackle any similarity, and further difficulties.

Therefore, the distribution utilities must build a good planning team to support first, the strategic team in concentrating on the top recurring barriers to the PQP, and secondly, by detecting the most appropriate areas, where the resources can be spent to help resolve PQDs on a regular basis. The decisions made by the planning team must be considered by the top management to avoid wasting time and effort, and to continue developing the distribution network effectively [102][103].

4.7.4 PQP Training Courses

PQP training is one of the crucial requirements. Therefore, training courses should be run regularly to raise staff awareness and knowledge, in order to meet the high level of skills required in resolving PQDs, and to maintain PQP implementation moving smoothly, and without any problems, at each stage [88]. Staff involved in PQP implementation, including top managers, engineers, and technicians, need to be well trained and educated to support and execute the process at each PQP stage, as developed by the strategic and planning teams [80]. Therefore, spending more time on education and training courses, and using advanced approaches in these training programmes, allows staff to cope with new technologies and achieve better results. Moreover, this would improve the level of awareness of engineers and technicians, as result of which, end user level of awareness will also improve [88]. Moreover, well trained staff are needed to deal with the PQ database, in order to monitor, measure, and analyse PQDs, as well as revise and compare them in terms of PQ standards. Hence, some researchers emphasised that if staff involved in PQP are not well trained, and do not adequately understand the purpose of such programmes, they will not tackle the roots of PQDs very well, given this existing obstacle [97].

Training courses are needed, in that, first, they are part of the PQP implementation requirement. Such training is about explaining the new technology causing PQDs, and enhancing the skills and experience of engineers and technicians, equipping them to best implement the PQP framework adopted, and demonstrating how it can be disseminated for better solutions needed to address end users' complaints. Therefore, sufficient education and awareness programmes for staff participating in PQDs improvement will lead to successful implementation of the PQP framework [100].

4.7.5 PQP Database and Infrastructure

The PQ database is another fundamental factor that affects the implementation and measurements of PQDs as part of PQP. It can be used to provide the equipment specifications and guidelines, identifying which are most susceptible to PQ variations, and informing end users. Moreover, both technical guidelines and PQ standards can be provided as part of the implementation of a PQ database, in order to reach a high level of quality satisfying customer requirements [26]. Databases are suggested as a means for electrical distribution utilities to evaluate PQ issues on a regular basis. These allow the PQ data and information captured to be regularly reviewed, revised, tested, and compared to PQ standards [75]. Moreover, the electricity companies can categorize the PQ dataset, taking into account the customer's perspective in collecting the data, rather than the utilities' [98]. It is also suggested that there should be more records on the most susceptible equipment [18][73][85]. This can help in identifying the severity of these disturbances and their sources. Therefore, one of the vital requirements for implementation of the PQP is to build a PQ database, after tackling the outstanding external factors to achieve appropriate and expected outcomes [96]. Furthermore, a PQ database will enable the measurement teams to conduct deep analysis of PQDs that affect both end users' sensitive equipment and the distribution networks' installed equipment. Hence, when the distribution utilities are willing to improve PQDs and implement a PQP, they need a database to compare the past and current of PQDs, which will enable them to perform better analysis, and have a better understanding of any further issues occurring in the future [44].

In this context, a PQ database requires tools and measurement equipment, as well as IT infrastructure to cope with all the distribution networks, and to record and identify the most significant issues and areas where PQDs occur so often. Moreover, an IT infrastructure will help the main departments involved in PQ improvement to assess PQDs by monitoring and analysing any severe disturbance by identifying its roots. This requires staff skills, knowledge, and experience to achieve this. Furthermore, the PQ database will contribute to the end users by giving them access to reports on the PQDs they face [19]. Therefore, end users will be one of the most significant elements in improving PQDs, as their level of awareness increases, with the ability to use the facility of accessing the PQ database.

Therefore, for distribution systems to be successful in attaining a high level of PQ, and successful PQP implementation, they need to establish an IT infrastructure based on a PQ database, which is capable of supporting and empowering the implementation of PQP, which will tap into the distribution network PQ database. Therefore, distribution networks infrastructure in terms of design, and categorising end users based on each level, will help the implementation teams diagnose and mitigate PQDs, and find the appropriate solutions that guarantee security, availability, and reliability of power. However, many distribution utilities systems in developing countries do not have the appropriate infrastructure required for implementing PQP throughout their distribution networks [87]. The importance of IT in distribution utilities is in allowing PQ teams to access and record PQDs, and identifies the disturbances roots, which enable better mitigation measures. Therefore, one of top management's commitments and responsibilities is to ensure that the PQ database in developed based on the international standards, before starting to implement PQP, and avoid wasting time and effort [103].

4.7.6 PQP Consultants and Implementation Team

Implementation teams are refer to as part of PQP framework requirements that need a high level of awareness, knowledge, skills and good experience to conduct PQP measurements without any obstacles. According to Dorr and Melhorn, "*Convenience and Completeness*", are vital variables to diagnose any PQDs, and in implementing a PQP to satisfy end users [102]. Therefore, the purpose of preparing an implementation team is to complete the PQP framework strategies and the objectives set to improve PQDs, including monitoring, recording and analysing the data captured. However, if the implementation team lacks sufficient qualifications and skills to cope with the new technology equipment's classification, then this will lead to poor PQP implementation. Therefore, the absence of top management support and commitment, will lead the implementation team to ignore the outstanding difficulties, which need to be considered as top priority.

Reaching a high level of PQ is subject to preparing a qualified implementation team or PQ consultants, because it assists and supports the distribution utilities in tackling PQDs on a regular basis, and following the objectives of long term strategies set out for all teams involved in PQ improvement, as a part of PQP implementation. If the PQP framework lacks a proper and qualified implementation team, this will affect the distribution utilities' ability to address their end users' complaints, and will also cause delay in completing the top priority goals. As a result, this will affect the long-term strategy established by the planning teams [101].

However, successful PQP implementation refers to the planning teams' achievement by taking into account all the objectives developed for the PQP in the long term strategy for all staff and departments associated with PQ improvement. Therefore, distribution utilities with high and sufficient employee's skills, awareness and experience regarding PQ, including top managers, engineers, and technicians, will be better equipped and eager to deal with PQP implementation issues. Providing qualified PQ consultants will lead to the PQP satisfying end users, and enable them to cooperate with the implementation team by providing and sharing the important information needed from their sites, by accessing the PQ database and recording such data [109]. Therefore, running PQ measurement on a regular basis will help identify the most sensitive areas where PQDs occur, and will also help the distribution utilities to develop appropriate solutions. Moreover, the importance of PQ consultants or experts regarding the implementation of PQP is in giving feedback, which enables the planning teams to set further objectives for good PQ performance.

4.8 The Key Success Factors for Implementing a PQP Framework

As presented in Chapters 2 and 3, an extensive literature review was carried out to understand the concept of PQ. It also investigated and explored the significant factors for PQP framework implementation. The studies outcome provided good understanding of the barriers in the area of PQP, and helped distribution utilities to develop their systems based on recommendations and ideas regarding failure in implementing PQP.

The previous PQP frameworks from the literature review were evaluated in Chapters 2 and 3 and section 4.5. Section 4.6 developed the proposed framework for this study and discussed why the PQP framework is vital for Libyan distribution systems. This section will state the key success factors for each aspect, in order to allow gaining feedback after implementing the programme. Therefore, it is imperative to ask the following research question:

> *What are the most significant success factors of implementing a PQP regarding PQ awareness within LDNs in EGCOL?*

The key success factors are needed by top managers, engineers, technicians, and employees to effectively complete PQP implementation. These include end user satisfaction, employee participation, top management commitment, and staff and end user awareness. The success factors help the planning and implementation teams make the process of implementing each stage of the framework smooth, and obtain the required information to support improving PQDs. These factors are different from one electrical distribution utility to another due to differing situation, circumstances, and problems. As indicated in section 4.6, the PQP model framework consists of four main factors, which are awareness, resources, management attention and PQ involvement. Taking these success factors into account will enable the Libyan electrical distribution utility to implement the PQP within the time frame set in the company strategy [4].

Most of the professionals, researchers, experts, engineers and technicians involved in the PQP implementation, agree substantially on the identified success factors, which complement one another, allowing PQDs in Libyan distribution systems to be measured. Therefore, the evaluation of the PQP framework for LDNs in this study was approached through determining the factors, exploring case studies, and conducting a primary field study, empirical surveys, and face-to-face interviews with Libyan distribution systems experts, including head managers, engineers, and technicians from four departments, i.e. training, distribution, planning and customer services. Five factors have been identified as key and significant for the success of the PQP framework in Libyan distribution systems, namely;

1. Top management commitment
2. Customer satisfaction
3. Employee training and participation
4. Customers and Company Awareness
5. PQ Disturbances

All the the success factors and sub-factors in Table 4.5 were explained clearly and they were included in the questionnaire instruments and semi-structured interviews (section 7.3).

Table 4.5: The key success factors, sub-factors and description to evaluate PQ in LDNS

Key factor	Sub-factors	Description	Reference
Customer Satisfaction	Customer Complaints	Customer complaints should be considered when identifying PQDs to prevent the same disturbances from recurring in the future.	[4]; [79]; [78]; [120]; [19]
	Customer Satisfaction	Considering customer expectation can help the utility in keeping a high level of PQ regarding their satisfaction.	[33]; [15];[4]; [82]
	Customer Needs	Distribution utilities conduct measurement to encourage their employees to meet the customers' needs and expectations.	[1][72];[118];[18];[120]; [7-9, 77]
	Customer Awareness	Refers to end users being aware, understanding and highly knowledgeable about the PQ imperfections found in their facilities	[15];[88];[47];[18];[97];[89]
	Growing demand	Refers to accommodating the growing demand for electricity, in order to improve PQ for end users.	[33];[27];[87];[70];[102]; [79];[108];[7];[31, 104, 106, 119]
Top management commitment	Identifies the causes of PQ	When the distribution network faces any PQ problems, it should identify the root causes of the problems, then find and implement the optimal solution.	[19];[89];[74]; [107]
	Bear Responsibility	The distribution utility is responsible for ensuring the security and the quality of the electricity before it is delivered to its customers.	[1];[3];[4];[93];[27];[17];[100];[97];[78]; [103];
	Planning good strategy	Refers to the overall strategy, Planning a good strategy to increase the capability of the network is an essential factor to meet the increasing demand from customers.	[72];[101];[71];[102];[97]; [106]; [83]; [75]
	Recommendations and studies on the existing networks and consumers	Following the recommendations of researches is very important in order to improve the PQ for customers.	[80]; [72]; [70]; [120]
	Ensure security and quality	The failures in providing differentiated policies and regulations regarding PQ distributed to consumers with varying requirements, and to install and apply mitigation devices at their sites.	[3];[130];[9]; [11, 121, 125, 131]
	International or national PQ standards	Using international and national PQ benchmarks and standards are vital for the company's policy to identify PQ improvement.	[44];[26];[86];[105];[30]
	Contracts between the utilities and end users	Considering all conditions in the contracts by understanding the legal actions against illegal connections cause PQDs within the contractual terms between the company and the customer.	[15];[69]; [82]; [78]; [83]; [30]
Employees Participation	Survey or Feedback Techniques	Conducting a survey or other feedback techniques is important to identify the need of the employees for any specific training with regard to PQ problems.	[45-47];[95];[120];[96]

and Training	Sufficient Training	Sufficient training for employees can improve the company performance in avoiding any issues with PQ in the future.	[88];[90];[17];[35];[91];[26];[78];[103];[120][35][35][30][41][41]
	Employee Suggestions	The distribution utility takes any suggestions made by its employees related to PQ problems seriously.	[120];[19];[75]; [75]
	Employee Strategies	The company involves the employees in any strategies, which make customers aware of the impacts of PQ problems.	[18]; [120]
	Appropriate Qualifications	The appropriate qualifications and experience of the employees is an important factor in improving the network.	[35]; [102]; [109]; [10]
	Employee Involvement	Solving PQ problems requires the involvement of employees at all levels; engineers, technicians, and top managers need to increase their skills and professional abilities to enable them participate in PQP implementation	[17];[103];[95];[75];[96]
Customers and Company Awareness	Technical Losses	This refers to classifying the problems, and identifying the causes of these problems; improving PQ by reducing technical disturbances with regards to the PQ definition adopted.	[15];[80];[78] [120]
	Faulty Connection	Power could be stolen through improper connections by users, settled in rural areas, to satisfy their needs.	[15];[108];[120];[19];[75];
	Mixed Users	This can help in identifying the severity of these disturbances and their sources. The identification will be based on customer load characteristics, which are crucial for the distribution utilities in dealing with customer PQ complaints	[18];[91];[44];[74];[73];[85]
	Concept of PQ	Understanding PQ definitions and their features is very important to solving PQ issues.	[33];[130];[27];[35];[34]; [123];
	Utility Faults	Utility faults due to non-regular maintenance or repair.	[90];[35];[120];[19];[75];[99]
	Illegal connection	Adopting international regulatory structures and contracts between the utilities and end users to tackle taking electricity in an illegal way.	[15];[3];[93];[74, 91];[120]; [75]
	Distribution Network Design	Characterizing distribution network installed equipment to cope with the new technologies for any future improvements, e.g. long high voltage lines with heavy or light loads.	[15];[3];[118];[87];[70]; [91];[44];[7];[106];[120]; [75];[125]

Source: developed for the purpose of this research

Table 4.5 explained these five factors, which identified are to examine the level of PQDs within Libyan distribution systems taking into account the different categories of staff who involved in PQP implementation and PQ improvements. Therefore, it is very important to classify, which one of the identified factor such top management commitment, customer satisfaction, employee training and participation and customers and company awareness is significantly different from one network to another. The support for these factors to be examined is produced firstly from the literature reviewed, and secondly from the pilot study. Each of the five factors has a number of items related to PQP in LDNs, totaling 39, which were carefully chosen to evaluate the level of implementation for every factor. This required asking the following research question:

> *Are there any statistically significant differences between the level of PQ awareness regarding employee characteristics, in terms of position, education, responsibility and experience within LDNs, and the success factors derived from the literature needed for implementation of a PQP for satisfying future needs?*

4.9 The Roadmap for PQP Framework and the process Stages

The literature review, presented in chapters 2 and 3, as well as sections 4.2 to section 4.6, stated that there is a need to develop a PQP framework roadmap. This was based on non-technical selected factors, taken from previous studies and the pilot data gathered for this study, and will allow LDNs to implement a PQP. However, this does not mean that the technical problems will disappear, but will appear less significantly, as the non-technical problems are being considered and tackled [136]. The prior questions and the proposed success factors from both the literature and the pilot stage are led to the following research question:

- *How PQP framework can be implemented, and what are the stages involved in the roadmap process and what are the outcomes should be gained after implementing PQP framework followed each process stage of the roadmap?*

The proposed framework consists of three essential phases. Thus, the framework designed to help LDNs to begin and continue with the implementation for a complete PQP. This framework is designed as a guideline for implementation of PQP in the LDNs environment. Table 4-6 explains the three phases of the proposed PQP framework. The progress of this framework and moving through from one phase to another depends on the level of awareness, knowledge, and skills gained after each phase is completed [53].

Table 4.6: PQP framework process stages developed for the purpose of this research

Framework Process	Objectives	Purpose	Requirements	Output	References
Stage One: Awareness	To determine the present level of knowledge and awareness regarding PQ among LDNs staff.	• Motivating the top management to be eager and enthusiastic to start implementing the PQP based on the staff knowledge and awareness • Understand the importance of PQP and its features	• Conducting education and awareness programmes regarding PQ on a regular basis • Encourage, support and guide the implementation teams to have a clear vision of overcoming existing obstacles facing PQP	• Top management and staff; become aware of PQP. • Understanding the importance of PQP. • Starting to prepare to implement PQP.	[88];[90];[49];[47] [101]; [26, 35, 44, 66, 79, 82, 91, 97, 100, 102]
Stage Two: Preparation	To state the actual needs of PQP, in terms of training, management planning, and commitment, and providing enough resources to implement PQP.	• Gain top management commitment and responsibility • Providing enough resources regarding the implementation of PQP • Accommodating economic growth • Involve staff at all levels; engineers, technicians and top managers • Top managers, engineers, and technicians from all departments have become aware of the importance of PQP	• Long term strategy • Conduct studies regarding PQ issues • Accommodating economic growth • Designing distribution networks • Enough resources • Equipment standards • PQ standards • Conduct PQ training courses	• Top management comprehends the need for a long-term strategy to accommodate economic growth and design the distribution networks based on each type of consumer. • Provides enough resources and PQ standards. • Both top management and staff having the same vision and willingness to solve PQDs and implement PQP. • Staff involved in PQ improvements and strategies.	[15];[80];[88];[90];[49];[47];[72];[101];[87];[70];[26, 35, 44, 66, 79, 82, 91, 97, 100, 102];[95]; [108]
Stage Three: implementation	• To investigate and solve the main reasons underlying PQ disturbances in LDNs.	• Monitor and collect PQ data • Focus on existing end user complaints regarding PQDs • Identify the real causes underlying PQDs • Considering all conditions in the contracts by taking legal action against illegal connections	• Training proper teams regarding PQP • Build PQ database • Conduct PQ measurements • Identify the difficulties and barriers facing PQP monitoring and measurement	• After the implementation of the three phases of the PQP framework, LDNs should have reached: high levels of PQ awareness, increased employee participation, and sustained PQ improvement.	[88];[90];[49];[47];[101]; [18];[26, 35, 44, 66, 79, 82, 91, 97, 100, 102]; [120]
Overall Benefits	• To identify the most significant factors, that would make a major impact on PQ improvement in the Libyan distribution grids after implementing PQP.	• Reaching a high level of skills and experience regarding PQP implementation • Increase the awareness level to practice and perform PQP practically with great attention from top management.	• Awareness, preparation, and implementation	**Increasing** end user awareness, **increasing** their satisfaction, **improving** PQ performance, **reducing** end users' Complaints, **monitoring** and measuring PQ disturbances, **providing** PQ diagnosis systems and databases, **reducing** the huge losses through PQ costs, **increasing** top management awareness, **increasing** employee skills and awareness, **increasing** PQ training courses, and **providing** strategic planning.	[80]; [63]; [72]; [93]; [18]; [71]; [79]; [78]; [109]; [103]

Source: developed for the purpose of this research

As noted above, phase one is designed to increase the level of awareness, while phase two involves preparation for PQP, which contains seven crucial requirements. Phase three, which is the implementation, is designed to prevent the outstanding problems from phases 1 and 2 from recurring, by determining both the weaknesses and obstacles; the aim is to reach a high level of PQ. LDNs are among those systems facing poor PQ, as in most under-developed countries. Unfortunately, the analysis of the quantitative and qualitative data in Chapters 6 and 7 showed that in the last two decades, LDNs have not implemented PQPs [133][138]. This is mainly because no PQ department has so far been established, to influence the measurement of PQDs. This absence of a PQ department is due to lack of awareness on the part of top management regarding the importance of PQ. As a result, LDNs have faced very significant difficulties in implementing PQP. In addition, lack of PQ awareness has led LDNs to face twelve significant difficulties through not implementing PQP, as was explained in Chapters 6 and 7 [14][130]. Therefore, the PQP framework is designed to solve PQ issues in distribution utilities, having similar circumstances as LDNs. Therefore, the implementation of PQP is influenced by top management's awareness, which must now move from studies and recommendations, to practice. This framework is designed as a guideline for the implementation of PQP in the LDNs environment [139]

4.10 Summary

The main conclusions of this chapter presented the key findings of this research, which clearly indicate the poor implementation of PQP in LDNs. As a result, lack of PQ awareness has led LDNs to face twelve significant difficulties due to lack of PQP implementation. According to qualitative analysis, this gap will continue if PQP barriers are not tackled. In LDNs, empirical research was conducted to categorize and underline the barriers to, and benefits from, a PQP in the context of a distribution utility, which has not implemented PQPs in the last two decades. The knowledge and results obtained from this study will guide LDNs in implementing a PQP framework, including all departments and staff, directly responsible for remedying PQDs, in tackling any PQ problems by setting up clear and long-term strategies, with crucial objectives and proper knowledge of barriers. Therefore, the implementation of a PQP requires great attention from top management to assist the distribution networks in achieving their goal of offering and providing a PQP in practice. The literature review helped the researcher to understand the different barriers to PQP implementation, and the expected benefits arising from the PQP. However, without solving the non-technical problems, technical problems will only be aggravated. Therefore, paying more attention, and concentrating on these issues, will lead to resolving PQ events, and the distribution networks' efficiency will be improved.

Furthermore, one of the main challenges in implementing a PQP is to link all the difficulties with the objectives and strategies set by all departments. Hence, the implementation difficulties should be regularly assessed to identify the hidden reasons associated with, and causing poor implementation. Thus, without adequate knowledge, awareness, planning, designing, preparation, training, PQ standards, clear strategy, and most importantly, the support of top management for this programme, PQDs will never end and their severity will affect all consumers. Other conclusions that have emerged from this chapter are as follows:

- Previous PQP frameworks, proposed in the literature, gave different conclusions, which were not beyond recommendations. However, the developed framework roadmap focused also on implementing the PQP in practice as was explained.

- Analyzing and tackling the multiple levels of existing PQP barriers is one of the significant requirements, which leads to overcoming any outstanding difficulties for long term solutions on a regular basis.

- The contribution of this study goes beyond the developed framework stages, requirements and implementation, and shows how they lead to improved PQ in LDNs as explained in section 8.4.2.4. Relatively few similar studies were conducted globally, concentrating on technical rather than the non-technical issues. This is seen as significant compared to previous studies, and so understanding and interpreting their impact on PQ is important, as is how the distribution network can improve PQ after tackling these issues.

The next chapter (5) presents the research methodology used to examine the implementation of a PQP framework in LDNs.

Chapter Five: Research Methodology

5.1 Introduction

This chapter explains the methodology followed in this research, which is an essential element in achieving the research aim, i.e. to validate the PQP framework developed for LDNs. Choosing the appropriate methodology is critical in addressing specific research questions, in that collecting primary data for the entire framework relies on the type of methodology, strategy and approach. The research questions and associated aims and objectives were designed to investigate and determine why LDNs have not implemented a PQP to evaluate PQ, before delivery to customers. At the same time, the survey focused on the future of PQDs at LDNs, in line with any expected increases in demand. The survey questionnaire was prepared based on main factors, derived from the extensive literature review and LDNs data. On the other hand, interview questions were formulated based on the main conclusion from the survey findings, and the updated literature review.

In this chapter, Section 5.2 discusses deductive and inductive research approaches, and why a mixed approach was chosen in this study. Section 5.3 presents positivism and interpretivism as research philosophies, and the reason why both research philosophies can be merged to explain complex research problems. Section 5.4 describes the research design and its process stages, while Section 5.5 identifies quantitative and qualitative research strategies as the more appropriate for this study, in answering the research questions and meeting the objectives. Section 5.6 describes the combination of research methods employed in this research, in what is known as triangulation, and their strengths and weaknesses. Section 5.7 presents the data collection methods used, including secondary and primary data collection methods. Section 5.8 discusses the selection of departments that participated in the qualitative data collection. Section 5.9 illustrates, in detail, the selection of quantitative survey population and sample frames development. Section 5.10 explains the methods of analysis for both quantitative and qualitative data and their requirements. Finally section 5.11 summarises the whole chapter.
Therefore, this chapter addresses the methods used for gathering data and subsequent analysis to answer the following research questions:

1. *What is the actual overall level of the PQDs, in terms of measurements, solutions and implementation regarding PQ awareness?*

2. *What are the current state of PQ awareness and efforts regarding the implementation of PQP in LDNs?*

3. *What are the most significant success factors of implementing a PQP regarding PQ awareness within LDNs in EGCOL?*

4. *Are there any statistically significant differences between the level of PQ awareness regarding employee characteristics, in terms of position, education, responsibility and experience within LDNs, and the success factors derived from the literature needed for implementation of a PQP for satisfying future needs?*

5. *What are the difficulties and barriers facing LDNs in implementing PQP?*

6. *What type of PQP implementation model framework should be developed in order to guide LDNs in improving PQDs and what are the requirements involved in the implementation of PQP?*

7. *How PQP framework can be implemented, and what are the stages involved in the roadmap process and what are the outcomes should be gained after implementing PQP framework followed each process stage of the roadmap?*

5.2 Research approach

Saunders suggests that before choosing the methods for data collection, four aspects should be carefully considered, i.e. *"research approach, research philosophy, research design and research strategy"* [140]. According to Singleton and Straits, the two research approaches are quantitative and qualitative, where each uses various techniques and procedures to answer different or specific research problems, objectives and questions [141] .

A quantitative approach concerns researches dealing with respondents, in studying samples' experiences and background on specific phenomena. A quantitative research is deductive, and is useful for testing theory. It is based on positivism and objectivism, and relies heavily on numerical and statistical data [142]. Meanwhile, a qualitative approach concerns investigations into deeper details of phenomena, including attitudes, opinions, thoughts and behaviours. It relies heavily on words and verbal responses from participants. A qualitative research is more subjective, and is based on interpretivism and constructionism; therefore, it produces results from words, rather than numbers, such as interviews. According to Cohen and Manion, quantitative and qualitative research approaches are the most commonly used in different fields [143].

Some research methods scholars emphasised that the steps involved in the research process rely significantly on the type of research approach chosen [143-145]. As presented in chapters 2 and 3, PQP is a new phenomenon, specific to LDNs utilities. PQP involves different multidisciplinary factors due to the variety of PQ problems, such as management commitment, employee knowledge level, and awareness and understanding regarding PQ. Therefore, in order to achieve the expected level of PQP framework, there should not be any complexity in investigating all the factors directly related to it, based on the appropriate research approaches chosen. Hence, it is essential to understand the PQP framework issue, and clarify the factors, affecting its implementation in LDNs, by using 'what', 'why' and 'how' questions, which can be obtained by applying the inductive approach.

5.3 Research philosophy

It is very important to identify the most appropriate research philosophy that helps answer the research questions for the phenomena being studied. The research philosophy chosen in this study combines positivism and interpretivism. According to Saunders, the two research philosophies can be merged to explain unique research problems, which lack sufficient information. Indeed, Dewey confirms that both inductive and deductive philosophies can be used in one research study, which he described as *"double movement of reflective thought"* [146].

In response, positivism is the first appropriate philosophy chosen for the context of this research due to the availability of explanatory variables for measurement. Section 4.6 explained the conceptual framework, including the four main factors of PQP model framework, namely awareness, resources, management attention and PQ involvement, which determine the key success factors and requirements for PQP framework implementation. All these factors and variables can support the knowledge of why the positivism philosophy is applied in this research. Therefore, the deductive approach attempts to explore a relationship between the set of variables and operationalisation of concepts to clarify and test the validity of theory due to the importance of generalising data, which can be controlled and structured by the specific number of samples involved in data collection [140].

In addition, an interpretivism research philosophy is applied in this research as well. The motivation for choosing the interpretivism approach is because PQP has different multidisciplinary factors, due to the variety of PQ problems, such as management commitment, employee knowledge level, end user awareness and understanding, and awareness regarding PQDs as explained in Chapters 2, 3 and 4 on the conceptual PQP framework. Each of the different multidisciplinary PQP factors has its own influence on implementation, which allows the researcher to consider interpretivism as the second appropriate research philosophy to understand and justify barriers to implementing a PQP, due to its exploratory nature, in asking "why and what" questions. Therefore, the inductive approach attempts to explain the significance of participants involved in specific research issues by understanding the research perspective on the phenomena and by collecting qualitative data, through interview, group discussion or observation. It is also flexible allowing modification or removal of some of the research construction through the research procedure, and because it pays less attention to generalisation [140]. Table 5.1 explains the three research philosophies, which are positivism, critical philosophy, and interpretivism, and their influence on this study.

Table 5.1: Different research philosophies

Research philosophy	Explanation
Positivism	• Bryman and Bell have mentioned five categories of positivism, which are phenomenalism, deductivism, inductivism, objective and scientific statement [142]. • Positivism is one of the philosophies used in this study under the form of deductive (quantitative) and inductive (qualitative), which investigate most factors associated with PQP framework implementation.
Critical	• Critical philosophy is used more in social studies, such as in historical, cultural and political studies, due to its power and impact on social and economic changes [147].
Interpretivism	• Discovering patterns, meanings and thoughts that can contribute to providing the exploration of phenomenon reality of knowledge, and reflect the sample beliefs [148]. • Understanding both the nature and complexity of the research problems through interpretivism research [148, 149]. • The contexts of the PQP factors, requirements and roadmap process can be understood by interpretivism research due to their influence on one another [150].

5.4 Research Design

According to Blaikie, research design is *"a technical document that includes integration and justification statements, which is developed as a guide or plan to carry out a research project"* [151]. On the other hand, Yin defines research design as *"an action plan for getting from here to there"* [152], by which *"here"* means the decisions that need to be made at the initial stage of the research proposal about the research questions to be answered, and *"there"* means that the conclusions, findings, and outcomes gained in answering these questions.

Boris et al. also defined research design as *"the plan, structure, and strategy of investigation to obtain answers to the research questions"* [146]. This means the research design must meet the research questions' requirements, in order to obtain the right sampling characteristics and select the appropriate methods to be used to collect data to answer them. This procedure depends on the type of strategy chosen to collect and analyse the primary data.

Therefore, research design represents the full procedure for data collection and analysis [142]. Bell and Bryman suggested that a research process is reflection of what type of priority dimensions are set to address the formulated research questions and problems, and to clarify the nature of organisation and sampling, from where the data will be collected. Creswell asserted that successful research results depend on choosing the right research design and following the research process steps to completion [153]. The research design and process for this study are shown in figure 5.1.

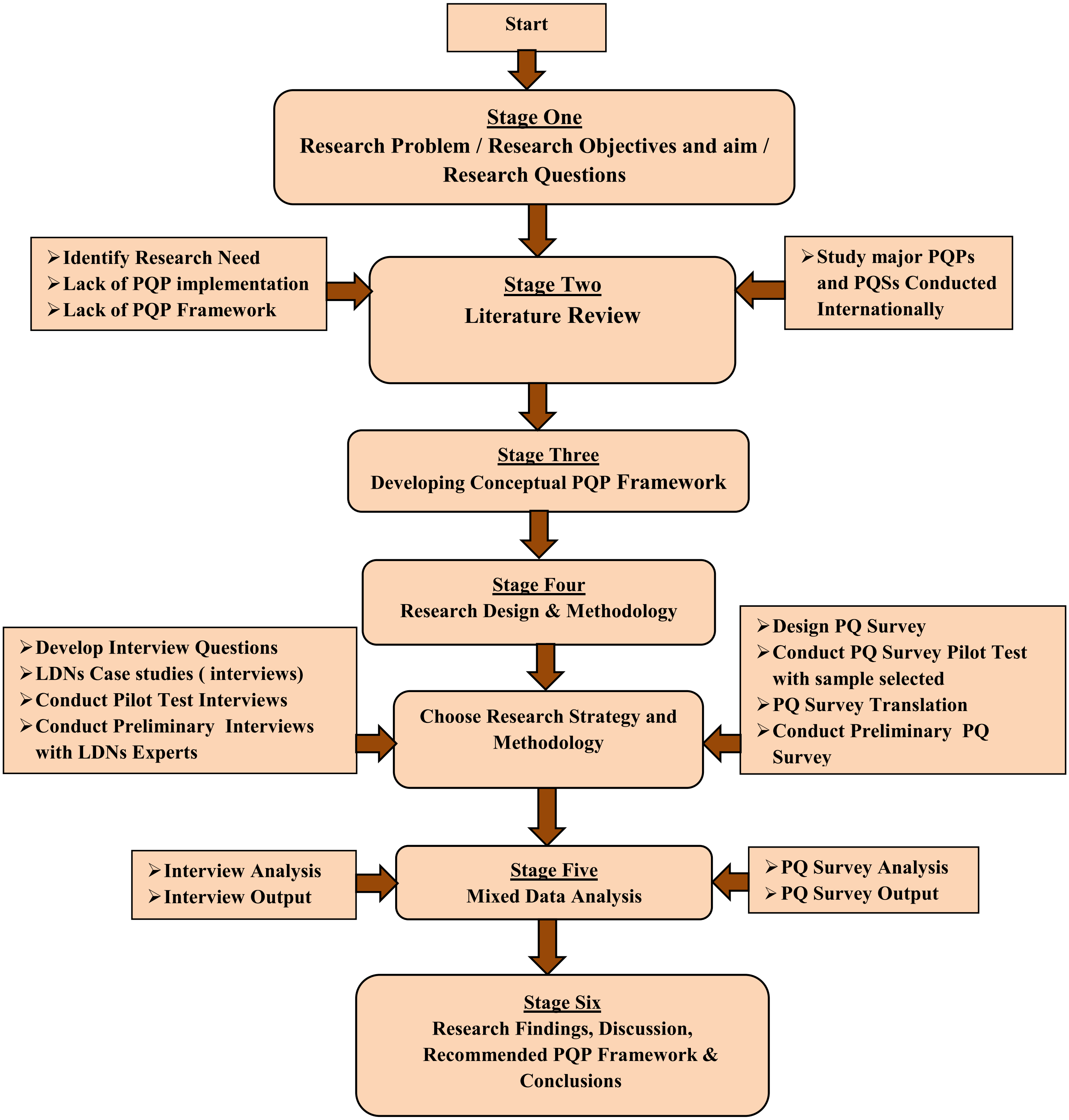


Figure 5.1: Research Design and Methodology Stages Flowchart

5.5 Research Strategies

Sections 5.3-5.4 clearly explained the research approaches, philosophies and design identified for this research. According to Robson, "*The research strategy and the processes or procedures employed, must be appropriate for the questions that the researchers want to answer"* [154].
This study has developed the research strategy to achieve superior outcomes and findings. This is done to support and validate the survey instrument designed for statistical data and qualitative analyses from the samples selected for data collection. This study uses two methods, i.e. *"quantitative and qualitative"* as appropriate strategies to answer the research questions, and meet the objectives by gaining reliable and valid information. The research strategies applied in this study address each research question as follows:

Question 1 was answered by conducting an extensive literature review of all the literature related to PQP measurements, solutions and implementation. This helped the researcher understand the overall level of PQP from different studies conducted in various electrical utilities worldwide, and gauge the experience in implementing PQP, in order to help overcome PQDs and hence, implement PQPs in developing countries.

Question 2 was answered by choosing an appropriate PQ survey. Questionnaire surveys have become one of the appropriate methods used by various PQ experts and professionals to address PQDs and implement PQPs. **Question 3** was answered through PQ survey findings and supported by 44 face-to-face semi-structured interviews conducted with professionals, experts in LDNs, and staff in four departments, including head managers, engineers, technicians and employees, to state the difficulties and barriers facing LDNs in implementing PQP and to make the developed PQP framework more valid.

Question 4 was answered by examine the effect of the critical success factors on PQP implementation and supported by multiple techniques used to measure the questionnaire instrument reliability and validity regarding Cronbach's alpha and factor loading.

In addition, **question 5** was answered by employing a one-way multivariate analysis of variance (using SPSS V 18.01) between groups, to investigate if there are significant differences between the level of PQ awareness regarding the success factors derived from the literature for implementation of PQP within LDNs and employees' work position, education, responsibility and experience which explained in details in section 6.8.

Question 6 was answered by analysis of various empirical PQ surveys, case studies and reports that measured and validated PQP implementation. While **Question 7** was answered by validating the conceptual PQP framework developed for this research, which is supported by the findings from 397 respondents of the PQ survey questionnaire, and 44 face-to-face semi-structured interview outcomes, to see if the developed PQP framework suits LDNs. It was also answered based on the researcher's experience and the study findings by considering the prior stages in implementing the developed PQP framework.

On the other hand, the researcher attended national and international conferences, and met experts in the field of power systems, to exchange experiences and discuss the most up-to-date topics in power engineering, mostly regarding the latest issues and technologies developed that are driving the move towards competitive, sustainable and secure power quality in the less developed countries and the world. The researcher also attended training courses and development sessions at Brunel Graduate School in order to understand all the tools and techniques that he adopted and followed in his research, which helped him to get many benefits and skills to develop the framework suited to the LDNs context.

5.6 Research Methods Employed in this Study

As mentioned in sections 5.3-5.5 this study adopts a mixed approach using both quantitative and qualitative methods to achieve the research objectives. These are explained in the following.

5.6.1 Quantitative Method

The quantitative method is used to generate numbers data, which can then be analysed statistically to determine the whole idea of the problem by estimate and test parameters from enormous number of samples. Babbie defined the quantitative method as *"The numerical representation and manipulation of observations for the purpose of describing and explaining the phenomena that those observations reflect"* [155]. Quantitative methods are usually conducted in the form of surveys, which allow researchers to gather the required data to test a set of assumptions. According to Tanur, the survey is defined as *"gathering information about* *the characteristics, actions, or opinions of a large group of people, referred to as a population"* [156]. Survey questionnaires aim to collect data to test, measure or estimate attitudes, experiences, knowledge, beliefs and preferences from individuals or a large population. Surveys or questionnaires should be designed carefully in order to provide useful information and evidence regarding the issues being investigated. Conducting surveys will depend on the availability of time, resources and a budget, which will contribute to providing the explanation of assumptions reflecting the sample behaviour. Therefore, quantitative surveys will take a deductive form by asking the *"how questions form"*, which support building and testing hypotheses or theory due to the ability in addressing complex situations and rich explanation of study [157]. Some scholars in the field of research methods have classified some characteristics of the quantitative research [152][158, 159] as follows:

- The aim of using a quantitative strategy is to enable the authors to predict, clarify and comprehend specific phenomena that are developed from theory.
- It will help the researcher to find what he/she is looking for in investigating particular phenomena and by focusing objectively rather than subjectively.
- All variables are formulated carefully from the literature review, before collecting data from the specific samples, which should be statistically appropriate and reliable.
- It gives the ability to produce charts, graphs and figures, and it is easy to measure both reliability and validity.

Therefore, surveys are not only used in social sciences but are also widely used in the field of electrical engineering and power quality. They are used to collect data to measure the impact of PQDs and identify the factors beyond PQP implementation difficulties. Quantitative data is presented in tables, charts and figures in chapter six to justify why it is chosen in this study. PQ surveys were completed by LDN staff in three distribution networks including head managers, engineers, technicians and employees. The survey questions were designed to identify the current level of knowledge, awareness and understanding of the participants regarding PQP problems, barriers and difficulties.

5.6.2 Qualitative Method

On the other hand, qualitative method is used to provide deep and rich data by interviewing specific samples of populations to gain significant insights about the problems and factors underlying a phenomenon. Qualitative data is explained more clearly in the form of quotations, figures and tables presented in chapter seven to justify why it was chosen in this study. The qualitative method is applied in the form of interviews and case studies, which allow the researchers to gather the required data and information from relevant people or individuals based on their experience and opinions about the phenomenon being investigated. Strauss and Corbin defined qualitative research as *"any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification"* [159]. Qualitative research is more subjective, and concerns words rather than numbers. Bell and Bryman stated that *"qualitative data is richer, time consuming and less generalized"* [142]. Qualitative data would help the researcher to discover patterns and thoughts, which will contribute to the exploration of a phenomenon, and reflect the sample beliefs. Miles and Huberman described reliability and validity in qualitative research is similar to that in quantitative research [144]. Therefore, one of the considerations that the researcher should pay attention to is to allow adequate time with interviewees to get as much reliable data as possible [146]. This will enable the researcher to understand both the nature and complexity of the research problems. Some scholars such as Miles and Huberman, Cornford et al., and Creswell [144][153][160] emphasised that as the qualitative data is more rich in words, hence; the researcher needs to take into account five important steps during the interpretation process;

- Ability to control data collection process
- Ability to deduct needed data
- Ability to repeat required data for triangulation
- Ability to generalise.
- Ability to control analysis stage

5.6.3 Combining Quantitative and Qualitative Methods

The research methods applied in this study address each of its questions; therefore, both quantitative and qualitative methods are used as this study, which is the first conducted in Libya to assess PQP level. The difference between quantitative and qualitative research is that quantitative research deals more with numbers, in which data can be gathered, controlled and then analysed in an attempt to explain the correlation between sets of factors for the phenomenon being studied. Whereas, qualitative research deals with data that attempts to explore the form of interrelating factors in the phenomenon by investigating it deeply, which leads to making it more understandable [161]. Silverman mentioned that the use of case studies has increased, with extensive use in different fields due to the descriptive data that helps researchers to understand and describe particular phenomena and the factors beyond them [162]. Nonetheless, Aguinis argued that using one research method to provide more information and sufficient explanation about knowledge and new phenomenon not widely being investigated would not be helpful [163]. Therefore, Stake highlights that three key distinctions should be always considered between quantitative and qualitative research, which are:

- "Explanation and understanding".
- "Personal and impersonal role for the researcher".
- "Knowledge discovered and knowledge constructed".

Moreover, Crompton and Jones are cited by Bryman as stating "*it is difficult to study organisations without using both methods"* [164]. They emphasised that the researcher investigates new phenomena that require additional explanations from individuals participating in a study to provide reliable conclusions. Indeed, Bryman identified both quantitative and qualitative methods' strengths and weaknesses [165]. Blaikie mentioned that *"there are no issues to use combination of two methods quantitative and qualitative due to their interpreted within a consistent ontology"* [151]. However, Miles and Huberman stated that applying both methods in one study is called *"triangulation"*, where each method's strengths will overcome the other's weaknesses [144]. Moreover, one of the benefits of mixed methods is the ability to validate quantitative analysis results by adding additional information from the qualitative analysis findings or vice versa. Kaplan and Duchon also emphasised that conducting one research approach cannot deliver the richness of data needed to understand the research context deeply. Therefore, to understand the whole context of PQP implementation in LDNs, this necessitated that the researcher apply both methods to obtain the intensive and extensive data needed, which could then be analysed to evaluate the real level of PQ. It also makes the developed framework more reliable and valid.

The researcher applied both research methods in this study, in the form of PQ surveys (quantitative) and semi-structured interviews (qualitative). The aim is to gather the best and most reliable data for the investigation being carried out on PQP framework implementation in LDNs, including knowledge, opinion, experience, thoughts, and attitudes from LDNs staff regarding PQP. Therefore, PQ survey questionnaire was conducted to assess the current level of PQ and the implementation level of PQP from LDNs staff involving in PQ improvements. The researcher chose to conduct semi-structured interviews based on the survey findings by taking a random sample from the questionnaire respondents to collect more information about the implementation of PQP framework.

Table 5.2: Classifications of quantitative and qualitative research methods

Dimension	Qualitative	Quantitative
Concepts	Research development	Operationalized
Approach	Unstructured, driven and open	Structurally driven
Relation between field and researcher	In-depth investigation	no deep investigation
Relation between respondent and researcher	Close and direct contact	Indirect contact
Findings	Deep and rich data	Can be generalised to large population
Analysis	good insight into the persons' experience and behaviour and easy to recognised into analysis	Easy to analyse numerical form and high level accuracy; allows analysis to be presented graphically

Source: Bryman and Bell 2007 [165]

Table 5.2 explains that the major purpose of combining two methods is mainly to improve both the reliability and validity of the data collected. Such data is mainly sought to answer the designed set of research questions [166].

5.7 Data Collection Methods

There are different methods of data collection conducted for this study. According to Yin, Bryman and Irani, choosing several different procedures, such as documentation, archival records, reports, case studies, survey questionnaire and interviews for data collection will support the outcomes of the research being investigated, as the validity and reliability is increased [145][165][167]. Oates stated that each data collection method has some strengths and weaknesses, and pointed out that a *"data generation method is the means by which you produce empirical (field) data or evidence"* [168]. The two types of data collection methods used in this study are described as follows: the secondary data were collected from documentation, books, reports, journal article and archival records, while primary data collection used methods like case studies, survey questionnaire, and interviews.

5.7.1 Secondary Data Collection Method

The researcher used different sources for collecting secondary data in order to produce sufficient background and information for PQP framework implementation. These include several PQ books, conference proceedings, journal articles, and on-line databases, such IEEE, Science-direct, Scribd, Scirus, EPRI and reports. All these resources were used to determine PQP framework implementation factors to be tested and investigated in the PQ survey questionnaire and interviews, in the primary data collection stage. Moreover, secondary data collection continued in parallel with the primary data collection.

In addition, previous documents in the field of PQ play very important roles as secondary sources of valuable information [169]. The types of documents reviewed, included seminars, presentations, technical reports, annual reports, journal articles and theses. These were very significant, as the researcher determined the initial aims and objectives of all these resources, which then led to the research questions design.

On the other hand, archival documents and records were also part of the data collection. As a result, both national records of PQ surveys and statistical data were kept by different electrical distribution utilities, regarding PQDs and PQP. These data were used to achieve good understanding of the lack of PQP framework implementation, as well as PQDs solutions [169]. The researcher was initially permitted to check archival records regarding PQP measurements conducted in LDNs before this study took place. Table 5.3 shows some of the documents and archival records studies, which used both quantitative (questionnaire) and qualitative (interview) methodologies.

Table 5.3: Different studies and their methodologies influencing this research

Author (s)	Research question and aim of the study	Subject and topics	Methodology	Reference
Dorr and Melhorn (2000)	To monitor PQ levels at residential customer power entry points.	Convenience and completeness for PQ management	Qualitative/ telephone interviews and Quantitative / instruments)	[102]
Grady and Noyola, 1992	To study the impact of PQ problems on industrial and commercial customers for the successful implementation of a mitigation strategy in a PQP.	Understanding and visibility	Qualitative / case study and Quantitative /questionnaires	[73]
Chung, et al. (2007)	To develop a PQ diagnosis system to measure PQDs at the end user's point of connection.	PQ diagnosis system	Quantitative/ experiment	[68]
Lee and Hoffman (2009)	To describe a vision for a holistic distribution power supply and delivery chain regarding PQ within smart grid operation and planning.	Electric power industry delivery infrastructure	Qualitative/ review literature of power system industry in the USA	[87]
Targosz and Manson (2007)	To investigate the industrial sector's share of non-residential energy users on the consequences for European Industry of poor PQ.	PQ awareness	Qualitative/ 62 interviews in 8 EU-countries within 16 industrial, Quantitative /questionnaire in 7 languages	[89]
Forsten and Key(2005)	To develop the basis and guidelines for development of measurement metrics for each of the SQRA elements at the level of the electrical distribution systems.	Guidelines for PQ SQRA improvement	Qualitative/ re-analysis literature reviews, the existing standards and Quantitative/surveys	[75]
Salam and Nasri (2005)	To conduct a PQ survey in Egyptian industrial zones.	Strategic issue	Quantitative/ monitoring	[109]
Ortiz-Rivera (2004)	To study PQDs in commercial buildings in Puerto Rico and find the significant factors leading the issues to be compared to other studies conducted in other distribution utilities.	Power supply infrastructure	Qualitative/case study Quantitative/ surveys	[11]
McGranaghan, et al.(1999)	To understand the existing levels of PQ provided to consumers and to determine the levels of PQ that can be reasonably expected.	Evaluating economics of PQ improvement and PQ Understanding	Qualitative/case study Quantitative/ instrument and surveys	[7]
Kottick (2008)	To present a statistical analysis of preliminary measurement results regarding a large majority of customer complaints of PQ.	PQ monitoring system	Quantitative/ monitoring and surveys	[69]
McNulty and Howe	To determine whether or not there was a	PQ awareness and	Qualitative/case study, re-	[49]

(2002)	significant PQ issues in Massachusetts and the extent to which renewable energy technologies could play a role in remedying PQDs.	education	analysis of existing PQ datasets, and interviews with 16 large business customers.	
Barnard & Van Voorhis (2000)	To investigate utility-based PQPs: domestic and industrial rather than any type of quantitative data.	PQPs awareness	Qualitative / 70 interviews with managers and engineering	[15]
Meyer, et al.(2005)	To describe a method of PQ surveying in distribution networks by several performance indices.	End user structure and behaviour.	Quantitative/ measurements in 8 sites	[91]
Orillaza, et al. (2006)	To present the development of models and a methodology for the segregation of PQ distribution system losses.	Strategies	Quantitative/ measurements in 119 electric utilities	[112]
Freeman , et al.(2009)	To examine PQDs in distribution systems based on the "local delivery" concept, considering the range of factors causing the issues.	Distribution networks infrastructure	Quantitative/ monitoring and surveys	[74]
Howe (2007)	To provide information and tools to facilitate the implementing of PQP utilities by regulators and end users.	PQPs implementation	Qualitative / case study individual facility level analysis.	[113]
Deshpande and Chitre (2009)	To develop a system where knowledge regarding PQP must be shared as a team project by manufacturers, utilities, government and end users.	PQPs awareness, guidelines , and implementation	Qualitative / study of existing power supply infrastructure.	[100]
Bruce (2007)	To provide PQ for the21st century needs effort and requires extensive education programmes to increase the level of understanding.	PQPs strategy and recommendations	Qualitative/case study Quantitative/ PQ surveys	[80]
Grebe, et al. (2012)	To conduct different PQ seminars regarding the implementation of PQP around the USA's distribution utilities.	Education and awareness programmes	Qualitative/case studies, PQ seminars	[95]
Negnevitsky, et al. (1997)	To obtain a clear picture of the current problems of PQ supply in Tasmania by conducting PQ monitoring and administering a questionnaire.	Management awareness	Quantitative/ PQ surveys in 26 industry	[36]
Hannan, et al. (2010)	To identify the factors leading to PQ flicker, this represented 57.5% of all the PQ disturbances that occurred in industrial sites in Malaysia.	PQ guidelines and awareness	Qualitative/ industrial data and Quantitative/ PQ questionnaire in 26	[88]

			industries	
Eberhard (2011)	To allocate responsibility for resolving PQ issues in Croatian distribution utilities.	Customer satisfaction and economic impacts	Quantitative/ PQ survey in 1,400 sites in 8 EU-countries , Qualitative/ case study and interviews in EU-25 countries	[78]
Winkler, et al. (2006)	To determine the most critical factors causing PQ issues in German utilities' distribution systems.	Consumer structure and behaviour.	Quantitative/ PQ surveys in 8 distribution utilities	[114]

5.7.2 Primary Data Collection

5.7.2.1 Case Study

The aim of this research is to study the implementation of PQP framework, and the obstacles and barriers faced by LDNs utilities in implementing a PQP. In order to achieve these objectives and develop an appropriate PQP framework for LDNs, two resources were used. First, an extensive literature review to understand the barriers and benefits of implementing a PQP as explained in chapters two and three. The main purpose of the PQP framework developed is to guide LDNs, which have not previously implemented PQP, to improve PQDs. Secondly, this framework will enable LDNs to step forward, to tackle any PQ problems by setting a clear and long term strategy, with the most crucial objectives, by involving all departments and staff, directly related and responsible for improving PQDs. Oates suggested that using more than one data collection method can lead to understand the complex relationship between the PQP factors identified in sections 4.6-4.8 [168]. The methods used to explore the complex relationship between the PQP factors were PQ survey questionnaire, and face-to-face interviews to collect the data from LDNs staff in four departments. Therefore, LDNs were chosen as the case study for this research, so as to investigate in depth PQP implementation barriers.

This research focused on three distribution networks only, as shown in Figure 3.9. The distribution networks chosen included western, eastern and southern distribution networks, and are clearly described in chapter three. The three networks were selected due to the severe PQDs and also due to the mix of end users connected to these networks. Most of the users connected to the western distribution network are residential and industrial users, while agricultural and residential users dominate in the southern distribution network, with mostly industrial and agricultural users in the eastern distribution network. However, the three distribution networks' share many conditions, in terms of infrastructure not designed to meet the increases in demand due to economic development and the rising population demand for electricity. Also, significant lack of awareness and a large number of non-linear equipment utilised by end users are factors that have caused PQDs, which lead end users to connect to these networks illegally. Therefore, similar circumstances substantiated the research by allowing straightforward comparative analysis between the three distribution networks. Hence, it is possible to reveal the similarities and the factors underlying both PQDs and PQP. In addition, the three distribution networks are located geographically in different parts of the country, as shown in Figure 3.9. However, Figure

3.10 shows the classification of the three networks, and why they were chosen for data collection; each distribution network is discussed and described separately. This helps in classifying the problems, and identifying the causes of these problems, and then by gathering and studying the three networks aids in understanding the specific requirements of the technical and non-technical elements of PQP implementation.

In response to these elements, the PQ survey was conducted at the three LDNs, west, east and south, to investigate and determine why LDNs have not implemented a PQP to evaluate the power supply before delivery to customers. At the same time, the survey focused on the future of PQDs at LDNs, in line with any increases that they are expecting. The survey was prepared based on main factors, which were derived from the literature review, and the LDNs archived data.

5.7.2.2 Questionnaire

Questionnaire surveys are one of the data collection methods used extensively in different fields of science for a long time. Previous studies on PQ issues and PQP implementation had used survey questionnaires using the Likert scale to measure PQ levels across electrical distribution utilities. The aim of this study was to develop a PQP framework for evaluating PQDs in two ways. Firstly, to identify the most significant factors that would have a major impact on PQ improvement in LDNs to facilitate PQP implementation. This framework encourages and guides implementation teams to have an obvious and clear vision of how to prevent existing obstacles from reappearing in different forms, leading to improvements in the long-term. Secondly, this research aimed to investigate the extent to which end users and staff in LDNs are aware of PQ. This can determine the PQ levels from perspectives of both end users and LDNs staff, and so create greater understanding and awareness. Therefore, one of the main challenges in implementing PQP is to link all the difficulties with both objectives and strategies. Furthermore, the implementation difficulties should be assessed regularly, to identify the hidden reasons associated with poor implementation. Therefore, it is very important to classify the causes of PQ issues into two categories, namely technical and non-technical problems. Therefore, the methodological approach was to use a PQ survey questionnaire to test and measure a number of PQP variables drawn from the literature review. Figure 5.2 shows the flowchart of the study, using a PQ survey questionnaire.

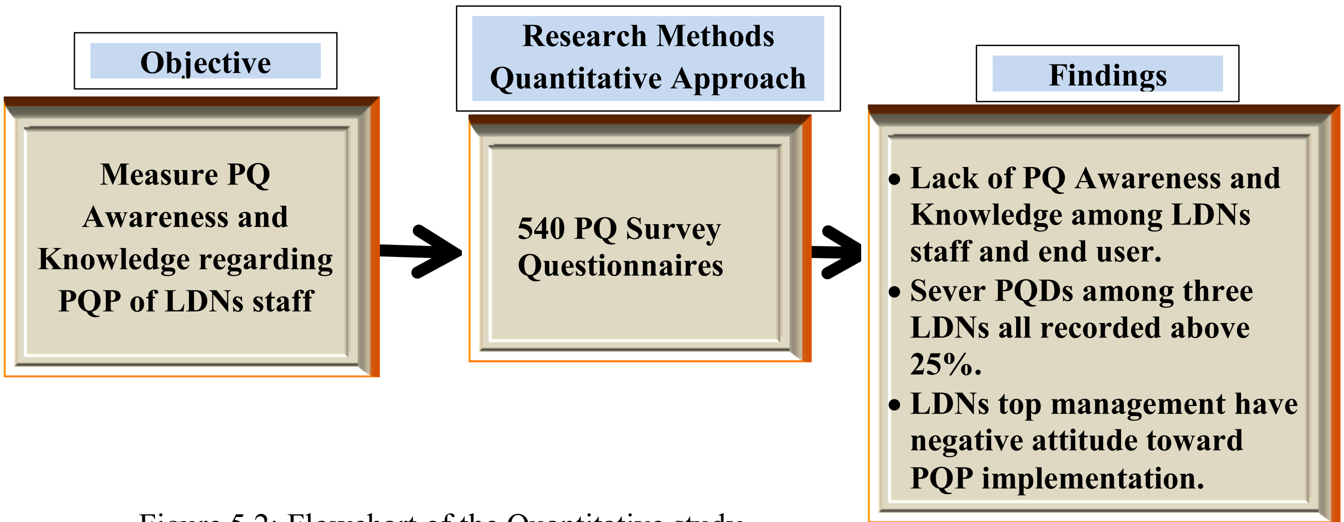


Figure 5.2: Flowchart of the Quantitative study

According to Oates, one of the advantages of a questionnaire is that it can be administered in different ways, such as e-mail, Web, post or via phone without the attendance of the researcher [168]. For this study, the PQ questionnaire surveys were sent in a closed envelope to each department head, which then were collected within a specific period agreed by the researcher and each participant. The researcher considered this approach to be suitable to the nature of the problem addressed in this research. Hence, the PQ level was assessed by the questionnaire survey instrument distributed to a large number of LDNs staff, including engineers or technicians involved in PQP implementations. The aim was to explore their observations and opinions regarding the significant effects and consequences of PQDs for end users. This study adapted and prepared a Likert scale survey, as shown in appendix A to provide the initial understanding and analysis of PQP implementation level in LDNs in the form of quantitative data.

5.7.2.3 Semi-Structured Interview

The interview is the second data collection method used in this study. Its underlying interpretative philosophy was explained in section 5.3, and is the reason why it was chosen in this study. The interview questions were prepared to investigate the qualitative perspective of PQP implementation, as shown in appendix B. According to Denzin and Lincoln, the interview is the key data collection technique in qualitative research [170]. Nachmias and Nachmias also stated that "*The interview is a face-to-face interpersonal role situation designed to elicit answers pertinent to the research hypotheses*" [171]. Furthermore, Frey and Fontana indicated that there are different styles of interview that can be used for data collection, such as telephone interviews, and group interviews, discussion and face-to-face [172]. Hannabuss emphasised that the main purpose of conducting interviews is to enable the researcher to collect data from participants, and making direct observations verbally. He also stated that the physical interaction, in face-to-face interviews, between the interviewee and interviewer, and spending more time on the essential questions to discuss complex phenomena can be revealing [146][173]. There are many advantages to interviews, but the disadvantage can be cost and time, if the participants are not in the same place, which requires the interviewer to make long journeys, which are time consuming [146].

Yin stated that *"interviews of this nature tend to reach a point of data saturation after interviews with about eight individuals"* [167]. Indeed, 44 face-to-face semi-structured interviews were conducted in this study. This large set of interviews helped the researcher to reduce the data bias problematic in qualitative research of this nature, and increase the reliability and conformability of the research findings [161] . The interview questions were formulated based on the updated literature review and the findings of the quantitative data. These were prepared in advance in order to cover the most of the concepts including difficulties, obstacles and barriers that have been identified as preventing the implementation of PQP in LDNs.

However, the samples were selected based on the participants' wishes to participate in further research in the same study, indicated by writing down their contact details. The researcher then contacted them in advance before conducting the second phase of data collection to manage the time and plan for each individual separately. Fortunately, most of the individuals, who the researcher contacted for interviews, were positively disposed, and represented different work responsibilities, experiences and positions, which included head managers, middle managers, engineers, technicians and employees. The departments from which interviewees participated were planning, distribution, training, and customer service. The researcher chose these departments due to their direct relation and involvement, to discuss in depth and gain insight into issues of PQDs assessment and PQP implementation. The interviews in each department were scheduled and organised according to the nature of the research question, and to collect and manage the data necessary for the research. Cornford and Jarratt classified interviews into three types, namely structured, semi-structured and unstructured interviews. The key difference between them is the nature of research questions, where each is designed to answer and collect the appropriate data [160][174].

- **Structured Interview:** The interviewees are asked the same questions in order by the interviewer without any interruption, and filling in their answers in a template provided.
- **Semi-structured Interview:** The interviewees are asked the same questions, but not in order, as the interviewer attempts to elicit deep information to achieve the research objectives. It also allows the researcher to ask any additional questions arising from the interviewee's responses, in order to reveal some further facts that can cover the explicit range of topics.
- **Unstructured Interview:** The interviewees are allowed to talk regarding specific issues without restrictions from the interviewer, as applying this type of interview will bring valuable answers.

For this study, face-to-face semi-structured interviews were highly appropriate to address the lack of PQP implementation barriers in LDNs. Therefore, the main interview style for this study was semi-structured. Such interviews allow greater scope for discussion and elicit deeper knowledge of the problems, experiences, future predictions, opinions and views of the respondents [175]. The semi-structured interviews questions were used to investigate and understand the difficulties and barriers facing LDNs in implementing PQP. The interviewees signed consent forms, and provided their names and job position, experience and responsibilities. After that, the researcher explained the aim of the interviews, before starting record the main interview with the interviewee's permission. The researcher then spent time with each interviewee, of approximately 45 to 60 minutes, subject to the interviewee's time. Figure 5.3 shows the flowchart of the second data collection conducted, i.e. 44 face-to-face semi-structure interviews.

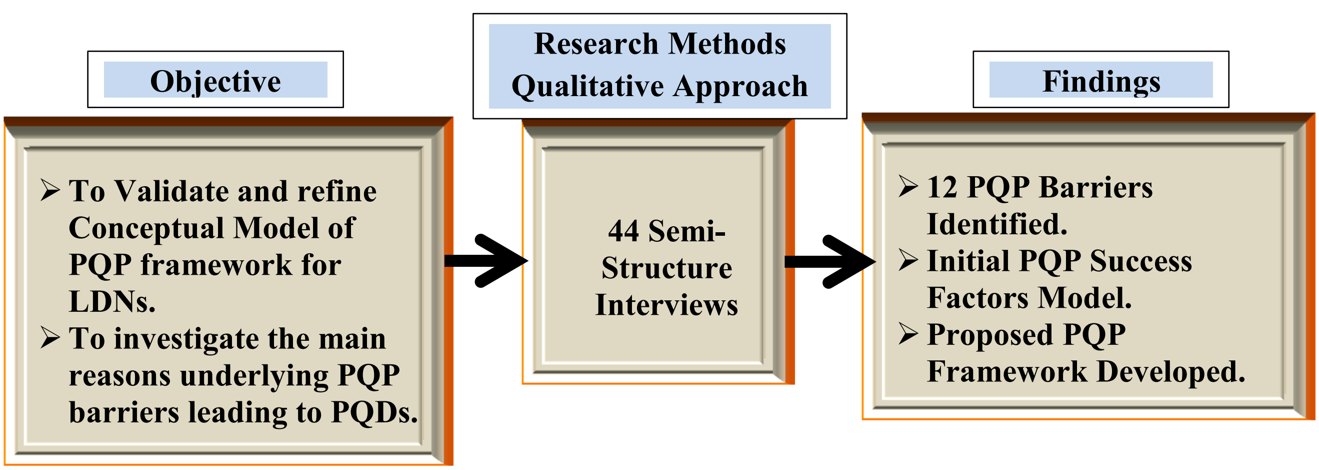


Figure 5.3: Flowchart of the qualitative study

5.8 Selecting Departments for Qualitative Study

Four departments were selected by the researcher for the second phase of the data collection. The researcher believes that these departments have direct relation to identifying the factors of improving PQDs in LDNs. Each department contributed to the research objectives by determining the exact factors needed to develop a PQ adoption model framework suitable for LDNs. The researcher determined that these four departments deal directly with PQ issues [115][133][120]. When the researcher first met the head managers of each department, they expressed their interest to be a part of this study and giving their knowledge, as well as providing access to any data with relation to PQ problems. In this context, Stake *"emphasizes the importance of including organizations, departments which have displayed willingness to participate in the research and share their knowledge to be accessible to the researcher"* [161]. The four departments are presented in the following sections:

5.8.1 Planning Department

Function:

- Planning the company's new projects, and setting out the strategy for both power supply standards and equipments standards.

Services:

- Designing the distribution systems between the company networks.
- Adjusting the current distribution networks by distributing the loads equally based on each area capacity.
- Preparing future plans as urgent strategies of projects in all the company's departments.

Duties:

- Prepares studies and researches of the current networks and the implementation of new projects.
- Supervises the company's projects and analyses their progress.
- Represents the company in planning, proposals, studies and researches of new projects.
- Follow up the studies of strategic projects on the national level, and prepare monthly reports on the on-going work.

Objectives:

- Carry out the company plans based on consultants' studies.
- Follow up the strategies of the company in providing recommendations to decision

makers in different aspects to develop an appropriate solution through the received suggestions.

5.8.2 Distribution Department

Function:

- Design the distribution networks based on each type of consumer.
- Providing power supply measurements on a monthly basis regarding its standards and problems.

Services:

- The department is responsible for all aspects of providing good PQ to its customers.
- Deals with customer complaints regarding PQ disturbances.
- Tackling existing problems by installing new equipment and building new distribution stations.

Duties:

- Meets the increase demand for power from all consumers, and taking into account economic growth.
- Bear responsibility for the maintenance section for any urgent problems affecting the networks.
- Set out PQ standards to be compared with the problems occurring in the networks.
- Satisfy the consumer regarding PQ.

Objectives:

- Providing good PQ for all consumers based on each type and load.
- Tackling illegal connections to the network by providing the appropriate solutions to prevent it recurring in the future.
- Ensure the quality of the power before distribution to consumers.

5.8.3 Training Department

Function:

- Train employees by giving relevant courses based on their background.
- Improve employee skills in dealing with specific problems facing the company.
- Evaluate the employees experience and feedback of insufficient courses.

Services:

- Manages and meets all the requirements of the company departments for specific training courses.

- Solves staff difficulties, especially in the distribution networks by giving them relevant material.
- Develop particular courses based on new technology.

Duties:

- Represents the company in dealing with training centres to tackle specific issues.
- Prepares and trains teams to analyse and solve any PQ problems.
- Accommodates the new knowledge regarding the company's problems.
- Overcome any challenges facing the company staff regarding any training courses.

Objectives:

- To make staff aware regarding any PQ issues.
- To develop and increase employee skills based on their background.

5.8.4 Customer Department

Function:

- Representing the company to explain the consumer's duties.
- Make consumers aware regarding PQ issues.

Services:

- Measure customer satisfaction regarding power supply.
- Provide good services for consumers when they pay their bills.
- Explain the importance of customer cooperation with the company.
- Providing customer centres in different areas across the country.

Duties:

- Cooperate with the consumers based on their types to satisfy them and meet their needs.
- Deals with customer complaints regarding PQ issues.
- Tackling any outstanding PQ problems facing consumers.
- Prosecute consumers who connect illegally to the networks.
- Receive new applications from new consumers.
- Giving consumers the chance to improve their knowledge by spreading awareness in different ways, such as media, press and Internet.

Objectives:

- To provide services and cooperate with consumers in solving their problems regarding PQ immediately.

- To make consumers aware regarding any PQ issues.
- To help consumers understand any existing problems in their lines.

5.9 Quantitative Survey: Population and Sample Frames

5.9.1 Populations

According to Sarndal, there are two types of populations, namely the target and the survey populations. These are the data collection units; for example, the target populations are the units from which data is collected on a specific phenomenon, while the survey populations are the individuals that the researcher can survey [176]. For this study, the target population is used along with a probability sampling method to collect the data, which contains all LDNs staff primarily working in departments, such as repair, maintenance, operation, control, production, plan, customer service, sales, marketing and design.

5.9.2 Sampling and Sample Size

Sampling is the process of selecting units. Therefore, one of the considerations in designing samples is that the larger the sample size, the higher the accuracy that can be achieved. According to Sarndal, there are different techniques for selecting a sample, such as *"simple random sampling, stratified sampling, cluster sampling, systematic random sampling, and convenience sampling"*. However, the convenience sampling is the sampling method used due to the mix of employee categories, involved in PQDs improvement and PQP implementation in LDNs. The total sizes of the selected sampling frame chosen for this study only included those individual engineers, technicians and employees from all LDNs, totalling 34.268 employees, who are working in PQP improvements [133]. According to Sproull, it is difficult to survey all the population, and including them all in one study is time consuming and prohibitively costly [177].

Krejcie and Morgan used rigorous statistical techniques to generalise the sample ratio [178]. According to their estimation, the whole samples needed for this study are 34.268, and they were not included in the table produced. However, they gave an estimation of the average/mean for the closest population size, which is 15,000 and 4000. The exact sample population appropriate for this research is calculated as follows:

If the given population (N) =15,000 then sample (S) is required to be=375 equation (5.1)

If the given population (N) =4,000 then sample (S) is required to be=351 equation (5.2)

Therefore, the population size needed for this study;

N=34.268, samples is ((375+375+351)/3) =367 equation (5.3)

Ahire and Golhar defined small firms as having less than 250 individuals in sample size. The number in the sample frame included in this study is 540 from all three distribution networks and all departments, which are considered like large firms in examining PQP framework factors; sample size should be greater than 367, based on Krejcie and Morgan's estimation of 34.268 employees [179].

5.9.3 The Total Survey Error

According to Thompson, the total survey error means the estimation percentage that differs from the average of the true value between the main point magnitude and the population parameter [180]. He also indicated that even if the samples are selected and designed correctly, a survey error may occur and affect the overall response rate, if some responses are not obtained from a few units. The non-response error makes the results less reliable and less valid. In response to this, Groves emphasised that *"any non-sample error should be dealt with in order to increase the response rate accuracy by carefully following up the survey instruments, instructions, and procedures in order to minimize both variance and bias",* which will increase both reliability and validity [181]. Blaikie mentioned three important relationships between sample size, error and accuracy [151];

- As sample size increase, sampling error decreases and sample reliability increases
- As population homogeneity decreases, sample error increases and sample reliability decreases
- As sample error increase, sample reliability decreases, and vice versa

Dillman also mentioned five main points, which require the researcher to pay attention when conducting research, to minimise the sampling error as follows:

- Selecting the proper time for conducting the survey.
- Designing the survey and choosing the precise samples frame.

- Increasing the skills in using the survey and the interview techniques.
- Choosing the factors that need to be investigated carefully.
- Considering the reasons underlying the non-sampling responses.

In this study, the researcher minimized the non-sampling error throughout the survey designing, data collection and data analysis process stages [158].

5.9.4 Response Rate and Non-response

For this study, the target population was chosen and probability sampling was used for data collection, and so estimates the response rate. Dillman recommended that the response rate can only be measured from the *"eligible responses"* [182]. This result came up in different arguments by various scholars, which suggested that responses to all questionnaire surveys must be filtered based on the feedback of the samples responding to the questionnaire, before entering data into the statistical analysis software. The survey questionnaire shown in appendix (A) was sent to a total number of 540 respondents in LDNs. When the questionnaire was collected, the data was entered into SPSS version 18.01.
The total number of respondents, who completed the survey, is 441, with a high response rate of 81%. However, approximately 99 of the respondent's questionnaires were not completed and so excluded. A further 44 completed questionnaire were excluded, as they were unusable, with multiple and repeated answers, mainly in part five in section B and C of the questionnaire. These were instantly excluded from the data sets and the final number was 397 responses, which are more than 367 samples, based on Krejcie and Morgan's estimation.

$$\text{Response Rate} = \frac{Number\ Returned}{Number\ in\ Sample} \times 100\% \qquad \text{equation (5.4)}$$

$$\text{Response Rate} = \frac{441}{540} \times 100\% = 81\% \qquad \text{equation (5.5)}$$

This study used a postal survey, from which it can be easy to detect the non-responses; it was due to some respondents not being familiar with IT, if the questionnaires were sent by email. According to Lepkowski, *"the higher response rate the more extreme results obtained and the lower the response rate, the greater the sample bias"* [183]. As a result, this research had a calculated high effective response rate at 81%. This high response rate was obtained as the researcher carefully considered the following during survey preparation;

- Great attention in survey design.
- Piloting the questionnaire to ensure it is more understandable for the target population to gain reliability and validity.
- Careful steps for data collection in order to minimise the non-response error.
- Brief introduction was given for all the respondents before distributing the questionnaire.
- All the questionnaires were handed to each head manager in each department to collect them easily.
- The researcher assured that all their information will be treated in confidence, and no one was authorised to look at this information except him and his supervisor.

5.9.5 Questionnaire Design

Translating the research objectives into clear statements required good questionnaire design. The statements are the research questions, which the researcher was seeking to answer by collecting data from the target population. Therefore, planning and designing a good questionnaire will reflect on the research outcomes, and so required careful process steps in formulating the questions derived from the literature review. Chapters two, three and four are the basis of the literature reviewed for this study, which clearly identified and explained the critical factors in PQP implementation. Fowler stated that the features of designing a good survey questionnaire [184] were as follows:

- Should be clear, short, easy, and specific.
- Should motivate the respondents to fill in and provide relative data.
- Should not be threatening to the respondents, in order to obtain reliable and valid data.
- Should respect a respondent’s privacy.

In this thesis, the PQ survey questionnaire was designed to elicit the actual needs of the PQP, in terms of training, management planning, and customer awareness, and to investigate the main reasons underlying PQ phenomena leading to PQDs in LDNs. The questionnaire was designed based on five parts, with the variables determined by the researcher from the comprehensive literature review, as explained in tables 4.2 to 4.7. Table 5.3 presents some, but not all the studies that used reliable and valid instruments to assess PQP internationally; these were included in the survey conducted in this study. Part one, collects demographic information, such as work position, education level, work experience, work responsibility, number of employees and working time. Part two, consists of elements of PQ improvements, such as PQ definitions, customer satisfaction and management commitment. Part three, consists of elements of PQ requirements, such as employee's participation and training and customers and company awareness. Part four consists of barriers to PQP, such as awareness, top management attention, resources and involvement and PQP benefits. Part five, consists of PQDs and network history, such LDNs characteristics, PQDs measurement history, PQDs affecting LDNs, PQDs causing malfunctions to end users' tools and PQ solutions history. Therefore, based on the questionnaire design, the respondents participated, to express their opinions and experience regarding the variable being identified in the survey.

5.9.6 Characteristics of the Five-Point Likert Scale

After designing the questionnaire the next step was to choose the scale to explore the respondent's opinion regarding the statements. As stated earlier, the survey was divided into five parts, therefore, a five-point 'Likert' scale was the key instrument in the questionnaire, and each part has different structure responses with clear instructions. The researcher selected a 5-point Likert scale as being commonly used, and it is appropriate to obtain the data needed to easily evaluate the respondents' experience, opinion and knowledge regarding PQDs and PQP. The selection came from many recommendations by different experts and scholars in statistical data analysis, and some PhD students, who previously used the same scale. According to Sekaran, the 5-point Likert scale is the best technique to apply for a study using many different constructs [185]. According to Saunders, a longer and more detailed survey can be used in order to cover the wide range of answers regarding a new phenomenon [186].

The survey structures are as follows:

Part one was designed to obtain background information and the respondents were asked to tick a suitable answer in the relevant category. Part two was designed for PQ improvements with a list of 17 statements, and part three was designed for PQ requirements with a list of 14 statements, and respondents were asked to tick an answer based on their experience and opinion with a rating scale from 1=Strong Disagreement, and 5=Strong Agreement. Part four was designed for PQP barriers and benefits, and respondents were asked to tick an answer based on their experience and opinion with rating scale from 1= Not applicable, and 5= High Extent for PQP barriers with a list of 16 statements and 1= Not Sure, and 5= Very Positive for PQP benefits with a list of 11 statements. Part five focused on PQDs, and respondents were asked to tick an answer based on their experience and opinion with rating scale from 1= Very Little and 5= Very Much for PQDs affecting LDNs with a list of 10 statements, and 1= Not at all, and 5= Do not know for PQDs damaged end users equipments with a list of 8 statements. Moreover, Part five was designed with further a list of 12 questions for PQDs solutions history, measurement history and LDNs details, where the respondents were asked to tick an answer suitable to their knowledge. Furthermore, the respondents were asked to answer an open-ended question to specify any comments, related to PQ, that were not included in this questionnaire and they wished to bring it up.

5.9.7 Coding of Responses

Coding the responses is very critical process step, which requires the researcher to pay greater attention when coding each single variable in the survey. Therefore, classifying the coding of the survey variables would facilitate obtaining the answers for the research questions and objective. De Vaus identified six key steps in coding the survey questionnaire [187];

1. Categorizing responses
2. Giving codes to each variable
3. Specifying column numbers to each variable
4. Generating a codebook
5. Checking coding errors
6. Entering respondents data

The quantitative data was entered and statistically analysed using SPSS based on the 5-point Likert scale, which converted the answers into numbers. When the 441 copies of questionnaire were collected back from the respondents, then each individual questionnaire was given an id number, by which it is easy to refer to that number, in case there was any issue for secrecy reasons. A database was built based on the survey variables after completing coding the whole questionnaire variables. On the other hand, the qualitative data was coded by listening to tapes, typing the text and reading transcripts, in order to identify what are the existing issues, concepts, beliefs, and themes. The qualitative data was coded based on LDNs staff, including head managers, middle managers, engineers, technicians and employees. Each interviewee was given a code based on their work position, responsibility, education and department. After the essential steps were conducted, then the data was transcribed and coded into NVivo 9. Appendix J shows details of how both quantitative and qualitative data were coded.

5.9.8 Questionnaire Translation

The PQ survey questionnaire was designed in English based on the extensive literature review. Douglas and Craig identified that *"translating the questionnaire into the same language as that of the respondents will ensure valuable outcomes by answering the same survey variables from different respondent categories"* [188]. After the English version was pilot tested, it was then translated into Arabic by the researcher and his supervisor. Brislin indicated that a survey submitted to a two phase translation process can achieve the survey objectives [189]. The translated English and Arabic versions were sent to a professional to validate both versions in terms of accuracy, fluency, meaning and words. This procedure was done according to Bulmer and Warwick, who stated that mistranslating the survey could lead to inaccuracy in the data acquired [190]. In response to this, and after the Arabic version was approved, two copies were sent by email to the researcher's friends, who work in LDNs to make any comments before conducting the final survey. Two comments were received, the first proposed that some of the English definitions needed to be explained further, and translated into Arabic in order to be understood by the respondents. Secondly there were some suggestions to distribute more copies to different employee's categories and departments, who will participate in providing comments regarding the content of the whole questionnaire, in terms of clarity, before the final distribution. The researcher further considered these comments in terms of amendments. However, any changes in the survey variables were compared to the literature review. This step was done to ensure that the respondents can understand the questionnaire content in Arabic. On the other hand, the interview questions were translated in the same way as for the questionnaire. The researcher took some points revealed after administering the questionnaire into account, in order to avoid them.

5.9.9 Questionnaire Formulation

Formulating the questionnaire was another crucial step considered in this study, based on extensively reviewing all the relevant literature on PQP measurements, solutions and implementation, and PQ survey conducted by various experts and professionals to address PQDs. This helped the researcher understand the overall level of PQP from different studies conducted in different electrical utilities worldwide, and gauging the experience in implementing PQP. Zikmund identified several stages involved in the questionnaire design process [191];

- Clarifying the questionnaire objectives
- Designing the questionnaire questions
- Piloting the questionnaire
- Reviewing and considering the questionnaire changes
- Controlling the questionnaire
- Analysing the data
- Reporting the questionnaire findings

Therefore, this procedure in formulating the questionnaire was very helpful in order to obtain reliable results, and increase the response rate in terms of valid responses, by designing the questionnaire appropriately. Moreover, the questionnaire was formatted carefully in order to make the respondents enthusiastic in filling it in. The researcher further considered some points in formatting the questionnaire, such as cultural factors, as he from the same country, where the survey was conducted. Making the questionnaire professionally presented and more obvious can increase the response rate. Some crucial suggestions were received after piloting the questionnaire from Brunel University 2009/2010 MSc students to make the questionnaire layout more attractive rather than crowded, which can avoid any error that might confuse respondents. Appendix A shows the questionnaire format. On the other hand, the interview questions were formulated based on the findings of the quantitative data, and the updated literature review. Appendix B shows the interview survey format.

5.9.10 Questionnaire Pilot Test

After the questionnaire was designed, the next step was to pilot test it. According to Zikmund, conducting the questionnaire pilot test is a significant stage required before primary data collection. Pilot testing the questions increases the reliability and validity of the primary data, and overcomes any the weakness, based on respondents' feedback [191]. Ticehurst and Veal mentioned that pilot testing the questionnaire could reveal some vital points beyond the questions, which might not be recognized by the researcher and could affect the findings, such as *"testing question wording, sequence, layout, familiarity with respondents, response rate, questionnaire completion time, and analysis process"* [192]. They further specified that the sample size for the pilot test should be between 10 to 30 respondents. In this study, the total sample size used for pilot test was 42, comprising 2009/2010 MSc students in the School of Engineering and Design at Brunel University. Out of the 42, 35 survey instruments were returned, of which 7 were excluded due to missing data and repeated answers. The response rate in the pilot test was 83%. The time estimated to complete the questionnaire was from 14 to 20 minutes.

Moreover, after the English version was pilot tested, then an Arabic version was sent to 30 LDNs staff to ensure that the survey instrument was understandable in Arabic. Out of the 30, 26 survey instruments were completed with a response rate of 86%. There were also some valuable comments in terms of the clarity and rating scales for some questions. On the other hand, the interviews were also pilot tested in Arabic, before starting interviews with all participants. The samples selected were one employee from each department to see if the questions were understood and could have the expected findings. It also helped estimate the exact time for each individual to ensure that the interviews were valid and reliable.

5.9.11 Research Covering Letter and Instructions

A covering letter was prepared with clear instructions explaining the purpose of the survey. The covering letter for both questionnaire and interview were printed on Brunel University official paper for the School of Engineering and Design, Electronic and Computing Engineering Department. The intention of the covering letter was to introduce the purpose of the research to the respondents, and how PQP is a significant subject that needs to be considered for LDNs as well as the researcher's background and education.

All respondents were given clear questionnaire and interview instructions. The instructions were given in the questionnaire covering letter explaining the purpose of the study and how important their participation was. At the beginning of each part in the questionnaire, there was a clear explanation of the statements. In the covering letter, the researcher clearly explained the following points:

- All responses given will be treated with the utmost confidence and the results will be used for research purposes only. The access to data is restricted to the researcher and his supervisor.

- Instructions were also given that after completion, the questionnaires attached should be sealed in the envelope provided and returned to the distribution department, within three weeks from the date, in which the survey was handed to you.
- The time estimated to fill in the questionnaire should not be more than 20 minutes of your time to complete.
- All respondents noted that this work was approved by the Engineering and Design Research Ethics Committee at Brunel University in the School of Engineering and Design.

Appendix D shows the covering letter presented with the PQ questionnaire and PQP interviews. On the other hand, the interview instructions were given in a participant information sheet for each interviewee, before starting to conduct the main interview. Moreover, the researcher gave detailed instructions to the potential interviewee, who he contacted about the purpose of the study, to obtain initial agreement from EGCOL. In the participant information sheet for the interviews, the instructions were given as follows:

- The importance of understanding why the research was being conducted, and what it involved.
- The researcher emphasised to the interviewee to take enough time to read the information provided in the covering letter, and to ask him if there was anything that was not clear or if they needed more information.
- The results of the study, which will be a part of the researcher's thesis and data, will be published in national and international journals and conferences.

After the data was collected, the researcher received an official letter from EGCOL as shown in Appendix L.

5.9.12 Research Ethical Considerations

Sekaran stated some ethical consideration, which the researcher should take into account to protect human rights, such as *"personal information will be kept strictly confident; should not force respondents to become part of the survey; defining the purpose of the study and the* *researcher should get consent prior to collecting the data"* [193]. Following Sekaran, the ethical considerations that the researcher paid attention to in this study were:

- Explaining the purpose of the study and the importance of the respondents' participation.
- Informing the respondents that the data collected in this study will be part of his PhD thesis.
- Informing the respondents that the collected data will be published in national and international journals and conferences.
- Informing the respondents that their responses will be treated with the utmost confidence.
- Informing the respondents that the results will be used for research purposes only.
- Informing the respondents that the access to data will be restricted to the researcher and his supervisor.
- Informing the interviewees to take enough time to read the instructions and the information provided in the covering letter.
- Informing the interviewees that the ethical approval has been confirmed and issued from Brunel University, School of Engineering and Design Research Ethics Committee.

These considerations also followed the Brunel University School of Engineering and Design Research ethics committee before collecting the primary data. The respondents were also informed in the consent form that their participation was completely voluntary, and that they were free to change their mind and withdraw from the study at any time. The ethical approval of PQ survey questionnaire and interviews are shown in Appendix C.

However, the only ethical issues that the researcher encountered when he conducted the interviews were that some interviewees did not permit the researcher to record the interviews. This issue arises from cultural factors, and some of them were not familiar with such a procedure, or because they thought their information would be passed to their managers. However, the researcher convinced them that all their information was protected and treated with the utmost confidence, and no one except him and his supervisor could access the data. As a result, the researcher believes that participating with fear might lead to data error, and the research objectives can be misunderstood.

5.10 Methods of Data Analysis

After choosing the research design, data collection methods and population and sample frames, this part highlights the data analysis. In this study, two stages of data analysis were applied to answer the research questions and objectives. The first stage involved PQ survey questionnaire data collection, conducted during April and May 2010. The second stage involved interview survey data collection, conducted in late December 2010 and early January 2011 in LDNs.

5.10.1 Quantitative Data Analysis

The first stage of analysis was for quantitative data, which essentially involved statistical analysis. This analyses numerical data collected from responses, which is then entered into SPSS (Statistical Package for the Social Sciences version 18.01). There were different techniques applied in this phase to choose the proper data analysis strategy after the data is entered and coded for the completed surveys, in terms of completeness, accuracy and quality [185][194, 195]. The data was processed based on some initial steps, such as scanning, cleaning, editing and coding. The next process step used some techniques to measure the questionnaire instrument's reliability and validity, regarding Cronbach's alpha and factor analysis loading. After that, descriptive analysis was carried out to measure the central tendency and measures of dispersion of the participants, who completed the survey, such as frequencies, percentages, means, and standard deviations, with regard to their different characteristics and information.

Moreover, Pearson's correlation coefficient was also utilized to indicate the strength of correlations between critical success factors of PQP in three LDNs. Then, the MANOVA of General Linear Model was used to test, if there were any differences between the levels of group, PQP factors and LDNs employee' categories. In addition, analysis of variance (ANOVA) was used in this study, to compare the means or variance between PQP barriers and different groups, such as three LDNs. Finally Multivariable Linear Regression was used to determine the most contributed factors for developing a framework of PQP in LDNs.

In doing so, all these techniques were used to achieve reliable and valid findings for the developed PQP framework, after considering the preliminary assumption, which involved checking for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity, with no serious violations noted. Table 5.4 describes the types of tests used to analyse the quantitative data, which are explained in detail in chapter 6.

Table 5.4: Data analysis Techniques and Descriptions Applied in this study

Required analysis	Purpose	Analytical technique	Tool	Reference	Required value
Data Coding and Editing	To define the labels for each variable and assign numbers to each of the possible responses	Variable coding	SPSS	[196]	NA
Missing data examination	Examination of missing data and its possible treatment.	Expectation maximization (EM) with Little's MCAR test	SPSS	[197]	p>0.05 missing patterns are completely at random
Reliability	To ensures that measures are free from error and therefore yields consistent results	Cronbach's α	SPSS	[198]	α> 0.6
		Item-to-total correlation	SPSS	[195]	Value>0.3
Factor analysis (EFA)	To confirm that scale selected for the present study is supported by the data	Kaiser-Mayer-Olkin (KMO)	SPSS	[199]	Value> 0.60
		Bartlett's test of sphericity 0.3	SPSS	[200]	Value> 0.3
		Communality	SPSS	[201]	Value> 0.5
		Variance/loading	SPSS	[195]	Value>0.4
Univariate outliers	To identify a case of an extreme value	Standardised score (z-scores)	SPSS	[201]	Value <± 3.0
Multivariate outliers	To identify case of extreme values in two or more than two variables	Mahalanobis	SPSS	[197],[201]	D2/df< 3, or p<0.05
		Box Plot	SPSS	[201]	IQR < 3.0
Univariate normality	To ensure that the data is linear and normally distributed	Q-Q plot	SPSS	[202]	straight line
		Kolmogorov-Smirnov and Shapiro-Wilk (K-S) test, Skewness and kurtosis	SPSS	[201], [203]	P>0.05 Value < ± 2.58
Multivariate normality	To ensure that the data is linear and normally distributed within group of more than two items	P-P plot,	SPSS	[196]	straight line
Homoscedasticity	To ensure the assumption of normality that the dependent variable(s) display an equal variance across the number of independent variable(s)	Levene's test	SPSS	[196]	P<0.05
Multicollinearity	To ensure that correlation matrix of three of more independent variables should be weakly related to each (<0.90)	Pearson's correlation,	SPSS	[197]	<0.8
		VIF and Tolerance effect using linear regression	SPSS	[204, 205]	VIF<10, and tolerance >0.1
Demographics	To examine the background information of respondents	Mean, standard deviation, frequency, cross-tabulations	SPSS	NA	NA
A MANOVA of General Linear Model	To compare the means or variance between three different groups or more and two or more dependent variables	MANOVA, Wilks' Lambda, F, P Values	SPSS	[197, 201]	Eta squared < ±0.6, P<0.05
ANOVA	To compare the means or variance between three different groups or more and one dependents variable	Post Hoc Tests, Pearson's correlation, Mean difference	SPSS	[196][206]	P<0.05
Multivariable Linear Regression (MVLR)	To assess the contribution to the outcome factors within two or more than two predictor variables	R^2, P and T values of the items contributed to the model	SPSS	[207-209]	R^2 > 0.30, P<0.05, T > 1.96

Source: adopted from [210]

5.10.2 Qualitative Data Analysis

The qualitative study was conducted in the second data collection method to find out why there were difficulties and barriers facing LDNs to improve PQDs. Forty-four semi-structured interviewees participated in this research were based on the interview questions, as stated in Appendix (B). Secondly, it was to investigate why there was a lack of PQ awareness among existing LDNs staff, including head managers, middle managers, engineers, technicians and employees. From the findings gained from the PQ survey questionnaire showed that a low level of PQP implementation factors in LDNs. This is due to the lack of PQ awareness found among top management and staff.

The qualitative data questions were designed from the findings obtained from the quantitative analysis of phase one, by firstly covering the improvement factors of implementing PQP to investigate the reason for the lack of PQ awareness in the three LDNs. Secondly, the questions also included the PQP barriers that prevent LDNs from implementing PQP.

5.11 Summary

This chapter provided perspectives on the research methods, including approaches, philosophies, design and strategies for this study. In this respect, the positivism and interpretivism philosophies were justified for their selection and how they are powerful when merged together to provide further explanation and exploration, regarding spectacular research problems in the PQP framework in LDNs. On the other hand, the methodological perspectives were applied to data collection methods; both the quantitative method, as in PQ survey questionnaire, and the qualitative method, as in interview survey. These were used as primary data collection methods to understand and explore in-depth the barriers and difficulties of PQP framework implementation. The research methods used in this study are widely accepted and adopted in electrical and electronic engineering researches, as explained in Section 5.7.1, and described in Table 5.3. The secondary data collection method used is the review of documentation, books, reports, journal articles and archival records, which subsequently enabled PQP framework implementation factors to be identified, tested, and then investigated in a PQ survey questionnaire and interviews questions.

The target population comprised LDNs employees, who work in different departments along with different work position and responsibilities. The samples size of this study was 397, which was selected carefully following the quantitative survey population and sample frames development rules. The PQ survey questionnaire and interview survey were designed, formulated and pilot tested with clear instructions, given using SPSS and NVivo 9. Moreover, ethical approval considerations were followed in this study, in order to avoid any error during the data collection process and analysis to ensure reliable and valid information.

The next chapter (6) presents the quantitative data analysis and findings used to examine the implementation of a PQP framework in LDNs.

Chapter Six: Quantitative Data Analysis and Results

6.1 Introduction

This chapter presents the analysis of the quantitative data collected through the questionnaire survey designed for this research. The main purpose of conducting both questionnaire survey and interviews was to generate data, which answers the research questions. The data analysis procedure was chosen based on the appropriate type of technique used for each item in the questionnaire. The questionnaire survey was conducted to obtain the significant reasons, which prevented LDNs from implementing PQP. The data was analysed using (Statistical Package for Social Scientists) SPSS version 18.1. Section 6.2 describes the initial analysis of the data, such as screening, cleaning, accuracy, outliers and normality. Section 6.3 explains the statistical methods, included in the data analysis process steps, whether descriptive or inferential statistics applied to the quantitative data, along with a description. This chapter presents the data analysis in two stages;

Stage one examines the Critical Success Factors (CSFs) of PQP, including the following sections; where Section 6.4 illustrates the tools used to measure the questionnaire instrument reliability and validity. Section 6.5 describes the correlation analysis of the PQP CSFs. While section 6.6 describes the demographic analysis of the respondents in the survey, with regard to different characteristics, such as work position, education level, work experience and work responsibility. Section 6.7 illustrates the current level of PQP implementation in LDNs. Section 6.8 discusses the General Linear Model of Multivariate Analysis Of Variance (MANOVA) used to test whether or not there were any differences between the derived CSFs of PQP and three LDNs.

Stage two explores the level of PQPs implementation among LDNs, and shows the experience of those PQPs that LDNs implemented or tried to implement. Section 6.9 evaluates the level of PQP, including the sub-sections, where 6.9.4 states the current level of PQDs in LDNs including main sources of PQDs, PQDs affecting LDNs, PQDs measurements history and the main causes of PQDs. In addition, section 6.9.5 describes One-way Analysis of Variance (ANOVA) to test the 16 PQP barriers, if there are any differences between the three LDNs and the 16 PQP barriers, and whether or not they differ from one network to other. Section 6.9.6 examines the 16 PQP barriers in terms of reliability and validity by using both factor analysis and reliability.

While section 6.10 looked at Multivariable Linear Regression (MVLR) analyses to investigate, firstly, the relationship between the CSFs derived from the literature and the implementation of PQP within LDNs, including four predictors, namely customer satisfaction, management commitment, employee participation and training, and PQDs affecting networks; secondly, the relationship between the PQP barriers and the implementation of PQP framework within LDNs including four predictors, namely PQP awareness, PQP management commitment, PQP resources, and PQP involvement. Finally, section 6.11 summarises the whole chapter.

6.2 Initial Analysis of Data

This section describes the procedure of screening and cleaning the data to make sure it is input correctly, and is ready, before starting the process of main analysis to prevent any error. In exploring the appropriate technique for this type of data, it must be checked in terms of accuracy, outliers and normality, in order to gain good results [211, 212].

6.2.1 Screening and Cleaning Data

This procedure describes the three steps of screening and cleaning the data before it was analysed.

6.2.1.1 Accuracy

The survey questionnaire shown in appendix (A) was sent to a total number of 540 respondents in LDNs. When the questionnaire was collected, the data was entered into SPSS. The total number of respondents completing the survey was 441, i.e. a high response rate (81%). However, approximately 99 of the questionnaires were not fully completed, and were excluded. A further 44 completed questionnaires were excluded due to unusable, multiple and repeated answers. In the excluded 44 questionnaires, the responses causing the exclusion were found to be in part five, specifically sections B and C, of the questionnaire. There were instantly excluded from the data sets and the final number was 397 responses, which are more than the 367 samples based on Krejcie and Morgan's estimation [178]. There were 159 respondents from west network, 131 respondents from east network and 107 respondents from south network.

The test of screening and cleaning was conducted by re-running the descriptive statistics and frequency tables for each variable. The descriptive statistics test was run for every continuous variable to detect if there were any missing or out of range responses. A frequency test was conducted for the category variables to identify any inadmissible or null responses. According to

Malhotra, this technique is referred to as case-wise deletion for missing data [213]. However, these incomplete responses can be dealt with in pair-wise deletion, where only the completed cases are included for analysis, while keeping those that are incomplete out of the analysis, yet without deleting them from the data sets [214].

6.2.1.2 Outliers

The next step, after applying the accuracy procedure, is to examine outliers in the data. There are four causes for outliers; the first is incorrect data entry. The second is failure to identify missing values, and so the computer analyses them as real data. The third reason for outliers is error in the sampling, where the cases are not from the intended or relevant population, from which the survey aimed to collect data. The fourth reason may be due to the intended population, which gives more extreme values than the normal distribution for the variable [212]. In response, this study has worked to detect univariate and multivariate outliers using box and whisker, and normal probability plot. The univarite outlier analysis detected few cases with large standardized scores of outliers (± 3.0), as the sample size is large (n=397). The outliers were expected to be in few cases, given this sample size [197]. Moreover, Mahalanobies distance test was also performed to detect outliers. It revealed that the detected multivariate outliers were not significant, and had small effect on the construct factors in retaining them, since the result value of R^2 was medium (0.522), with a tolerance reading of "1- R^2" (0.478) [197][201]. The normal probability results exposed a multivariate normality by using the normal P-P plot of the regression standardised residuals, as shown in Figure 6.1.

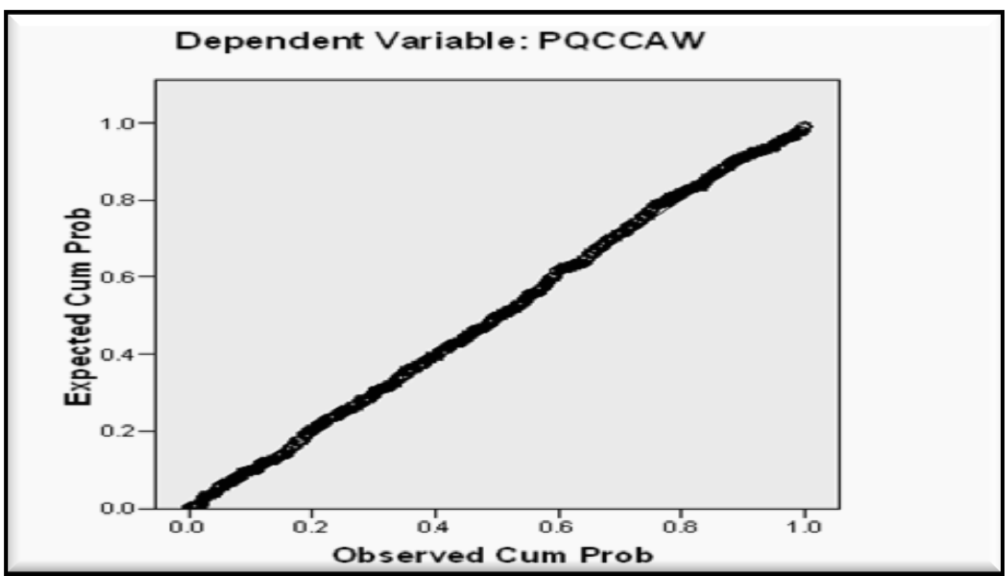


Figure 6.1: Normal P-P plot of regression standardised residual

6.2.1.3 Normality

Normality is complementary to the outliers test. Some statistical tests depend on the assumption of normality. Unluckily, in some researches, where the sample size is more than a hundred, the data may not roughly keep to a normal distribution. In order to assure a normal distribution of the data, it should be checked and assessed for normality, in terms of skewness and kurtosis. After the data were coded, a normality test was applied to guarantee that the data has not violated the normality assumption to assure that all the constructs are within the acceptable limit of the skewness-kurtosis ranges [7]. Skewness-kurtosis critical values should lie within a range of ± 2.58 at the 0.01 significance level [6, 7], as shown in Table 6.1.

It is very important to check all continuous variables for normality at an early stage, to see whether there is positive or negative skewness and kurtosis. Skewness refers to the distribution of the variables, in how they are symmetric, where the mean is not at the centre of the distribution. On the other hand, kurtosis refers to the peakedness of a distribution, whether it is too peaked or too flat. Therefore, if the skewness and kurtosis are zero, this means the distribution is normal [2]. As a result, all the constructs were tested for the three networks and were found to lie within the acceptable limits of the skewness-kurtosis ranges, as explained in Table 6.1.

Table 6.1: PQP constructs mean, standard deviation, variance, skewness and kurtosis

Distribution Network	**Construct**	N	Mean		Std.	Variance	Skewness		Kurtosis	
		Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
West Network	Definitions	159	4.05	0.051	0.639	0.409	-0.636	0.192	0.071	0.383
	Customers Satisfaction	159	2.46	0.053	0.664	0.441	0.159	0.192	-0.473	0.383
	Management Commitment	159	2.25	0.045	0.571	0.326	-0.072	0.192	-0.729	0.383
	Employees Participation and Training	159	2.21	0.055	0.696	0.484	0.198	0.192	-0.588	0.383
	Customers and Company Awareness	159	3.18	0.047	0.588	0.346	-0.182	0.192	0.832	0.383
	Disturbances Affecting Networks	159	2.82	0.072	0.903	0.815	0.053	0.192	-0.962	0.383
	Disturbances Malfunction Users Tools	159	3.01	0.061	0.764	0.583	-0.377	0.192	-0.051	0.383
East Network	Definitions	131	4.01	0.054	0.621	0.386	-1.209	0.212	2.074	0.421
	Customers Satisfaction	131	2.45	0.051	0.583	0.339	0.361	0.212	-0.393	0.421

	Management Commitment	131	2.21	0.051	0.581	0.337	0.241	0.212	-0.307	0.421
	Employees Participation and Training	131	2.15	0.062	0.704	0.496	0.334	0.212	-0.713	0.421
	Customers and Company Awareness	131	3.24	0.055	0.632	0.401	-0.279	0.212	0.373	0.421
	Disturbances Affecting Networks	131	2.71	0.078	0.894	0.799	0.178	0.212	-0.799	0.421
	Disturbances Malfunction Users Tools	131	3.01	0.077	0.877	0.768	-0.196	0.212	-0.834	0.421
South Network	Definitions	107	4.08	0.061	0.621	0.384	-0.751	0.234	-0.061	0.463
	Customers Satisfaction	107	2.52	0.054	0.561	0.314	0.411	0.234	-0.449	0.463
	Management Commitment	107	2.31	0.063	0.649	0.422	-0.317	0.234	-0.776	0.463
	Employees Participation and Training	107	2.33	0.062	0.644	0.415	0.188	0.234	-0.401	0.463
	Customers and Company Awareness	107	3.17	0.056	0.579	0.335	-0.551	0.234	0.028	0.463
	Disturbances Affecting Networks	107	3.01	0.091	0.944	0.891	-0.186	0.234	-0.818	0.463
	Disturbances Malfunction Users Tools	107	3.14	0.081	0.843	0.711	-0.623	0.234	0.091	0.463

6.3 Statistical Methods

6.3.1 Descriptive Statistics

The purpose of using descriptive statistics is to analyse the collected data, and make it more easily understandable and clear. Graphs and tables are used to present the measure and calculation of various descriptors. This includes the central tendency with mean, mode, median, and range, and the variability, such as variance, and standard deviation, and range of scores of both skewness and kurtosis [194].

6.3.2 Inferential Statistics

The purpose of using inferential statistics is to analyse the small group and making an inference regarding the large group. The small groups were gained from the sample population. The types of inferential statistics, included in this study, are the relationship between each individual variable and independent variables, and the test of differences used between those variables. Therefore, in order to reach the scope of this study, these techniques must be applied to all data.

Figure 6.2 shows both the statistical methods applied in this study.

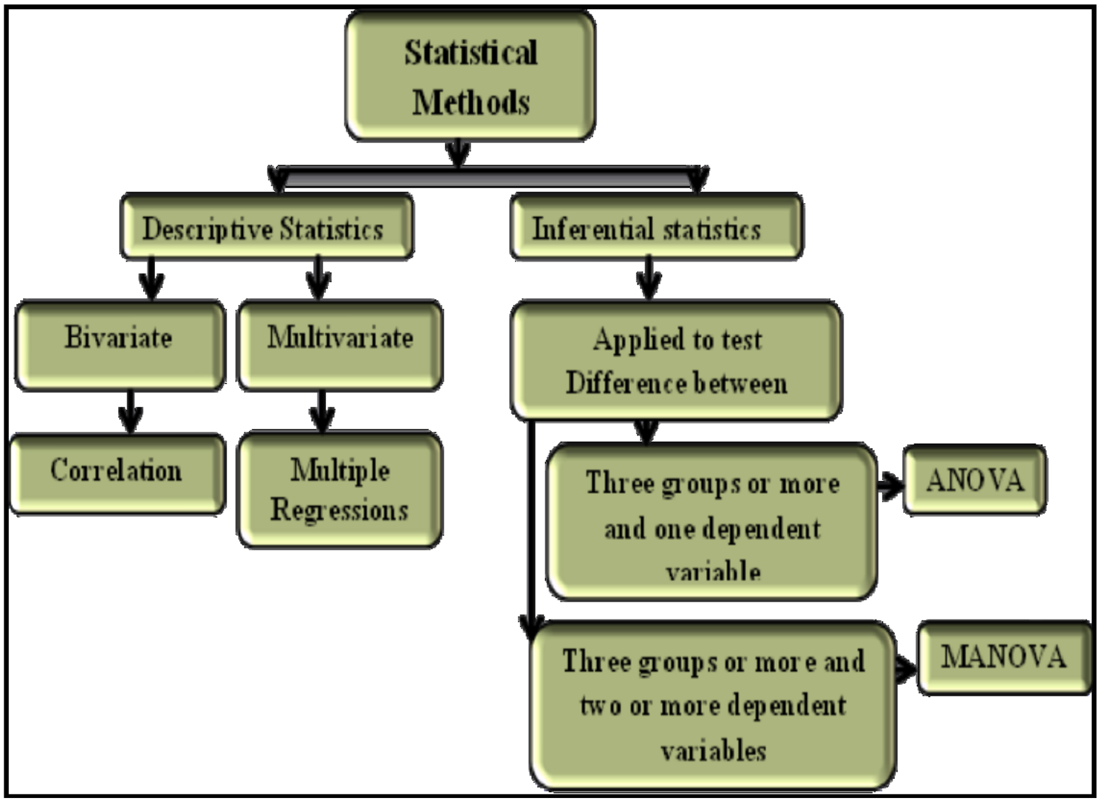


Figure 6.2: Statistical Methods

6.3.3 Data Analysis Steps

Table 6.2 shows the four steps of data analysis were carried out in the research. These steps are data integrity test, descriptive analysis, relationship between the variables of the data gained from the survey and test of differences to compare the variance of variability between the three different groups. Each technique has its internal features to provide the results needed to test the research hypotheses. However, several pre-analysis techniques were applied to check for the error in data. This is done after the initial analysis was performed for the data entered, to check for accuracy, outliers and normality.

Table 6.2: Producers of Data Analysis

Step One	Data integrity test	Data Collected are processed for both validity and reliability for the quality propose
Step Two	Descriptive analysis	The survey questions are measured for the central tendency include the frequency tables, figures and descriptive summery
Step Three	Relationship	Identify the relationship and the strength between variables
Step Four	Test of Differences	Compare the variance of variability between the different groups

Table 6.2 shows the steps in the process of quantitative data analysis in this thesis. After the initial analysis was completed, and the type of data analysis was determined, then the data were coded and entered into SPSS. The tests of reliability and validity were conducted by different series of analyses.

STAGE ONE: POWER QUALITY PROGRAMME (PQP) CRITICAL SUCCESS FACTORS (CSFS)

Stage one was designed to examine the critical success factors of PQP, including the following statistical techniques; the questionnaire instrument reliability and validity by using exploratory factor analysis (EFA), based on the principal component analysis (PCA), with Varimax rotation to discover the structure of factors in the derived variables, using correlation analysis, demographic analysis, descriptive analysis and MANOVA.

6.4 Reliability and Validity

Reliability and validity are considered to be very important measurements to be conducted in any type of research based on quantitative data collection. Reliability refers to how the survey variables could be easily extracted together for each depending factor. Validity means that both target and methods are clear, with regard to the results obtained, and to measure whether these are what they were expected or intended to be or not [215]. In other words, both reliability and validity are in an asymmetric form, where the test cannot be valid, if it is not reliable and Vice Versa [216].

6.4.1 Reliability

One of the main problems concerning reliability is the internal accuracy represented by consistency, stability and repeatability. This refers to the degree to which one or more variables being assessed are homogeneous, and can provide a good degree of reliability in presenting the right score on a specific dimension. Reliability is a measure of the capacity to gain reliable measurements, and can be estimated using a reliability coefficient, such as Cronbach's alpha correlates [217]. The estimation of Cronbach's alpha is calculated for each item against more items in the same group, which gives the total score. Items less than the Cronbach's alpha can be removed to make an instrument with a high degree of, and total score of, homogeneity.

Since *"Coefficient alpha absolutely should be the first measure one calculates to assess the quality of the instrument"* [195], this was determined. This coefficient refers to the items that are below the standard level, which are to be dropped until the coefficient reaches the standard level of coefficient, which is 0.70. An internal consistency analysis was performed for each question of the six critical success factors of PQP. The reliability of the questionnaire was tested, and table 6.3 shows that all six factors of Cronbach's alpha ranged between 0.745 and 0.851. This means reliability coefficient of value 0.70 or more is considered to be high and good alpha [217][195][218][219][220][196][221]. The reliability for all the 39 PQ elements are recorded at =0.806. This indicates that the total Cronbach's alpha of the whole 34 items of the CSFs of PQP elements exceeded 0.70 [222][219][220]. Therefore, seven items, namely Q17, Q32, Q36, Q37, Q50.1, Q50.2, and Q50.3, were dropped from the analysis to improve the reliability for each group containing the excluded item.

Table 6.3: Instrument Reliability of PQ Elements

Six Power Quality Elements	Question Number	Number of Question	Items Cronbach's Alpha (a)	Total Cronbach's Alpha (a)	Questions Deleted
Definitions(D)	Q7	5	0.728	**0.769**	None
	Q8		0.741		
	Q9		0.683		
	Q10		0.759		
	Q11		0.722		
Customers Satisfaction (CS)	Q12	5	0.768	**0.811**	None
	Q13		0.773		
	Q14		0.782		
	Q15		0.761		
	Q16		0.784		
Management Commitment(MC)	Q18	7	0.805	**0.841**	1
	Q19		0.791		
	Q20		0.815		
	Q21		0.844		
	Q22		0.812		
	Q23		0.817		
Employees Participation and Training (EPT)	Q24	6	0.798	**0.806**	None
	Q25		0.767		
	Q26		0.792		
	Q27		0.747		
	Q28		0.767		
	Q29		0.777		
Customers and Company Awareness(CCA)	Q30	8	0.736	**0.745**	3
	Q31		0.681		
	Q33		0.672		
	Q34		0.697		
	Q35		0.725		
PQ Disturbances (PQDs)	Q50.4	10	0.844	**0.851**	3
	Q50.5		0.842		
	Q50.6		0.826		
	Q50.7		0.843		
	Q50.8		0.815		
	Q50.9		0.821		
	Q50.10		0.823		

6.4.2 Validity

Validity is a technique used to measure or assess the evaluation of the reliability or the accuracy of the results gained from the data. It refers to *"the degree to which it measures what it is supposed to measure"* [196]. There is no single way to assess the validity of an instrument

[221][223]. There are three kinds of validity, and they are commonly considered to calculate the degree of validity of the instrument. These are shown in table 6.4; however, only two types of validity were used in this study, namely content and construct validity.

Table 6.4: Different Types of Validity

Definitions and Types of Validity
Content validity: The scale to which the items in the measurement instrument represent the domain or universe of content the processes under study.
Construct validity: The degree to which the test of scale not against a single criterion in term of measurement instrument represents the nature of variable.
Criterion validity: The degree to which the relationship between the measurement instruments has ability to predict a variable that is in measurable criterion.

6.4.2.1 Content Validity

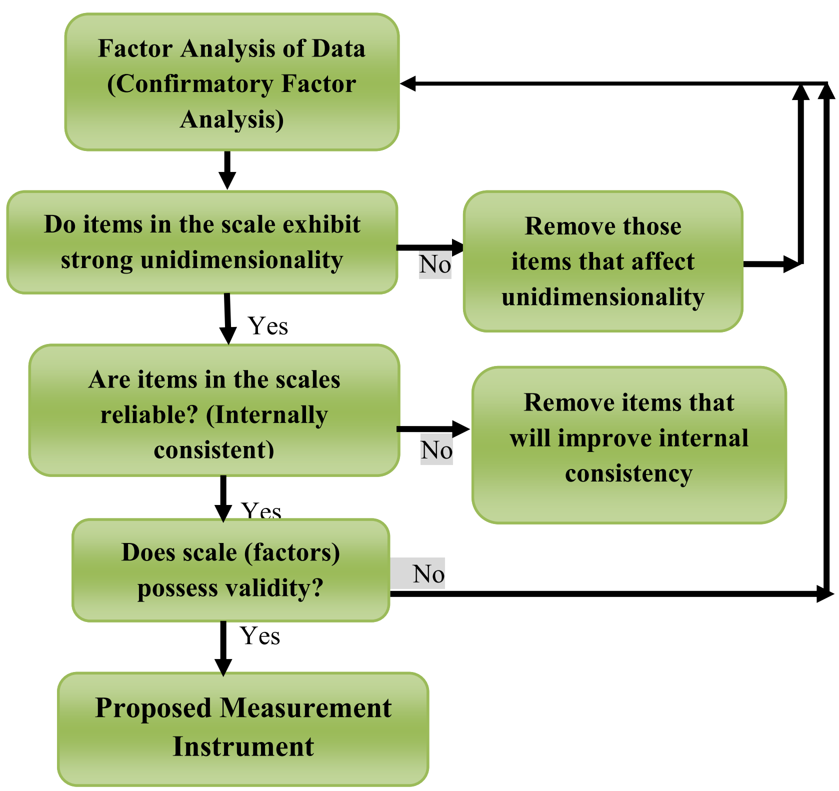
Content validity is based on the extent to which the scale of the items in the measurement instrument represents the domain or universe of content of the processes under study [196][221]. Content validity was assessed by reviewing the literature, and by gathering opinions of experts in the field of PQ to judge the items. Suggestions and comments were made on the structure of the questionnaire and its contents. Content validity was also tested, by presenting the questions to MSc students for assessment. The questionnaire was sent to the students in order to check the degree to *"which it measures what it is supposed to measure"* [196][223]. After the pilot-test study, the final questionnaire was formatted and made ready for distribution to the sample. The feedback also helped the researcher identify the questions, which were difficult to understand. The feedback obtained from the pilot-test made the survey contents clearer and easily understandable. The pilot-test also helped determine the time to complete the questionnaire, which would help the participants fill in the survey more comfortably.

In this research, the researcher believes that all 39 questions of the instrument, measuring PQ problems in LDNs, have content validity, since they were based on the literature, i.e. derived from previous studies. Furthermore, Principal Component Analysis (PCA) and Varimax methods were used in verification. Given sufficient verification, nearly all the factoring methods should provide the same results [221][199]. As represented in Table 6.6, all six factors extracted had a minimum factor loading of 0.40 [219]. Hence, all the six factors explained 54.582% of the PQP items variance.

6.4.2.2 Construct validity

Construct validity is the degree to which the test of scale is not against a single criterion in terms of the measurement instrument, which represents the nature of the variable [219][198]. According to Jaeger [224], *"factor analysis is used extensively as it is useful tool for examining the validity of the measurement characteristics of attitude scales"*. On the other hand, construct validity was tested for each key practice, and was evaluated in assessing each item, using factor analysis. Factor analysis is considered as *"a powerful and indispensable method of construct validation"* [225]. This step will make each key validate a scale by representing that its components load within the same common factor. Therefore, if all the variables catalogued over each key practice load on each factor on its own, then they calculate the same attribute. Moreover, the greater the variance, which is explained by the results gained from factor analysis, the more powerful the instrument is in measuring what it is supposed to measure [226].

For the purpose of the study, SPSS 18.1 was employed to run factor analysis to measure and determine which items are suitable for every dimension or factor. Figure 6.3 shows the diagram method to measure the scale validation.



(Source: Adapted from [175]*)*

Figure 6.3: Validation of the Measurement Scale

6.4.2.3 Factor Analysis (FA)

Factor analysis is a method used for a wide number of items to be verified, and to allow them to be into small number each to its internal related factors, which can largely illustrate items that produce the phenomena under study [196][227, 228]. The purpose of this technique is to make most of the related items into small factors that best describe the phenomenon [196]. Factor analysis technique can be used for three major purposes, as explained by Bryman and Cramer [229].

- Factor analysis can measure the degree to which those variables can be placed under the same concept.
- Factor analysis identifies the degree to which items could be reduced into a smaller set.
- Factor analysis was used to assist in making sense of the baffling intricacy by reducing it to a more bounded number of factors.

Besides, the factor analysis technique is related to the correlation components between each item. It was proposed that a correlation matrix of items should be built as an initial test [227]. It should eliminate any item that has correlation component values with any other items under 0.4 [227] or 0.3 [228]. Therefore, to determine adequacy of the extraction method in a factor analysis, there are three tests to be followed as recommended by Field [206]. These tests are The Kaiser-Meyer-Olkin (KMO) test of sampling adequacy, eigenvalues, and the Bartlett's test of sphericity. These tests will identify whether the factor analysis extraction method is acceptable, Field stress that: *"if the number of variables used in a factor analysis is less than 30, sample size is above 250, the average communality is greater than or equal to 0.6, and the Bartlett's test of sphericity is significant, then the factor analysis extraction method is accepted"* [206].

6.4.2.4 Results of Factor Analysis

The 34 items in the survey instrument used in this study were made on a five-point Likert scale where "1" referred to strongly disagrees, and "5" indicated strongly agree for each statement. Neutral was permitted as the midpoint on a five-point scale, which refers to undecided or unknown responses [230].

The 34 variables of the survey were inter-correlated by an exploratory factor analysis (EFA) based on the principal component analysis (PCA) with Varimax rotation to discover the factor structure in the derived variables. The data was measured in order to perform PCA for appropriateness of factor analysis. Inspection of the correlation matrix disclosed the presence of many coefficients of 0.3 and higher than the Kaiser-Meyer-Oklin (KMO). Measure of Sampling Adequacy value was 0.821, this exceeded the recommended value of 0.6 [231][199][206][232] and the Bartlett's Test of Sphericity, as shown in table 6.5, reached statistical significance, supporting the factorability of the correlation matrix [200].

Table 6.5: Kaiser-Meyer-Olkin (KMO) and Bartlett’s Test for all 34 items

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.821
Bartlett's Test of Sphericity	Approx. Chi-Square	4847.51
	DF	561
	Sig.	0.000

Measure of Sampling Adequacy value was 0.821 for all 34 items, this exceeded the recommended value of 0.6 [231][199][206][232]. The Bartlett's Test of Sphericity was also highly significant (Chi-Square = 4847.51with 561 degree of freedom, at $p<0.001$) as shown in table 6.5 [200]. This concludes that the factor analysis of all the scale variables was appropriate, and confirms that all the items were statistically significant in supporting the factorability of the correlation matrix in comparison with these cut-off levels as the KMO result was very high. The results obtained from Kaiser-Meyer-Olkin Measure (KMO) and Bartlett's Test for all 34 items are judged to give excellent validation for factor analysis [214]. Hence, it was found that all the scale variables were very suitable, based on factor analysis.

6.4.2.4.1 Factor Extraction

Factor analysis with PCA, using a Varimax rotation, was employed for the entire 34 CSFs of PQP factors to identify the number of loading factors. The scree plot was also used to explain when the factors begin to be extracted; the KMO method (Eigenvalue greater than 1) was used, as shown in Table 6.6, explaining the variance of the six extracted factors respectively; PQ definition explains 14.05% of the total variance, Customer satisfaction explains 11.56% of the total variance, Management commitment explains 9.96% of the total variance, Employees participation and training explains 9.59% of the total variance, customer and company awareness explains 5.55% of the total variance, and PQ disturbances explains 3.85% of the total variance respectively.

Table 6.6: Eigenvalues and Percentage of Total Variance Explained of CSFs

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.781	14.06	14.058	4.781	14.058	14.058	3.771	11.088	11.088
2	3.932	11.57	25.623	3.932	11.565	25.623	3.459	10.175	21.263
3	3.387	9.963	35.586	3.387	9.963	35.586	3.271	9.619	30.881
4	3.262	9.594	45.181	3.262	9.594	45.181	2.793	8.215	39.096
5	1.887	5.551	50.731	1.887	5.551	50.731	2.712	7.975	47.071
6	1.311	3.852	54.582	1.311	3.852	54.582	2.554	7.511	54.582
7	0.998	2.936	57.517						
8	0.972	2.861	60.378						
9	0.944	2.778	63.155						
10	0.846	2.488	65.643						
11	0.793	2.333	67.976						
12	0.741	2.181	70.156						
13	0.735	2.161	72.317						
14	0.701	2.057	74.375						
15	0.683	2.009	76.383						
16	0.624	1.834	78.217						
17	0.583	1.715	79.933						
18	0.573	1.686	81.619						
19	0.553	1.625	83.245						
20	0.512	1.506	84.751						
21	0.488	1.435	86.186						
22	0.471	1.387	87.573						
23	0.464	1.363	88.936						
24	0.437	1.285	90.221						
25	0.409	1.204	91.425						
26	0.407	1.199	92.624						
27	0.381	1.121	93.744						
28	0.351	1.033	94.777						
29	0.341	1.002	95.778						
30	0.317	0.932	96.711						
31	0.308	0.905	97.615						
32	0.295	0.868	98.483						
33	0.271	0.793	99.277						
34	0.246	0.723	100						

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

6.4.2.4.2 Plot Scree

Primary statistics were derived from principal components analyses, which were employed to describe a Scree plot. This plots a graphic image representing the eigenvalue for every component extracted. The most important point is where the curve begins to flatten out. Therefore, It can be seen that the Scree starts to emerge between the seventh and eighth factors. This indicates of a clear change in the steepness of the curve at seven factors. Therefore, the first six factors explained much more of the variance than the remaining factors as shown in Figure 6.4.

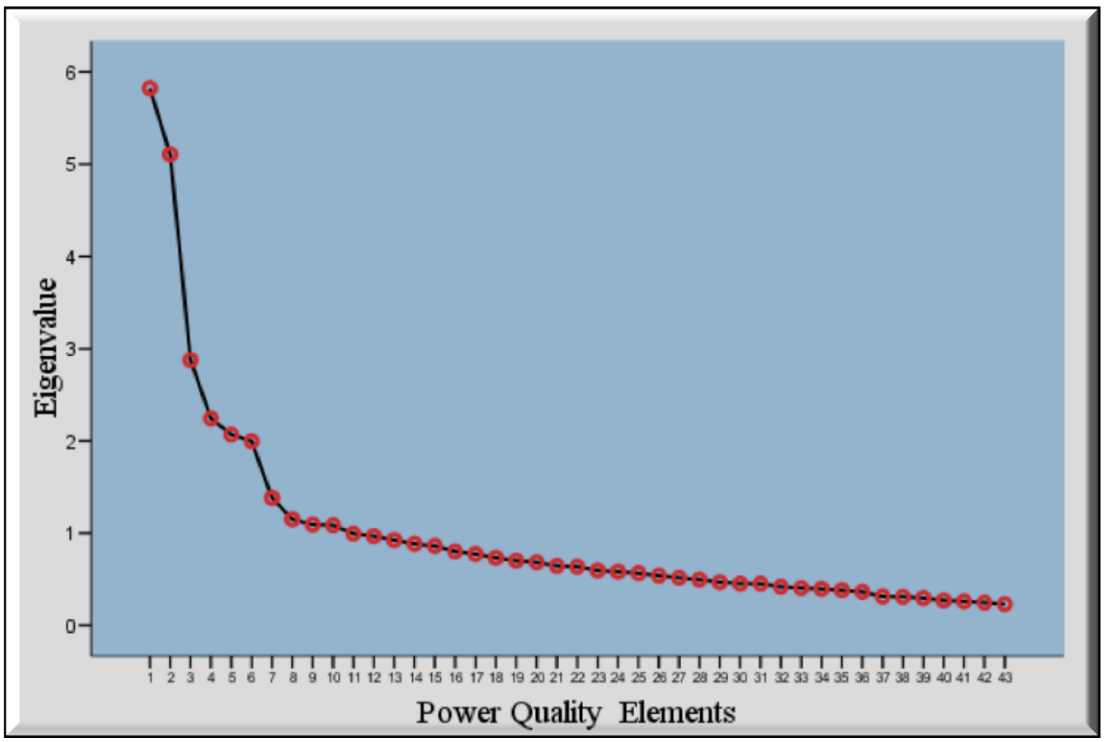


Figure 6.4: Scree Plot for PQ Improvements and Requirements Elements

This Scree test technique was used to select the suitable number of factors for extraction [214], which in general it considered to be mainly a suitable technique from the exploratory factor analysis (EFA) [233]. Six factors consisting of 34 items were extracted with Eigen values accounting for 54.582% of the total item variance, as shown in table (6.6).

6.4.2.4.3 Factor Rotation

The results of factors analysis in this study followed by the steps of the earlier tests of experts

[197][201] to identify the suitable rotation factor loading between each variable and its relative factors. The sample size of this research is (n=397 respondents), and the instructions were followed in this research based on Hair's [201] recommendation for determining a significant factor loading, which should be 0.3 and above at the significant value 0.5, as seen in Table 6.7. As result of that, the results of the rotation method show that the six rotated factors, all loadings above 0.40. Table 6.7 explains the six rotated factors; PQ definition explains 11.08% of the total variance, Customer satisfaction explains 10.17% of the total variance, Management commitment explains 9.61% of the total variance, Employees participation and training explains 8.21% of the total variance, customer and company awareness explains 7.97% of the total variance, and PQ disturbances explains 7.51% of the total variance respectively. Varimax rotation was used to support explanation of the six components. Seven items were excluded from this rotation, because they were cross loading with other factors. Factor loadings of the 34 items of the scale generated six factors, which were loading quite strongly, i.e. above 0.4, as presented in Table 6.7.

Table 6.7: Rotated Component Matrixes for PQP Elements

Label	Factors	Component					
		F1	F2	F3	F4	F5	F6
D	Q7	0.797					
	Q8	0.731					
	Q9	0.699					
	Q10	0.666					
	Q11	0.663					
CS	Q12		0.801				
	Q13		0.754				
	Q14		0.676				
	Q15		0.641				
	Q16		0.623				
MC	Q18			0.837			
	Q19			0.787			
	Q20			0.755			
	Q21			0.748			
	Q22			0.728			
	Q23			0.614			
EPT	Q24				0.766		
	Q25				0.711		
	Q26				0.701		
	Q27				0.671		

	Q28				0.642		
	Q29				0.571		
CCAW	Q30					0.754	
	Q31					0.748	
	Q33					0.666	
	Q34					0.651	
	Q35					0.641	
PQDS	Q50.4						0.803
	Q50.5						0.781
	Q50.6						0.763
	Q50.7						0.751
	Q50.8						0.661
	Q50.9						0.659
	Q50.10						0.655
	Eigenvalues	4.781	3.932	3.387	3.262	1.887	1.311
	% of Variance	11.088	10.175	9.619	8.215	7.975	7.511
	Cumulative %	11.088	21.263	30.881	39.096	47.071	54.582
	Cronbach α	0.769	0.811	0.841	0.806	0.745	0.851

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization
Rotation converged in 7 iterations.

The six factors and their items are stated below as follows:

Factor One: PQ Definitions Construct. This factor consists of 5 questions (7-11), which are Reliability and Availability, Satisfy Customers, Reduce Losses, Customer Awareness and Increase Efficiency. The entire five questions were distilled into a single factor and verify that all the items selected to measure **(PQD)** are statistically valid and reached statistical significance level, which supported the factorability of the correlation matrix [200]. The Cronbach alpha score for this factor **(PQD)** is 0.769.

Factor Two: PQ Customer Satisfaction Construct. This factor consists of 5 questions (12-16), which are Customer Complaints, Customer Satisfaction, Customers' Needs, Improvement for Customers and Customer Awareness. The entire five questions were distilled into a single factor, and verified that all the items selected to measure **(PQCS)** are statistically valid and reached statistical significance level, which supporting the factorability of the correlation matrix [200]. The Cronbach alpha score for this factor **(PQCS)** is 0.811.

Factor Three: PQ Management Commitment Construct. This factor consists of 7 questions (17-23), but question 17 was deleted to improve the overall reliability. The questions are: Identifies the Causes, Inaccurate Managerial Decision, Planning Good Strategy, Following the recommendations and studies, Ensure Security and Quality and International or National Benchmarks. The entire six questions were distilled into a single factor, and verified that all the items selected to measure **(PQMC)** are statistically valid and reached statistical significance level, which supporting the factorability of the correlation matrix [200]. The Cronbach alpha score for this factor **(PQMC)** is 0.841.

Factor Four: PQ Employee Participation and Training Construct. This factor consists of 6 questions (24-29), which are Survey or Feedback Techniques, Sufficient Training, Employees Suggestions, Employees Strategies, Appropriate Qualifications and Employees Involvement. The entire six questions were distilled into a single factor and verify that all the items selected to measure **(PQEPT)** are statistically valid and reached statistical significance level, which supported the factorability of the correlation matrix [200]. The Cronbach alpha score for this factor **(PQEPT)** is 0.806.

Factor Five: PQ Customers and Company Awareness Construct. This factor consists of 8 questions (30-37) but question 32, 36 and 37 were deleted to improve the overall reliability. The questions are Waste Use, Faulty Connection, Proper Design, Concept of PQ, Utility Faults, Illegal way and Bad Design. The entire seven questions were distilled into a single factor, and verified that all the items selected to measure **(PQCCA)** are statistically valid and reached statistical significance level, which supported the factorability of the correlation matrix [200]. The Cronbach alpha score for this factor **(PQCCA)** is 0.745.

Factor Six: PQ Disturbances Affecting Networks Construct**.** This factor consists of 7 questions (50.1-50.8), but question 50.1, 50.2, 50.3 were deleted to improve the overall reliability. The questions are Transients, Surge and Unbalance, Harmonics, Low Power Factor, Over Voltage, Under Voltage, Outage and Voltage Sags and Swells. The entire seven questions were distilled into a single factor, and verified that all the items selected to measure **(PQDANs)** are statistically valid and reached statistical significance level, which supported the factorability of the correlation matrix [200]. The Cronbach alpha score for this factor **(PQCCA)** is 0.851.

6.5 Correlation Analysis

Correlation is a technique used to measure the relationship or strength between two or more items or sets of data. This study has tested the linearity of the relationships between items as well. It used the bivariate correlation matrix at the 0.01 significance level (2-tailed) to determine the linearity and multicollinearity of the CSFs of PQP. Pearson's Coefficient (r) is most commonly used in general with continuous variables and expressed in the form of a coefficient with +1.00 indicating a perfect positive correlation; -1.00 indicating a perfect negative correlation; 0.00 indicating a complete lack of a relationship [197][201]. Table 6.8 shows the Pearson correlation between all pairs of the five CSFs, which used in this study to identify if there is any significant correlation among these factors to implement PQP. The five factors were PQDs Definitions, PQCS (Customer Satisfaction), PQMC (Management Commitment), PQEPT (Employee Participation and Training) and PQCCA (Customers and Company Awareness) throughout the three networks.

Table 6.8: Pearson's correlation the CSFs of PQP in Three Networks

Networks	CSFs of PQP	PQD	PQCS	PQMC	PQEPT	PQCCA
West Network	PQ. Definitions (D)	1				
	Customers Satisfaction (CS)	0.256**	1			
	Management Commitment (MC)	0.299**	0.486**	1		
	Employees Participation and Training (EPT)	0.361**	0.482**	0.485**	1	
	Customers and Company Awareness (CCA)	0.559**	0.595**	0.597**	0.621**	1
East Network	CSFs of PQP	PQD	PQCS	PQMC	PQEPT	PQCCA
	PQ. Definitions (D)	1				
	Customers Satisfaction (CS)	0.408**	1			
	Management Commitment (MC)	0.338**	0.470**	1		
	Employees Participation and Training (EPT)	0.486**	0.641**	0.554**	1	
	Customers and Company Awareness (CCA)	0.568**	0.610**	0.431**	0.551**	1
South Network	CSFs of PQP	PQD	PQCS	PQMC	PQEPT	PQCCA
	PQ. Definitions (D)	1				
	Customers Satisfaction (CS)	0.618**	1			
	Management Commitment (MC)	0.442**	0.464**	1		
	Employees Participation and Training (EPT)	0.481**	0.497**	0.665**	1	
	Customers and Company Awareness (CCA)	0.661**	0.715**	0.554**	0.657**	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

From table 6.8, it is clear that the correlations of the entire five CSFs of PQP are positive and statistically significant. High correlation appeared between the Employee Participation and

Training (PQEPT) and Customers and Company Awareness (PQCCA), with Pearson's Coefficient (r) of (0.621**) in the west network. Another high correlation appeared between the Employee Participation and Training (PQEPT) with Customer Satisfaction (PQCS) with (0.641**) in east network. Customer Satisfaction (PQCS) with Customers and Company Awareness (PQCCA) were highly correlated (0. 715**), which was strong enough be proved statistically in south network.

The correlations within the CSFs of PQP were tested to check the PQP implementation in LDNs. The test pointed out that all five factors were positively correlated. Therefore, this indicates that a PQP should be implemented for the Customers and Company Awareness with Employee Participation and Training in west network and Customers and Company Awareness with Customer Satisfaction in south network. This programme should be implemented holistically compared to gradually, to increase the awareness level of PQ across the two networks. Another indication is seen in Employee Participation and Training with Customer Satisfaction in east network to increase the level of satisfaction for both staff and customers. A holistic programme is a major factor to provide all these structures and studies to implement the critical success factor for PQ awareness, and in case of such LDNs, it is not easy to be implemented. The reason is that it includes network design based on manageable planning, and solving technical problems based on including people's skills, experience and customer awareness in the PQPs provided by the utility. The most important element is that if the distribution network is designed with a clear strategy, then it can reduce the pressure of demand, and will function effectively without any deviations [75]. Therefore, LDNs should be ready and enthusiastic to implement PQP awareness, which would improve the overall level of PQP implementation.

6.6 Descriptive Analysis

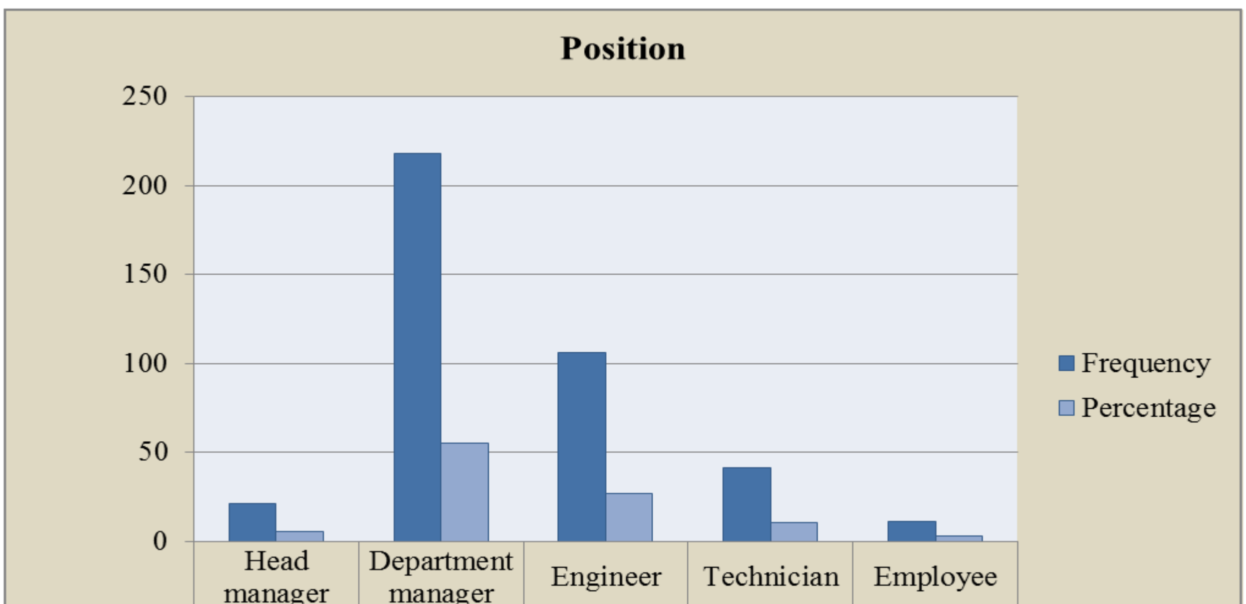
Descriptive analysis is a technique used in this study to describe and explain items either graphically or numerically to link the conclusions, which are based on the statistical analysis of a particular group of items or for specific observed cases. This technique includes both the univariate measures of dispersion and the central tendency, comprising means, medians, standard deviations, and percentages of the items. These analyses could generate the information to describe the correlation between items, for instance, regression prediction equations or correlation coefficients.

6.6.1 General Characteristics of the Sample

The crucial purpose of the section on descriptive analysis is to describe the respondents, who participated in this study and completed the survey, with regard to the following demographic variables: job position, level of education, work experience, and work responsibilities in each network. The following tables and figures give the descriptive information, which measures the descriptive statistics of the central tendency and the dispersion.

6.6.1.1 Job position

Figure 6.5 shows the different employee categories, in terms of job position in the three distribution networks, of those who participated in the survey. Department managers participated greatly, representing approximately (54.91%) of the total number of 397 respondents. This group includes the middle managers in Repair & Maintenance, Operation, Control, Production, Sales, Marketing and Design, who can criticise the level of power quality in their networks, and the extent to which they dealt with PQDs, in terms of mitigation or diagnosis.



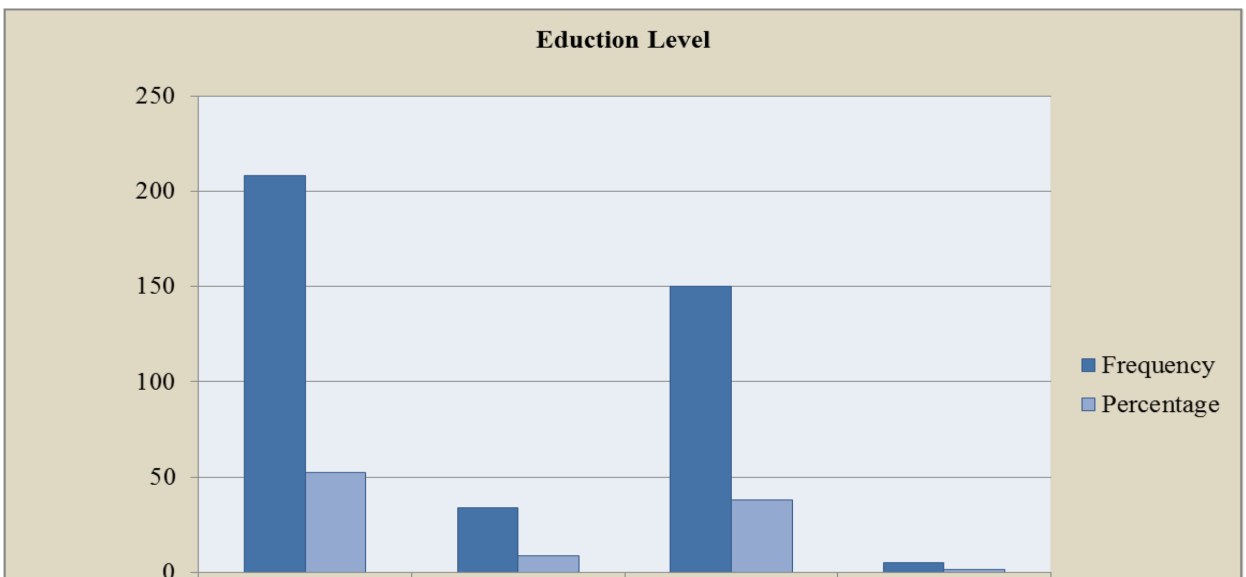
	Head manager	Department manager	Engineer	Technician	Employee
Frequency	21	218	106	41	11
Percentage	5.3	54.9	26.7	10.3	2.8

Figure 6.5: Employees' Position in the three Networks

Figure 6.5 also shows that roughly (26.7%) represent engineers, who dealt with these disturbances in the three networks, in the areas of Repair & Maintenance, Operation, Control and Design. This percentage of participation by engineers can give an indication of how they solved PQ events and what strategies or PQP was followed in order to diagnose the issues. It may also refer to the level of PQ awareness, in whether they were aware of it or not. Technicians also participated (10.3%) in this survey, as they have a role in solving any PQDs. This would help to determine what level of awareness they have in regard to PQ. Around (5.3%) of the respondents were head managers, who are the main and final decision makers regarding solving PQ problems in a country, such as Libya, as they decide the policies and strategies to be followed when facing any PQ problems. employees represented only (2.8%) of the number of respondents. The aim is to have a good environment for PQ promotion and support, as needed to increase the level of PQ, and also to create a PQP, which all the participants can interact with, in both PQ awareness and improvements; so they must have a clear strategy and good plans, as success factors to meet future requirements.

6.6.1.2 Level of Education

Training courses are crucial in contributing new knowledge regarding PQ issues, and in the success of diagnosing and mitigating the problems, in order to resolve PQDs. Using the advanced techniques of PQ analysis needs a high level of education for those involved see Figure 6.6.



	High diploma	High school deploma	Undergraduate degree	Post graduate degree
Frequency	208	34	150	5
Percentage	52.4	8.6	37.8	1.3

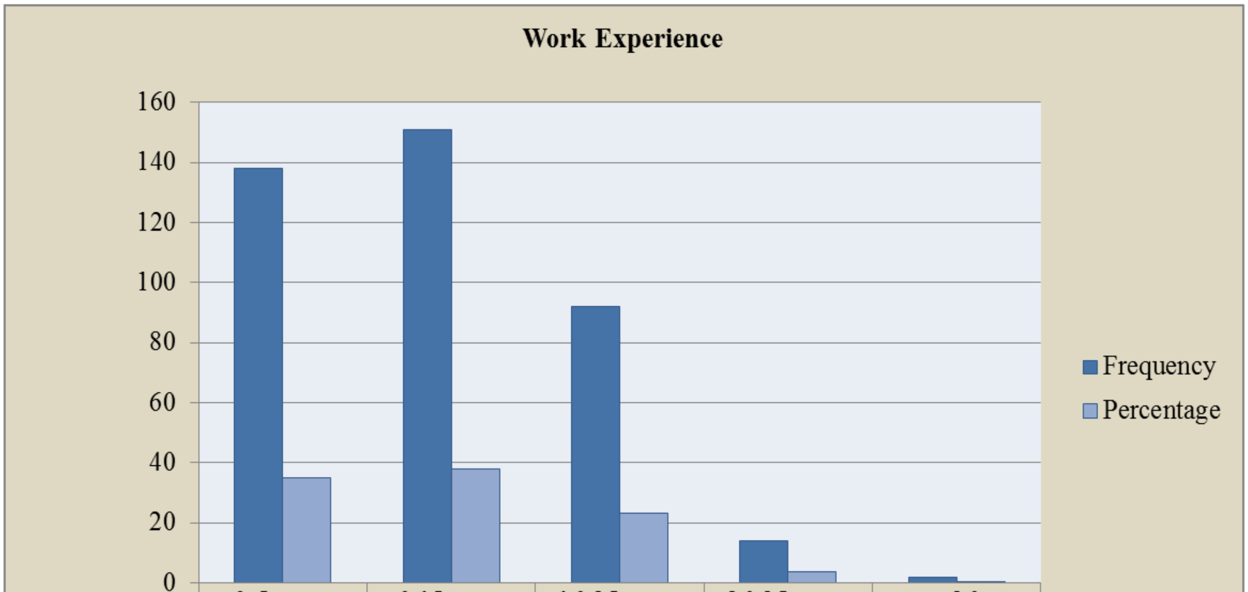
Figure 6.6: Employees' Level of Education

The level of education of respondents was categorised into four groups; (1) High School Diploma (8.6%), (2) High Diploma (52.4%), (3) Undergraduate Degree (37.8%), and (4) Postgraduate Degree (1.3%). The figure above shows that the majority of respondents (52.4%) hold the educational qualification of high diploma degree, considered the minimum educational qualification. This means that they are knowledgeable and able to understand and participate in completing the questionnaire. In order to deal with PQDs, this level of education would also enable them to cope with the current level of severity of PQDs. However, they would still lack the appropriate understanding to implement a PQP across the three networks. Engineers and technicians need to be better educated and trained to be able to deal with PQ issues, and find urgent and appropriate solutions that reduce the disturbances. Undergraduate degrees are required by GECOL as the baseline for greater responsibility, as personnel must be knowledgeable and able to cope with the new technologies and positions, compared to other lower levels of education.

From the data shown in figure 6.6, it can be said that LDNs' employees are well educated; however, they needed to be trained further, and given the motivation, which would increase the level of awareness of power quality, and contribute to participation in the implementation of improvements to LDNs. The data above shows that postgraduate qualifications are rarely found in the three networks at (1.3%). This means that most employees, who participated in solving PQDs, have high diploma and undergraduate qualifications, and so, need to be better trained to deal with these problems.

6.6.1.3 Years of Experience

Figure 6.7 shows that the years of experience of respondents are categorised into five different groups; (1) 0-5 years (34.8%), (2) 6-15 years (38%), (3) 16-25 years (23.2%), (4) 26-35 years (3.5%) and (5) 36 or more years (0.5%). A long period of experience means the respondents are more aware and knowledgeable about any issues regarding PQ. Such employees should have sufficient experience in participating in at least one or more jobs, since they started across the distribution network, where they can be ready to deal with any improvement related to PQDs. However, a lack of PQ training courses by the GECOL could be one of the reasons preventing the implementation of a PQP to date. The PQP would provide for proper quality of electricity, as well as giving staff the proper skills and experience.



	0-5 years	6-15 years	16-25 years	26-35 years	>36
Frequency	138	151	92	14	2
Percentage	34.8	38	23.2	3.5	0.5

Figure 6.7: Employees' Level of Working Experience

Almost 38% of the respondents have between 6 and 15 years' experience in the three networks. As a result, this indicates that most of the respondents have adequate and accurate data, enabling the researcher to be able to criticise the level of PQ across the three networks, based on their responses. More than 55% of the respondents were department managers, who had been with their networks for more than 10 years. Almost 26.7% of the respondents who answered question 1 were found to be engineers with approximately more than 10 years' experience in the areas of Repair & Maintenance, Operation and Design.

6.6.1.4 Job Responsibility

The distribution of respondents, in terms of areas of responsibility for both department managers and engineers, were: 35.3% in the Repair & Maintenance department, 32.7% in the Operation department, and nearly 20% from the Design department, as shown in Figure 6.8. This indicates that the responses of department managers should reflect awareness of the history of PQDs stated in this survey. Engineers should be familiar and have sufficient experience to deal with these disturbances. However, as mentioned earlier, lack of training courses in power quality has caused significant delay for the employees, specifically the engineers, who should cope with these disturbances and solve them.

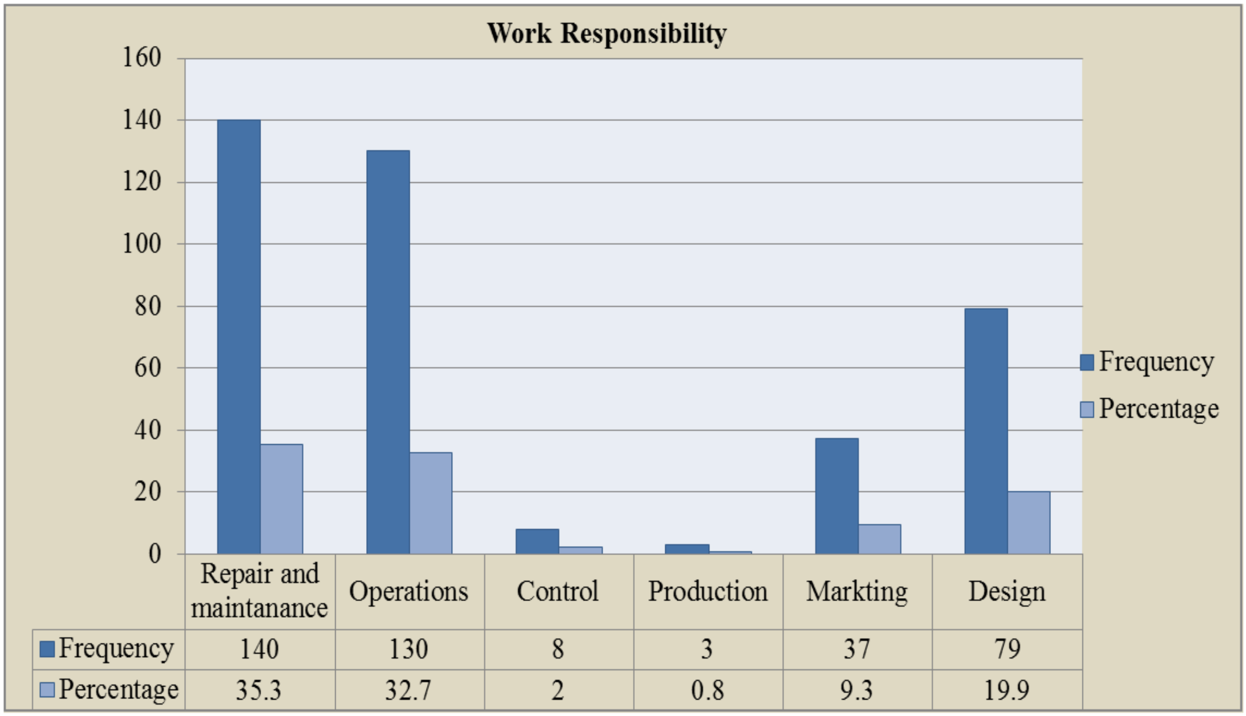


Figure 6.8: Employees' Level of Working Responsibility

In general, today, PQ problems are addressed in taught courses, due to their significant importance, especially in terms of the awareness and knowledge of engineers and technicians. Therefore, to address power quality issues in LDNs, more education and training need to be provided to employees.

6.7 The level of PQP Implementation in Libyan distribution Network (LDNs)

The level of implementation of PQP was the main focus of investigation in this survey. Table 6.9 shows that all seven factors have scored a mean, ranging from 2.22 to 4.03, on a 5 point Likert scale. PQ Definitions was given the highest overall mean rating of (4.03), and is the only factor, which gained the highest level of implementation of power quality on the 1-5 scale, while Employee Participation and Training (2.22) was the lowest scoring factor. Customers and Company Awareness (3.19) was the second highest scoring factor. Other factors that scored in the low range of implementation were Management Commitment (2.24), Customer Satisfaction (2.47), Disturbances Affecting Networks (2.86), and Disturbances Malfunction Users Tools (3.03). The overall mean for all seven CSFs was (2.86) with a low standard deviation of (0.71), which signifies an overall level of PQ awareness. The level of PQP implementation can be derived from the mean ratings or scores of all items in the survey instrument. The rating scale used in this survey ranged from 1-5; therefore, the average points indicated that the level of PQP implementation was low, which seems to be significantly low when compared to other studies [36]. This may refer to LDNs striving to implement PQP effectively. However, implementation is at a low level, in the current situation, where it hardly executes a programme, unless the main factors improve, as shown in Table 6.9.

Table 6.9: The Mean Level of all items of Implementation factors for PQP

Factor	**Item No**	**Description**	**Mean**	**S.D**	**Overall Mean**
X2.1:Definitions(D)	X2.1.7	D/Reliability and Availability	4.20	0.922	**4.03**
	X2.1.8	D/Satisfy Customers	4.10	0.922	
	X2.1.9	D/Reduce Losses	4.17	1.053	
	X2.1.10	D/Customers Awareness	**3.46**	1.151	
	X2.1.11	D/Increase Efficiency	**4.26**	0.846	
Factor	Item No	Description	Mean	S.D	Overall Mean
X2.2:Customers Satisfaction (CS)	X2.2.12	CS/Customer Complaints	**2.69**	1.039	**2.47**
	X2.2.13	CS/Customer Satisfactions	2.31	0.963	
	X2.2.14	CS/Customers' Needs	2.66	1.063	
	X2.2.15	CS/Improvement for Customers	2.44	1.015	
	X2.2.16	CS/Customer Awareness	**2.28**	0.871	
Factor	Item No	Description	Mean	S.D	Overall Mean
X2.3: Management Commitment(MC)	X2.3.17	MC/Identifies The Causes	2.23	1.060	**2.24**
	X2.3.18	MC/Responsibility	**2.03**	1.102	
	X2.3.19	MC/Planning Good Strategy	2.35	1.087	
	X2.3.20	MC/ Recommendations and Studies	**2.70**	0.937	
	X2.3.22	MC/Ensure Security and Quality	2.12	1.052	
	X2.3.23	MC/International or a National Benchmarks	2.06	1.076	
Factor	Item No	Description	Mean	S.D	Overall Mean
X3.1Employees Participation and Training (EPT)	X3.1.24	EPT/Survey or Feedback Techniques	**2.62**	1.147	**2.22**
	X3.1.25	EPT/Sufficient Training	2.21	1.173	
	X3.1.26	EPT/Employees Suggestion	2.29	1.120	
	X3.1.27	EPT/Employees Strategies	2.15	1.097	
	X3.1.28	EPT/Appropriate Qualifications	**2.01**	1.035	
	X3.1.29	EPT/Employees Involvement	2.05	1.092	

Factor	Item No	Description	Mean	S.D	Overall Mean
X3.2:Customers and Company Awareness(CCA)	X3.2.30	CCA/Waste Use	3.06	0.952	**3.19**
	X3.2.31	CCA/Faulty Connection	3.09	0.965	
	X3.2.32	CCA/Mixed Users	3.09	1.002	
	X3.2.33	CCA/Concept of Power Quality	3.01	0.863	
	X3.2.35	CCA/Utility Faults	**2.92**	0.957	
	X3.2.36	CCA/Illegal connect	3.34	0.732	
	X3.2.37	CCA/Bad Design	**3.81**	0.934	
Factor	**Item No**	**Description**	**Mean**	**S.D**	**Overall Mean**
X4.3:Disturbances Affecting Networks (DANs)	X4.3.50.4	DANs/Transient, Surge and Unbalance.	2.84	1.301	**2.86**
	X4.3.50.5	DANs/Harmonics	**2.75**	1.298	
	X4.3.50.6	DANs/Low Power Factor	2.81	1.295	
	X4.3.50.7	DANs/Over Voltage.	2.78	1.297	
	X4.3.50.8	DANs/Under Voltage	**3.08**	1.181	
	X4.3.50.9	DANs/Voltage Swell.	3.01	1.447	
	X4.3.50.10	DANs/Voltage Sags	2.77	1.091	
Factor	**Item No**	**Description**	**Mean**	**S.D**	**Overall Mean**
X4.4:Disturbances Malfunction Users Tools(DMUTs)	X4.4.51.2	DMUTs/ Harmonics	3.51	1.411	**3.03**
	X4.4.51.3	DMUTs/ Under and Over Voltage	3.52	1.332	
	X4.4.51.4	DMUTs/Transients and Surge	3.52	1.321	
	X4.4.51.5	DMUTs/Unbalance	3.47	1.332	
	X4.4.51.6	DMUTs/ Voltage Sags and swells	**3.68**	1.349	
	X4.4.51.7	DMUTs/ Long Interruption > 1 min	3.44	1.335	
	X4.4.51.8	DMUTs/ Outage	**3.16**	1.407	

The mean level of all items regarding the implementation factors for PQP is shown in table 6.9. Therefore, to reach a better understanding of the level of PQP implementation within LDNs, additional analysis was conducted to answer the research question (2).

> *What is the current state of PQ awareness and efforts regarding the implementation of PQP in LDNs?*

As the survey was designed on a five-point Likert scale, where “1” referred to strongly disagree, and “5” indicated strongly agree for each statement. Thus, the response scale was divided into three levels: low level (1 to 2), medium level (3), high level (4 to 5). This was done to help the participants approximate the level of implementation of each of the seven factors.

Table 6.10: The Distribution of Responses according to the above Scale.

Factors	Mean	S.D	Percentage Distribution of Mean Score %		
			High 4-5	Medium 3	Low 1-2
X2.1:Definitions(D)	**4.03**	0.627	83	14.4	2.6
X2.2:Customers Satisfaction (CS)	2.47	0.610	1.3	20.2	78.5
X2.3:Management Commitment(MC)	2.24	0.596	0.0	15.6	84.4
X3.1:Employees Participation and Training (EPT)	**2.22**	0.686	1.4	17.2	81.4
X3.2:Customers and Company Awareness(CCA)	3.19	0.600	9.0	52.7	38.3
X4.3:Disturbances Affecting Networks (DANs)	2.86	0.917	27.1	36	36.9
X4.4:Disturbances Malfunction Users Tools(DMUTs)	3.03	0.824	12.9	45.3	41.8
Overall Mean	**2.86**				

Table 6.10 revealed a low level of PQP implementation in LDNs. This finding was not accidental, as LDNs have not adopted any PQ standards, e.g. IET, IEE or IEC standards, which would reduce PQDs. Moreover, the lack of PQ awareness, among top management, employees and end users, was the main and critical aspect, and an obstacle to understanding the significant outcome that will be gained, if a PQP is implemented. Therefore, lack of top management responsibility in setting a clear and long-term strategy, in order to implement a PQP to change the current situation. As a result, one of management's commitments is to focus on strategy, networks design, training courses and PQ measurements, in order to meet customer needs. Employees are a part of these changes, and so their awareness, skills and knowledge should be at an acceptable level; high enough to deal with end users' complaints, and have better understanding of both PQ definitions and PQDs so as to satisfy customers.

6.8 Test of Significance on the Difference of Means

MANOVA was used in this analysis to reveal the differences between the levels of PQ awareness regarding the CSFs derived from the literature for PQP implementation within LDNs in GECOL, and employee characteristics, in terms of position, education, responsibility and experience, needed for satisfying future needs. MANOVA is one of the best techniques to test the differences between groups, which could avoid the risk of getting a type 1 and type 2 errors. Moreover, it can recognize the differences in mean values between groups, when several dependent variables are examined concurrently [197][201]. The (P) value of MANOVA indicates whether the difference between groups is "statistically significant". Yet, the probability values do not determine the degree if the two dependent variables are associated with one another. Therefore, the effect size (Eta squared) was chosen in this research to identify the extent of the effect of independent variables on dependent variables. Moreover, MANOVA was designed to examine whether or not any of the five CSFs are statistically different within LDNs, by generating the following question;

Are there any statistically significant differences between the level of power quality awareness regarding to employee characteristics, in terms of position, education, responsibility and experience within Libyan distribution networks, and the success factors derived from the literature needed for implementation of power quality for satisfying future needs?

6.8.1 Work Position

A one-way multivariate analysis of variance between groups was performed to investigate if there are significant differences between the level of PQ awareness regarding the CSFs derived from the literature for PQP implementation within LDNs in GECOL and employees' work position. Five dependent variables were used: (Customer Satisfaction, Management Commitment, Employee Participation and Training, Customers and Company Awareness and Power Quality Disturbances Affecting Networks) and work position. Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity, with no serious violations noted.

West Network

The result of MANOVA revealed that there was no statistically significant difference in the levels of PQ awareness between Head Manager, Department Manager, Engineer, Technician and Employee position on the combined dependent variables in west network: Wilks' Lambda = 0.866; $F (5, 498) = 1.101$; $P=0.344$, ($P > 0.05$); partial Eta squared = 0.035. An inspection of the mean scores indicated that employees reported slightly higher scores of PQP factors compared to Head Manager, Department Manager, Engineer and Technician, as shown in Table 6.11. According to [234] argument, Eta squared equal to 0.035, the effect of work position level on PQP factors in west network was considered small (Eta squared < 0.06).

Table 6.11: Means and Std. Deviation for CSFs of PQP by Work Position in West Network

CSFs of PQP	Head Manager (N=8)		Department Manager (N=84)		Engineer (N=59)		Technician (N=6)		Employee (N=2)	
	M	SD	M	SD	M	SD	M	SD	M	SD
Customers Satisfaction	2.58	0.767	2.41	0.658	2.52	0.673	2.37	0.513	3.21	0.566
Management Commitment	2.39	0.806	2.18	0.571	2.28	0.543	2.42	0.431	3.01	0.001
Employees Participation and Training	2.23	0.604	2.27	0.709	2.11	0.671	2.17	0.989	2.25	0.354
Customers and Company Awareness	4.28	0.281	3.99	0.449	3.86	0.489	3.83	0.589	3.38	1.414
PQ Disturbances Affecting Networks	2.88	0.749	2.78	0.895	2.81	0.934	3.26	0.774	2.51	0.707

East Network

The result of MANOVA revealed that there was no statistically significant difference in the levels of PQ awareness between Head Manager, Department Manager, Engineer, Technician and Employee position on the combined dependent variables in east network: Wilks' Lambda = 0.837; $F (5, 405) = 1.119$; $P=0.327$, $(P > 0.05)$; partial Eta squared = 0.044. An inspection of the mean scores indicated that Technician reported slightly higher scores of PQP factors compared to Head Manager, Department Manager, Engineer and employees, as shown in Table 6.12. According to [234] argument, Eta squared equal to 0.044, the effect of work position level on PQP factors in east network was considered small (Eta squared < 0.06).

Table 6.12: Means and Std. Deviation for CSFs of PQP by Work Position in East Network

CSFs of PQP	Head Manager (N=8)		Department Manager (N=95)		Engineer (N=11)		Technician (N=13)		Employee (N=4)	
	M	SD	M	SD	M	SD	M	SD	M	SD
Customers Satisfaction	2.38	0.729	2.42	0.574	2.47	0.546	2.66	0.602	2.65	0.641
Management Commitment	2.46	0.689	2.18	0.552	2.26	0.559	2.19	0.601	2.17	1.114
Employees Participation and Training	0.00	0.00	2.11	0.725	2.52	0.776	2.33	0.514	2.01	0.192
Customers and Company Awareness	4.27	0.182	4.06	0.523	3.91	0.647	4.36	0.478	4.13	0.102
PQ Disturbances Affecting Networks	2.11	0.715	2.66	0.901	2.75	0.712	3.08	0.874	2.57	0.559

South Network

The result of MANOVA revealed that there was no statistically significant difference in the levels of PQ awareness between Head Manager, Department Manager, Engineer, Technician and Employee position on the combined dependent variables in south network: Wilks' Lambda = 0.772; F (5, 325) = 1.322; P=0.162, (P > 0.05); partial Eta squared = 0.063. An inspection of the mean scores indicated that Technician reported slightly higher scores of PQP factors compared to Head Manager, Department Manager, Engineer and employees as shown in Table 6.13. According to [234] argument, Eta squared equal to 0.063, the effect of work position level on PQP factors in south network was considered medium (Eta squared > 0.06).

Table 6.13: Means and Std. Deviation for CSFs of PQP by Work Position in South Network

CSFs of PQP	Head Manager (N=5)		Department Manager (N=39)		Engineer (N=36)		Technician (N=22)		Employee (N=5)	
	M	SD	M	SD	M	SD	M	SD	M	SD
Customers Satisfaction	2.52	0.889	2.54	0.505	2.43	0.489	2.53	0.655	3.04	0.607
Management Commitment	2.23	0.742	2.44	0.569	2.19	0.648	2.23	0.809	2.43	0.303
Employees Participation and Training	2.61	0.673	2.38	0.662	2.31	0.591	2.09	0.661	2.87	0.506
Customers and Company Awareness	3.51	1.086	4.13	0.371	3.93	0.491	4.19	0.561	3.71	0.338
PQ Disturbances Affecting Networks	3.23	0.412	3.05	0.973	2.95	0.803	2.82	1.114	3.26	0.829

6.8.2 Education Level

Another examination of a one-way multivariate analysis of variance between groups was performed to investigate if there are significant differences between the level of PQ awareness regarding the CSFs derived from the literature for PQP implementation within LDNs in GECOL and employee's education level. Five dependent variables were used: (Customer Satisfaction, Management Commitment, Employee Participation and Training, Customers and Company Awareness and Power Quality Disturbances Affecting Networks) and employee's education level. Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity, with no serious violations noted.

West Network

The result of MANOVA revealed that there was no statistically significant difference in the levels of PQ awareness between High School Diploma, High Diploma, Undergraduate Degree and Postgraduate Degree holders on the combined dependent variables in west network: Wilks'

Lambda = 0.904; F (5, 417) = 1.033; P=0.419, (P > 0.05); partial Eta squared = 0.033. An inspection of the mean scores indicated that Undergraduate Degree holders reported slightly higher scores of PQP factors compared to High school Diploma, High Diploma and Postgraduate Degree as shown in Table 6.14. According to [234] argument, Eta squared equal to 0.033, the effect of education level on PQP factors was considered small (Eta squared < 0.06).

Table 6.14: Means and Std. Deviation for CSFs of PQP by Education Level in West Network

CSFs of PQP	High School Diploma (N=4)		High Diploma (N=83)		Undergraduate Degree (N=69)		Postgraduate Degree (N=3)	
	M	SD	M	SD	M	SD	M	SD
Customers Satisfaction	2.55	0.551	2.41	0.615	2.49	0.721	3.27	0.306
Management Commitment	2.63	0.658	2.19	0.539	2.28	0.609	2.33	0.441
Employees Participation and Training	2.04	0.725	2.11	0.666	2.31	0.719	2.78	0.694
Customers and Company Awareness	3.91	0.553	3.94	0.502	3.94	0.475	4.01	0.331
PQ Disturbances Affecting Networks	2.75	0.844	2.69	0.876	2.96	0.919	2.71	0.515

East Network

The result of MANOVA revealed that there was no statistically significant difference in the levels of PQ awareness between High school Diploma, High Diploma, Undergraduate Degree and Postgraduate Degree holders on the combined dependent variables in east network: Wilks' Lambda = 0.829; F (5, 339) = 1.589; P=0.075, (P > 0.05); partial Eta squared = 0.061. An inspection of the mean scores indicated that High school Diploma Degree holders reported slightly higher scores of PQP factors compared to High Diploma, Undergraduate Degree and Postgraduate Degree as shown in Table 6.15. According to [234] argument, Eta squared equal to 0.061, the effect of education level on PQP factors was considered medium (Eta squared > 0.06).

Table 6.15: Means and Std. Deviation for CSFs of PQP by Education Level in East Network

CSFs of PQP	High School Diploma (N=11)		High Diploma (N=83)		Undergraduate Degree (N=36)		Postgraduate Degree (N=1)	
	M	SD	M	SD	M	SD	M	SD
Customers Satisfaction	2.67	0.561	2.41	0.557	2.43	0.596	4.01	0.00
Management Commitment	2.31	0.662	2.11	0.558	2.36	0.575	3.01	0.00
Employees Participation and Training	2.36	0.521	2.13	0.676	2.08	0.759	4.01	0.00
Customers and Company Awareness	4.32	0.401	4.09	0.439	4.05	0.682	3.75	0.00
PQ Disturbances Affecting Networks	3.04	0.826	2.61	0.881	2.69	0.882	3.29	0.00

South Network

The result of MANOVA revealed that there was no statistically significant difference in the levels of PQ awareness between High school Diploma, High Diploma, Undergraduate Degree and Postgraduate Degree holders on the combined dependent variables in south network: Wilks' Lambda = 0.852; F (5, 273) = 1.091; P=0.365, (P > 0.05); partial Eta squared = 0.052. An inspection of the mean scores indicated that High Diploma holders reported slightly higher scores of PQP factors compared to High school Diploma, Undergraduate Degree and Postgraduate Degree as shown in Table 6.16. According to [234] argument, Eta squared equal to 0.052, the effect of education level on PQP factors was considered small (Eta squared < 0.06).

Table 6.16: Means and Std. Deviation for CSFs of PQP by Education Level in South Network

CSFs of PQP	High School Diploma		High Diploma		Undergraduate Degree		Postgraduate Degree	
	(N=19)		(N=42)		(N=45)		(N=1)	
	M	SD	M	SD	M	SD	M	SD
Customers Satisfaction	2.51	0.496	2.73	0.584	2.35	0.509	2.01	0.00
Management Commitment	2.32	0.709	2.28	0.623	2.32	0.668	2.51	0.00
Employees Participation and Training	2.34	0.719	2.38	0.618	2.29	0.652	2.01	0.00
Customers and Company Awareness	4.05	0.492	4.08	0.478	3.96	0.574	4.51	0.00
PQ Disturbances Affecting Networks	2.98	1.223	2.84	0.791	3.12	0.891	3.57	0.00

6.8.3 Work experience

Another test of a one-way multivariate analysis of variance between groups was performed to investigate if there are significant differences between the level of PQ awareness regarding the CSFs derived from the literature for PQP implementation within LDNs in GECOL and employees' work experience. Five dependent variables were used: (Customer Satisfaction, Management Commitment, Employee Participation and Training, Customers and Company Awareness and Power Quality Disturbances Affecting Networks) and work experience. Preliminary assumption testing was conducted again to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity, with no serious violations noted.

West Network

The result of MANOVA revealed that there was no statistically significant difference in the levels of PQ awareness between employee working experiences on the combined dependent variables in west network: Wilks' Lambda = 0.861; F (5, 498) = 1.148; P=0.297, (P > 0.05); partial Eta squared = 0.037. An inspection of the mean scores indicated that employees experience from 6 to 15 years reported slightly higher scores of PQP factors compared to other working experience periods, as shown in Table 6.17. According to [234] argument, Eta squared equal to 0.037, the effect of work experience level on PQP factors was considered small (Eta squared < 0.06).

Table 6.17: Means and Std. Deviation for CSFs of PQP by work experience in West Network

CSFs of PQP	0-5 years (N=60)		6-15 years (N=62)		16-25 years (N=32)		26-35 years (N=4)	
	M	SD	M	SD	M	SD	M	SD
Customers Satisfaction	2.47	0.625	2.44	0.711	2.56	0.669	2.05	0.526
Management Commitment	2.21	0.531	2.35	0.541	2.17	0.689	1.96	0.551
Employees Participation and Training	2.11	0.636	2.21	0.782	2.34	0.629	2.67	0.491
Customers and Company Awareness	3.96	0.327	3.92	0.638	3.96	0.381	4.09	0.401
PQ Disturbances Affecting Networks	2.75	0.895	2.96	0.872	2.57	0.872	2.89	1.026

East Network

The result of MANOVA revealed that there was no statistically significant difference in the levels of PQ awareness between employee working experiences on the combined dependent variables in east network: Wilks' Lambda = 0.938; F (5, 339) = 0.528; P=0.923, (P > 0.05); partial Eta squared = 0.021. An inspection of the mean scores indicated that employees experience from 16 to 25 years reported slightly higher scores of PQP factors compared to other working experience periods, as shown in Table 6.18. According to [234] argument, Eta squared equal to 0.021, the effect of work experience level on PQP factors was considered small (Eta squared < 0.06).

Table 6.18: Means and Std. Deviation for CSFs of PQP by work experience in East Network

CSFs of PQP	0-5 years (N=34)		6-15 years (N=64)		16-25 years (N=30)		26-35 years (N=3)	
	M	SD	M	SD	M	SD	M	SD
Customers Satisfaction	2.54	0.628	2.38	0.535	2.51	0.651	2.41	0.201
Management Commitment	2.22	0.623	2.15	0.527	2.31	0.658	2.06	0.419
Employees Participation and Training	2.21	0.737	2.07	0.673	2.28	0.724	2.11	0.948
Customers and Company Awareness	4.12	0.461	4.06	0.593	4.11	0.408	4.21	0.473
PQ Disturbances Affecting Networks	2.86	0.709	2.55	0.887	2.68	0.959	2.99	1.505

South Network

The result of MANOVA revealed that there was no statistically significant difference in the levels of PQ awareness between employee working experiences on the combined dependent variables in south network: Wilks' Lambda = 0.799; F (5, 325) = 1.139; P=0.308, (P > 0.05); partial Eta squared = 0.054. An inspection of the mean scores indicated that employees experience from 26 to 35 years reported slightly higher scores of PQP factors compared to other working experience periods, as shown in Table 6.19. According to [234] argument, Eta squared equal to 0.054, the effect of work experience level on PQP factors was considered small (Eta squared < 0.06).

Table 6.19: Means and Std. Deviation for CSFs of PQP by work experience in South Network

CSFs of PQP	0-5 years (N=44)		6-15 years (N=25)		16-25 years (N=30)		26-35 years (N=7)	
	M	SD	M	SD	M	SD	M	SD
Customers Satisfaction	2.41	0.531	2.59	0.599	2.54	0.528	2.74	0.629
Management Commitment	2.21	0.685	2.35	0.642	2.32	0.569	2.69	0.784
Employees Participation and Training	2.29	0.681	2.29	0.598	2.46	0.641	2.33	0.653
Customers and Company Awareness	4.01	0.456	4.03	0.428	3.93	0.634	4.38	0.541
PQ Disturbances Affecting Networks	3.08	0.887	2.92	0.823	3.06	0.983	2.53	1.065

6.8.4 Work Responsibility

Another test of a one-way multivariate analysis of variance between groups was performed to investigate if there are significant differences between the level of PQ awareness regarding the CSFs derived from the literature for PQP implementation within LDNs in GECOL and employees' work responsibility. Five dependent variables were used: (Customer Satisfaction, Management Commitment, Employee Participation and Training, Customers and Company Awareness and Power Quality Disturbances Affecting Networks) and work responsibility. Preliminary assumption testing was conducted again to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity, with no serious violations noted.

West Network

The result of MANOVA revealed that there was no statistically significant difference in the levels of PQ awareness between employee working responsibility on the combined dependent variables in west network: Wilks' Lambda = 0.862; F (5, 498) = 1.138; P=0.306, (P > 0.05); partial Eta squared = 0.036. An inspection of the mean scores indicated that employees, with responsibility for operation, reported slightly higher scores of PQP factors compared to those whose working responsibility was in Maintenance, Control, Planning and Customer as shown in Table 6.20. According to [234] argument, Eta squared equal to 0.036, the effect of work responsibility level on PQP factors was considered small (Eta squared < 0.06).

Table 6.20: Means and Std. Deviation for CSFs of PQP by work responsibility in West Network

CSFs of PQP	Maintenance (N=52)		Operation (N=65)		Control (N=5)		Planning (N=35)		Customer (N=2)	
	M	SD	M	SD	M	SD	M	SD	M	SD
Customers Satisfaction	2.48	0.599	2.49	0.673	2.48	0.335	2.38	0.764	2.71	1.273
Management Commitment	2.32	0.592	2.22	0.562	2.67	0.755	2.11	0.508	2.58	0.589
Employees Participation and Training	2.25	0.583	2.19	0.796	1.67	0.565	2.25	0.674	2.17	0.471
Customers and Company Awareness	3.85	0.511	4.01	0.434	3.61	0.797	4.01	0.472	4.19	0.265
PQ Disturbances Affecting Networks	2.56	0.855	2.93	0.91	3.21	0.935	2.91	0.86	3.01	1.414

East Network

The result of MANOVA revealed that there was no statistically significant difference in the levels of PQ awareness between employee working responsibility on the combined dependent variables in east network: Wilks' Lambda = 0.826; F (5, 405) = 1.207; P=0.244, (P > 0.05); partial Eta squared = 0.047. An inspection of the mean scores indicated that employees, whose responsibility is Maintenance, reported slightly higher scores of PQP factors compared to those whose working responsibility was in Operation, Control, Planning and Customer Service, as shown in Table 6.21. According to [234] argument, Eta squared equal to 0.047, the effect of work responsibility level on PQP factors was considered small (Eta squared < 0.06).

Table 6.21: Means and Std. Deviation for CSFs of PQP by work responsibility in East Network

CSFs of PQP	Maintenance (N=45)		Operation (N=48)		Control (N=2)		Planning (N=23)		Customer (N=13)	
	M	SD	M	SD	M	SD	M	SD	M	SD
Customers Satisfaction	2.56	0.632	2.35	0.575	2.01	0.566	2.45	0.498	2.51	0.563
Management Commitment	2.29	0.614	2.17	0.601	2.01	0.472	2.04	0.508	2.35	0.507
Employees Participation and Training	2.28	0.792	2.13	0.689	2.01	0.471	1.96	0.619	2.15	0.591

Customers and Company Awareness	4.11	0.469	3.99	0.597	3.88	0.00	4.14	0.468	4.37	0.373
PQ Disturbances Affecting Networks	2.81	0.882	2.43	0.83	3.64	0.303	2.75	0.98	2.82	0.703

South Network

The result of MANOVA revealed that there was no statistically significant difference in the levels of PQ awareness between employee working responsibility on the combined dependent variables in south network: Wilks' Lambda = 0.807; F (5, 361) = 0.861; P=0.661, (P > 0.05); partial Eta squared = 0.042. An inspection of the mean scores indicated that employees, whose responsibility is Customer Service, reported slightly higher scores of PQP factors compared to those whose working responsibility was in Maintenance, Operation, Control, distribution and Planning, as shown in Table 6.22. According to [234] argument, Eta squared equal to 0.042, the effect of work responsibility level on PQP factors was considered small (Eta squared < 0.06).

Table 6.22: Means and Std. Deviation for CSFs of PQP by work responsibility in South Network

CSFs of PQP	Maintenance (N=43)		Operation (N=17)		Control (N=1)		Distribution (N=3)		Planning (N=21)		Customer (N=22)	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Customers Satisfaction	2.53	0.507	2.61	0.649	3.61	0.00	2.13	0.611	2.42	0.562	2.55	0.565
Management Commitment	2.35	0.678	2.29	0.716	2.51	0.00	2.51	0.333	2.31	0.733	2.17	0.518
Employees Participation and Training	2.19	0.579	2.31	0.709	3.33	0.00	2.11	0.192	2.31	0.657	2.63	0.661
Customers and Company Awareness	4.05	0.507	3.99	0.573	3.25	0.00	4.21	0.261	4.04	0.687	4.01	0.341
PQ Disturbances Affecting Networks	2.85	0.764	2.89	1.03	3.01	0.00	3.33	1.51	3.01	0.99	3.31	0.981

The four main effects of MANOVA (work position, education level, work experience and work responsibility were examined in three LDNs. This signified that there were no statistically significant differences in employees' work position, educational level, experience, and responsibility along with all participants categories from all three networks, given the value of (P>0.05) and the levels of PQ awareness regarding the critical success factors derived from the literature for PQP implementation within LDNs. This finding supports research question five, as shown in table 6.23.

Table 6.23: MANOVA for CSFs of PQP by Employees' Characteristics

Wilks' Lambda and the F test for the main effect					
Distribution Networks	**Employees' Characteristics**	**Wilks' Lambda**	**F Value**	**P Value**	**Effect size**
West Network	**Work Position**	0.866	1.101	0.344	0.035
	Education Level	0.904	1.033	0.419	0.033
	Work Experience	0.861	1.148	0.297	0.037
	Work responsibility	0.862	1.138	0.306	0.036
East Network	**Work Position**	0.837	1.119	0.327	0.044
	Education Level	0.829	1.589	0.075	0.061
	Work Experience	0.938	0.528	0.923	0.021
	Work responsibility	0.826	1.207	0.244	0.047
South Network	**Work Position**	0.772	1.322	0.162	0.063
	Education Level	0.852	1.091	0.365	0.052
	Work Experience	0.799	1.139	0.308	0.054
	Work responsibility	0.807	0.861	0.661	0.042

STAGE TWO: POWER QUALITY PROGRAMME (PQP) IMPLEMENTATION

6.9 Power Quality Programme Evaluation in Libyan Distribution Networks

At this stage, and before starting to explore the level of implementation of PQ, it is essential to recognise what PQPs were carried out in LDNs. This investigation was done to answer research question one:

> *What is the actual overall level of the PQDs, in terms of measurements, solutions and implementation regarding PQ awareness?*

Some of the PQDs include harmonics, short interruptions, long interruptions, voltage sags & swells, under voltage, over voltage, flicker & unbalance, transient & surge, low power factor and voltage collapse. These disturbances are considered in the statistical analysis presented in this study. The results obtained from the survey indicated the current status of PQ in LDNs based on the staff's point of view. Almost 400 responses have been provided by one of the 3 major distribution networks, indicating opinions of the level of PQDs among residential, agricultural, commercial and industrial users.

6.9.1 PQP Monitoring History

Figure 6.9 shows the responses by the types of measurements used to monitor PQ issues in past history. As can be seen, the highest respondents mentioned that regular monitoring measurements of PQ were the only method used to monitor PQDs. In west networks, 37% of the participating respondents refer to a regular method. It was slightly different in east network, where 36% of participating respondents refer to the same method followed to assess PQDs. In south network, the regular monitoring type is also used with 29% of respondents. Overall, 35% of the responses for the three networks from 397 respondents indicated that PQDs were evaluated by regular monitoring.

The researcher observed that most employees in three categories, i.e. department manager, engineers and technicians in LDNs, are enthusiastic regarding PQ improvements. They need sufficient training courses to be well educated and aware. GECOL has enough resources to conduct more training courses and thus advance. However, the problems lie with top management in the three networks, where encouragement and support are required, not only for the period when problems occur, but can be given on a regular basis. As a result, staff experience and skills could be at the level of dealing with these issues. Failure of PQP implementation in LDNs has four main points:

1. Lack of understanding of the concepts or the definitions of any problems.
2. Lack of training courses for employees, and this point considerably to top management, where the decisions and planning should be within a team not an individual.
3. Lack of government responsibility, where there is no pressure to force the sector to improve staff skills.
4. Lack of customer participation with the utility to improve the quality of the electricity they utilise.

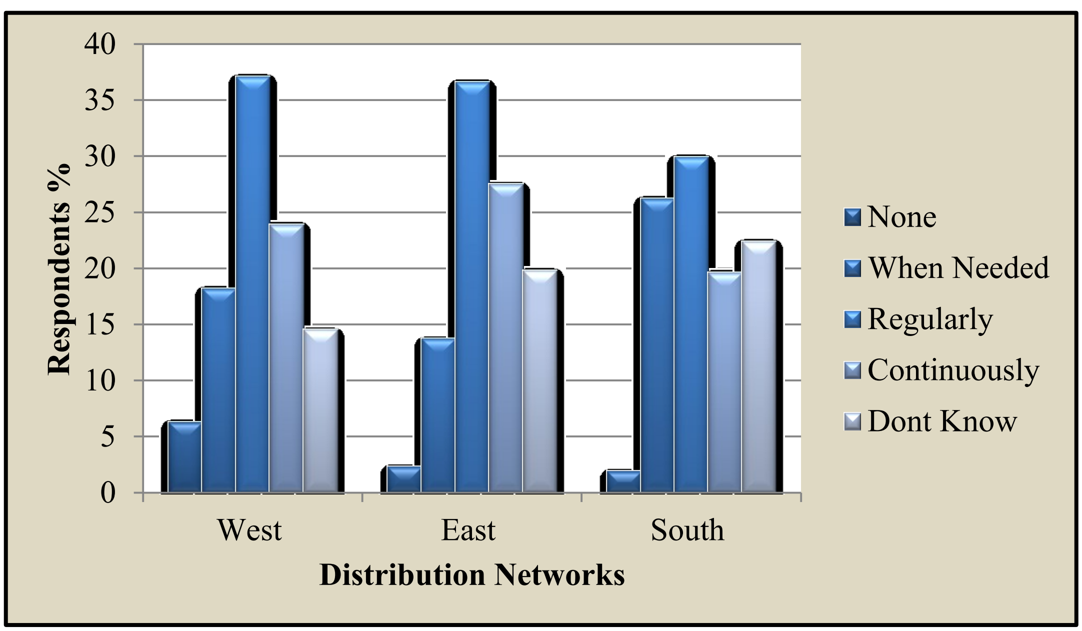


Figure 6.9: PQP Measurement History Monitor

6.9.2 PQP Measurement History Time

Figure 6.10 illustrates the measurement history period for PQP in the past. It shows that approximately 51.9% to 56.6% of the participating respondents, who were surveyed, were not aware if there was a PQP implemented across the three networks. Whereas, roughly 22.6% to 26.7% of the participating respondents indicated that PQPs were implemented two years ago in three networks. About 7.4% indicate that PQP was implemented three months ago before the survey was conducted in LDNs. Merely 3% of the participating respondents said that PQP was implemented last year. Therefore, there is a critical answer from the respondents with regard to PQP implementation in three networks, which significantly would indicate to that there was no PQP implemented in LDNs in the past, as the average of participating respondents (51.9% to 56.6%) pointed out. This can give an indication that most engineers, technicians and head managers were not aware of PQ problems, as a result of not being aware of the concept of PQ. On the other hand, approximately 26% of respondents know about PQ problems, as a result of being aware of power quality definitions.

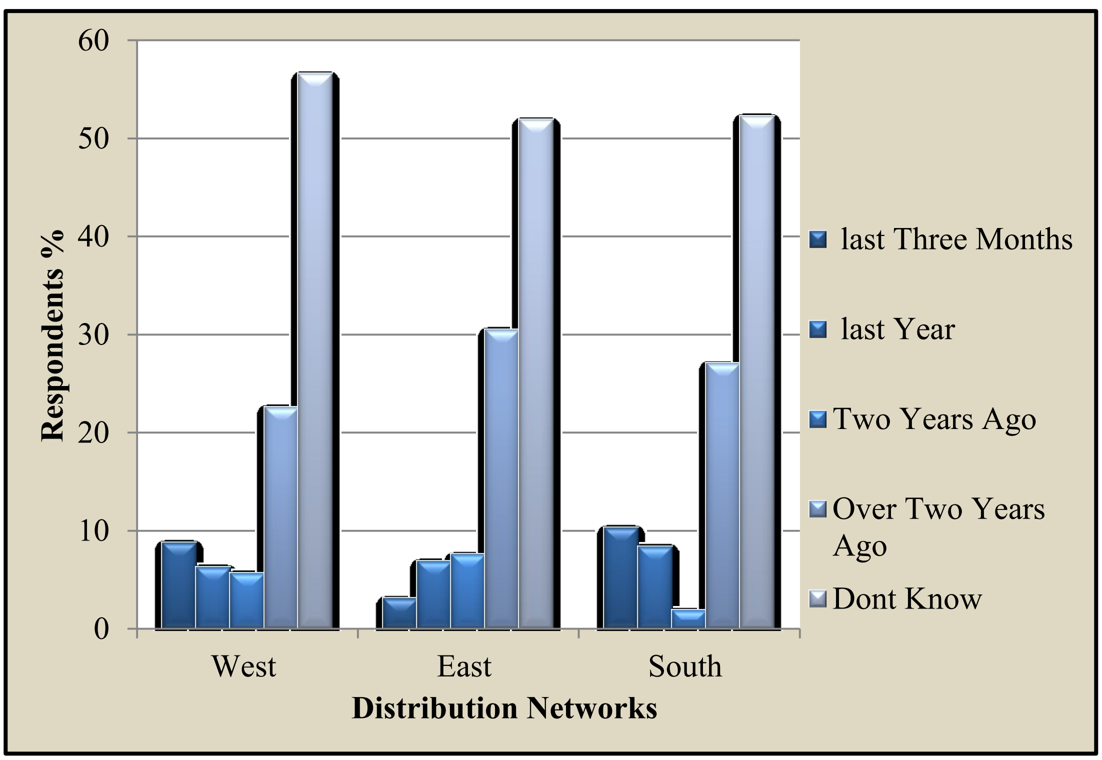


Figure 6.10: PQP Measurement History Time

6.9.3 PQP Measurement History Experts

Figure 6.11 illustrates the type of experts, who solved PQDs in past measurements history. Roughly 74% of the respondents identify that PQDs were solved by local engineers and technicians, whereas 23.9% of the respondents indicated that the problems were solved by contractors. From figure 6.11, the engineers and techicians surveyed predicted that they were aware of PQ problems. However, figure 6.10 showed that approximately 51.9% to 56.6% of those surveyed were not aware if there was a PQP implemented across the three networks. Figure 6.6 shows that the majority of respondents (52.4%) comprised the educational qualification of high diploma degree, which is considered a minimum education. As a result, this will lead to clear statement that even though PQ problems are solved by the local employees, yet lack of understanding its importance is still common among the employees, and this is very obvious in the absence of a PQP as needed.

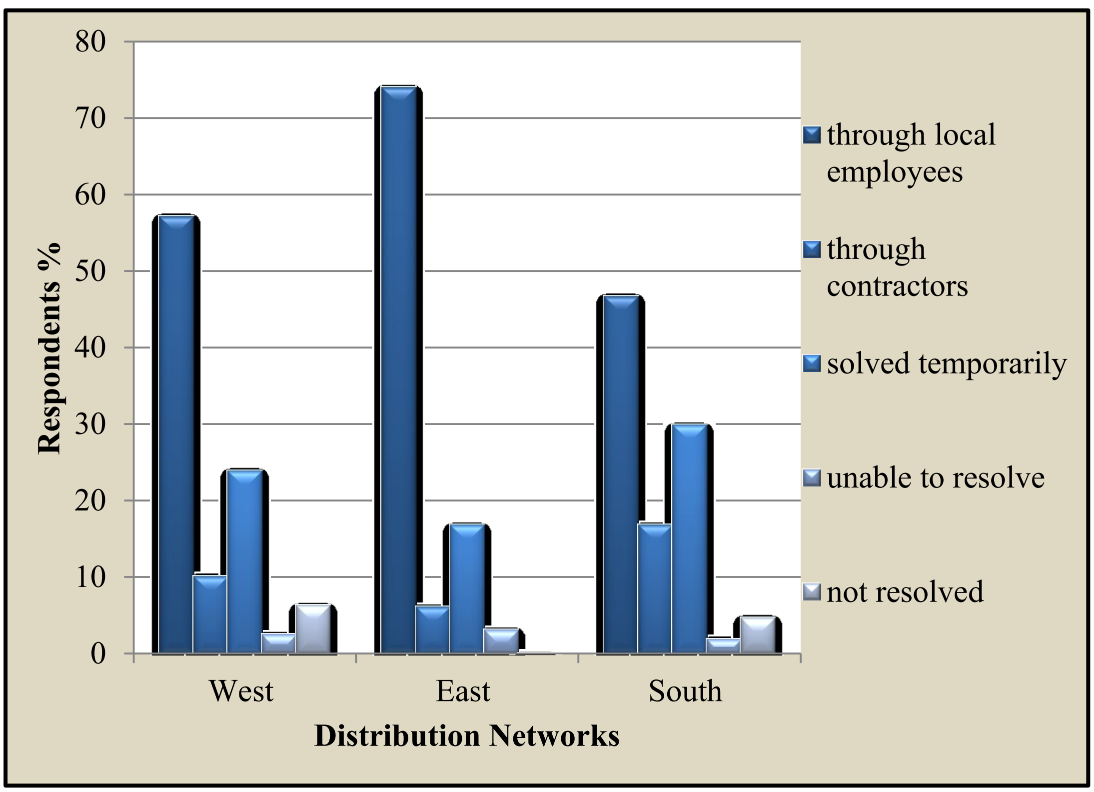


Figure 6.11: PQP Measurement History Experts

6.9.4 Power Quality Disturbances in Libyan Distribution Networks

6.9.4.1 Main Sources of PQDs

The differences among the six commonest types of equipment, which cause PQDs across the three networks, are presented in figure 6.12. Approximately 24% of the participating respondents refer to air conditioning as the top cause of PQDs in the three networks. Roughly 19% considered that electric motors were the second commonest equipment type causing PQDs. As a consequence of huge industrial concerns operating such motors, especially in west and east networks, PQDs were generated. Nearly 17% of the participating respondents indicate that lighting equipment and computers were the third type of equipment, which affects the networks. Indeed, electric motors (19%), and lighting and computer equipment (17%) were nearly equally considered as common causes affecting the networks. Approximately 15% of the participating respondents indicated that welding machines were mainly considered as one of the main factors causing the problems in the three networks. The IT networks and the telecommunication equipment were recorded to as causing equipment with 12%. As mentioned earlier these equipment were differing from one network to another due to combination between user's categories and equipment compared between the three networks.

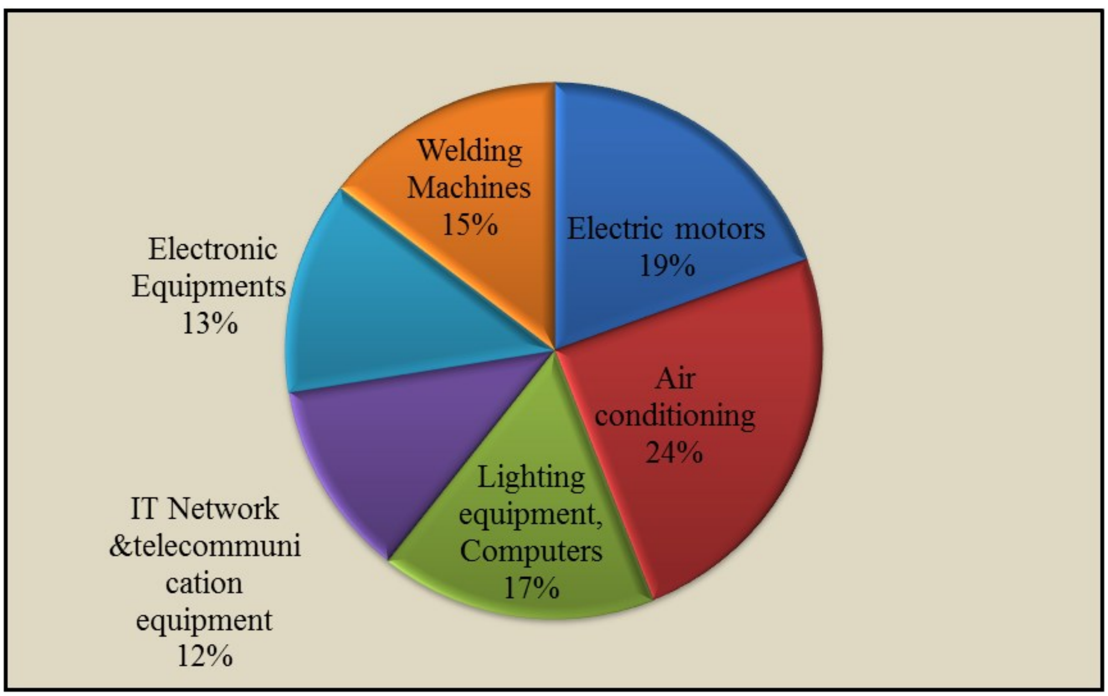


Figure 6. 12: Sources of PQDs in all LDNs - by responses %

Figure 6.12 figure shows that electronics equipment is the largest source of PQDs. Although electronic equipment can be seen as a small load compared to, say, air conditioning loads, PQDs generated by electronic equipment were extremely large with total harmonic distortion reaching 200% [33]. All loads shown in Figure 6.12 are non-linear loads, and it is these types of loads, which are on the increase.

6.9.4.2 PQDs Affecting LDNs

Figure 6.13 illustrates the most common PQDs as seen by the people working within the surveyed power distribution networks. It shows the industrial/commercial and residential figures, as well as the total. In general, Figure 6.13 shows that all PQDs are taken seriously (they are all above 25%). In addition, Figure 6.13 indicated that around 79% of the participating respondents refer to long interruptions as one of the elements, which cause PQDs, due to heavy loads such as the Artificial River Project and random private agriculture using large induction motors, which are connected to southern distribution network. The southern distribution network is only fed by one side of the transmission lines, which are driven far away from Alkhoms generation plants from the north to the south. As a result, the end users in this network are connected via different substations by transmission lines over a long distance, very far away from the generation source. For this reason, a 400 kV line was constructed and connected to this network to overcome the problems due to the long transmission distance. However, problems still persisted after the new line was introduced. It is also due to huge numbers of air conditioning units used, especially in summer. Many end users operate their air conditioning using “illegal” connections due to dissatisfaction with the quality of electricity supplied. In addition, citizens started private agriculture projects, as water can be found at less than 30m below ground. They started cultivating the desert without consideration of the network capacity and the impact of their activities on PQDs. As a result, the network lacks sufficient efficiency and ability to provide good PQ to all sectors, including residential, Great Artificial River project, and private agriculture projects. All these projects appeared after the 1999 economic blockade, and led to major PQDs in the network.

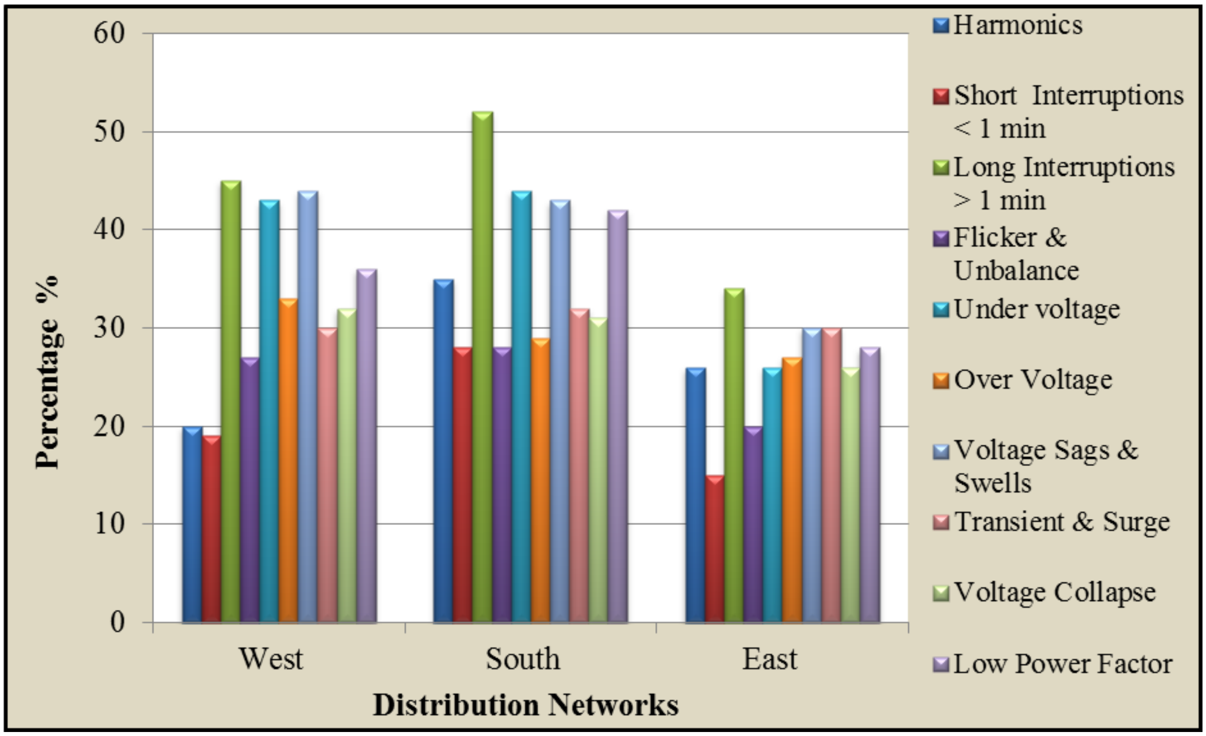


Figure 6.13: PQDs Affecting distribution Networks

From figure 6.13, this was clear evidence that both residential and industrial & commercial end users were affected due to the long destination of transmission lines. It is also due to a number of aspects being combined with varying user categories and equipment categories in the network. Consequently, as shown in figure 6.13, the dissatisfaction of end users with poor PQ rose sharply since 1999. Moreover, the PQD parameters are cited by each individual respondent in each distribution network. This was clear evidence that the three networks were significantly affected due to the main equipment sources of disturbances mentioned earlier (see figure 6.12). Consequently, the end users started to complain about poor PQ. The lack of both understanding and awareness of PQDs has led to this situation in all three networks.

6.9.4.3 PQDs Past Measurements by Responses Percentage

Figure 6.14 illustrates PQ parameters measured in the past. Long interruption is seen as the most common category, to which the three LDNs paid attention. This indicated that PQ problems in LDNs in the past was, and still is, long interruption, whereas voltage sags and swells, flicker, unbalance and power factor, were not significant as issues, as they are today. The increase in PQDs when compared to past measurements refers to the economic factor, which increased after 1999; there was a boom in housing, and private small agriculture projects were randomly established. Moreover, electronic equipment was also another reason, which caused significant disturbances in these networks. Finally, the lack of implementation of a PQP was one more aspect, where the level of these disturbances can be decreased, if they are monitored earlier as they first appeared. As a result, the other types of PQ parameters became more prominent, as seen in figure 6.13.

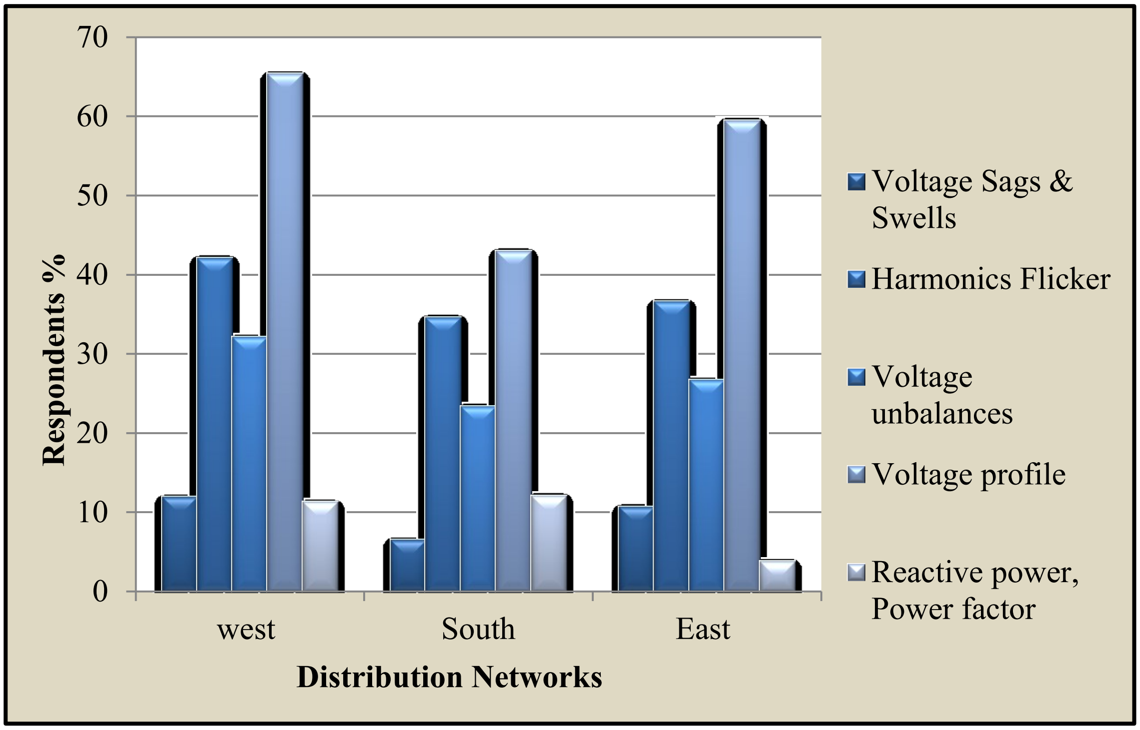


Figure 6.14: PQ Parameters Past Measurements by Responses Percentage

6.9.4.4 Power Quality Disturbances (PQDs): Past Solutions by Responses Percentage

Figure 6.15 shows the most PQ solutions were used by the LDNs in the past. It was seen that 23% of the respondents referred to voltage stabilizers as mostly used to solve PQ problems. Back-up generators were also used due to the significant appearance of long power interruption, in the view of approximately 22%. Nearly 17% of respondents participating in this survey highlighted that UPS was also one of the common power quality solutions used. As a result of using these types of solution, it was confirmed that long interruption is considered as highly significant, and highlighted by approximately 43.6% of respondents, as the most common PQD in the three networks.

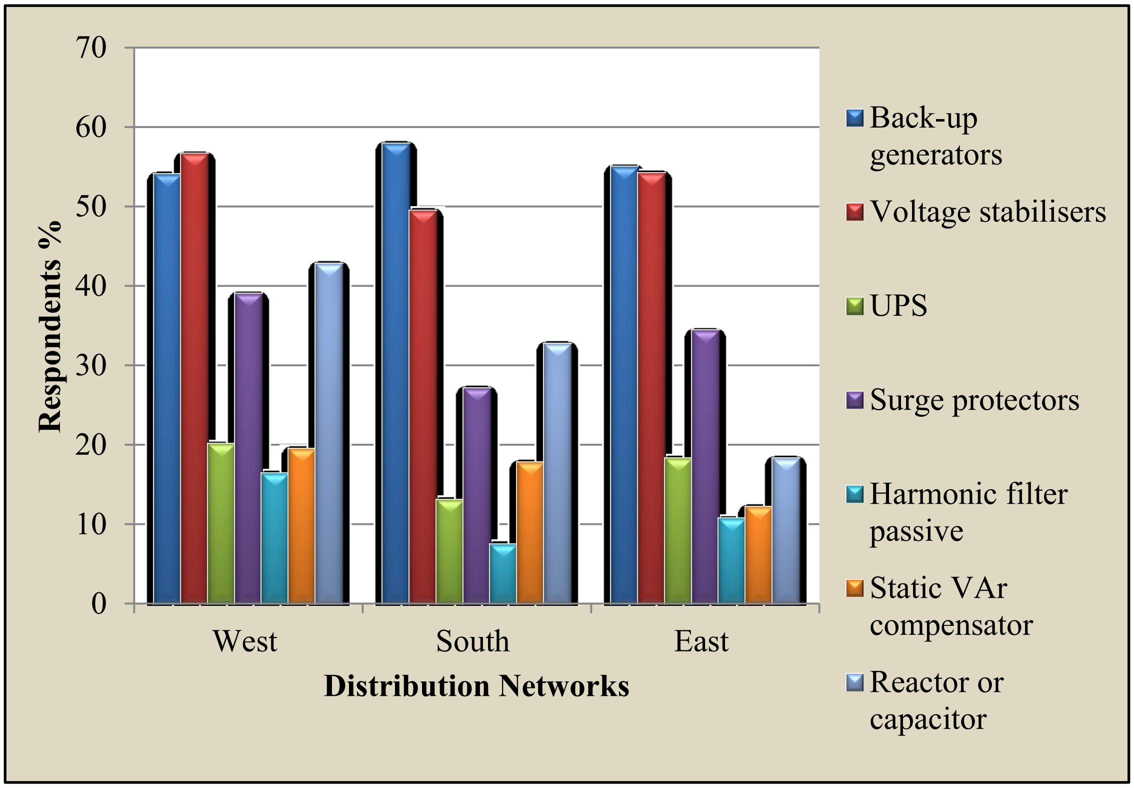


Figure 6.15: PQD Past Solutions by Responses Percentage

Figure 6.15 indicated that voltage profile was the main issue relating to PQDs in past history. Surge protectors, and reactors or capacitors were used as other solutions for PQDs. This also gave clear evidence that the most PQ problems related to LDNs was, and still is, voltage profile, voltage sags and swells, as seen in figure 6.13 and figure 6.14.

6.9.4.5 Main Causes of PQDs

Figure 6.16 shows the most common group causing PQDs. Lack of PQ awareness is seen as the highest significant factor causing the problems, where 31% of the respondents cited it. Regarding lack of awareness, approximately 26% of the end users connected illegally, as well as the increase in excessive use of electronic equipment, introduced after 1999, caused PQDs. This was due to non-linear equipment, which are very sensitive to power supply variation (long interruption, 79%). In addition, lack of appropriate network design at a higher level was the third factor causing PQDs in the view of 20%. Therefore, the demand on power generated has led industries to demand and share it along with the increased demand in the domestic sector in the same line. These complex combinations required LDNs to have PQPs to make the network more efficient due to the complex interconnection [28]. Figure 6.16 gives more details about each aspect causing PQ issues with a level of percentage by respondents. It was clear that the west distribution network was the most affected network, due the large number of mixed users connected to it, where large numbers of electronics equipment are used, as shown in figure 3.10. However, these factors differ from one network to another due to a number of aspects, such as geographical map of Libya and the high temperature, where power outage is common, especially in the south network.

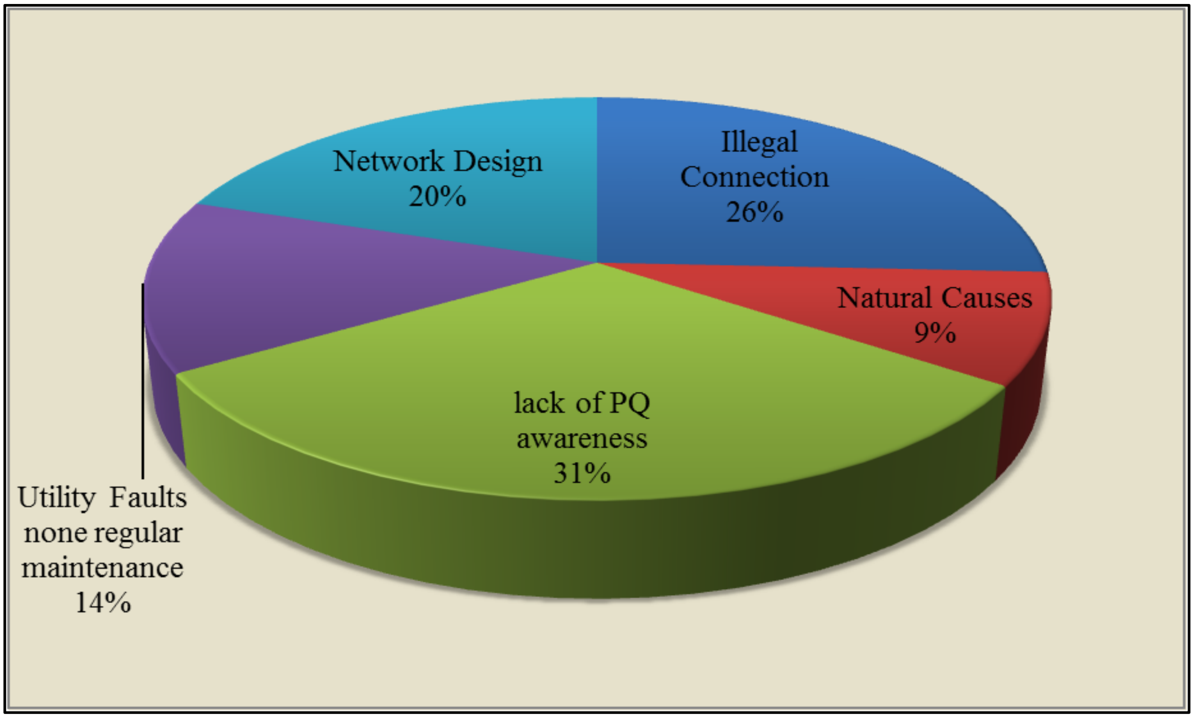


Figure 6.16: The current causes of PQDs

6.9.5 Power Quality Programme Barriers

6.9.5.1 One-way Analysis Of Variance (ANOVA)

One-way Analysis of Variance was conducted in this study to compare two or more means of set of factors to determine whether or not there were any statistically significant differences among groups [6]. The 16 PQP barriers were tested using ANOVA technique to estimate the variance of difference between LDNs, if the 16 PQP barriers differ from one network to other, which can be identified by F- statistic or F-ration [29]. An F ration is calculates the variance between the groups, divided by the variance within the groups. Moreover, if significant statistical difference is revealed between groups, then post-hoc tests can indicate which groups differ from one another [16]. Therefore, for the total number of 397 completed PQ survey questionnaires from three LDNs, the sampling distribution of means were not the same, and differed based on the each distribution network's circumstances and the samples categories, in terms of work position, responsibility, education and experiences. Table 6.24 shows the type of distribution networks along with the categories of end users involved in the study. Large distribution networks were considered to have more categories of end users; the western distribution network (WDN1), southern distribution network (SDN2) and eastern distribution network (EDN3).

Table 6.24: Type of Libyan distribution networks (LDNs)

Distribution Networks	Residential	Commercial	Industrial	Agricultural
WDN1	√	√	√	
SDN2	√		√	√
EDN3	√		√	√

In response to this, respondents were asked to define how far any of the 16 PQP potential barriers (BA) cause current difficulties in implementing a PQP in LDNs. The 16 PQP barriers are listed in table 6.25. All factors were designed in a five-point Likert scale format (1=not applicable; 2= very low extent; 3= low extent; 4= moderate; 5= high extent). Data gathered were checked once more in terms of accuracy, outliers and, normality; then analysed using (SPSS) software version 18.1 [230].

Barriers BA 1-4 belong to factor 1 and can be categorized under 'lack of PQP awareness', whereas barriers BA 5-9, belong to factor 2 and are categorized as 'lack of PQP top management attention'. Barriers BA 10-12 belong to factor 3 and pertain to 'lack of PQP resources' and finally barriers BA 13-16 belong to factor 4, dealing with 'lack of PQP involvement'.

Table 6.25: List of PQP Barriers Mean, SD. Deviation and Significant Values

Items	Factors	Barriers	Sig	Mean	S.D
BA1	**Lack of PQP Awareness**	lack of staff awareness, skills and experience	0.035	3.44	1.335
BA2		lack of end users awareness	0.033	3.68	1.349
BA3		lack of customer cooperation	0.337	3.52	1.321
BA4		lack of long-term strategy and planning	0.036	3.16	1.407
BA5	**Lack of PQP Top**	lack of top management commitment	0.044	3.51	1.411

BA6	**Management Attention**	lack of network designing	0.049	3.52	1.332
BA7		lack of distribution networks infrastructure	0.021	3.47	1.332
BA8		lack of conducting research and studies	0.447	3.01	0.863
BA9		lack of top management responsibility	0.043	3.34	0.732
BA10	**Lack of PQP Resources**	lack of training courses, education and support	0.022	3.06	0.952
BA11		lack of enough resources	0.044	3.09	0.965
BA12		lack of financial incentives	0.242	3.09	1.002
BA13	**Lack of PQP Involvement**	lack of PQ measurement	0.031	3.76	1.015
BA14		lack of PQ consultants	0.041	3.81	0.934
BA15		lack of PQ standards	0.029	3.75	1.068
BA16		lack of PQ monitoring and database	0.028	3.94	0.997
Overall Mean				**3.44**	**1.126**

Table 6.25 illustrates the ANOVA test along with the list of PQP Barriers Mean, Std. Deviation and Sig values. Out of 16 barriers, 13 were statistically significantly different at the P value <0.05. The significant PQP barriers were BA1, lack of staff awareness, skills and experience, BA2, lack of end users awareness, BA4, lack of long-term strategy and planning, BA5, lack of top management commitment, BA6, lack of network designing, BA7, lack of distribution networks infrastructure, BA9, lack of top management responsibility, BA10 lack of training courses, education and support, BA11, lack of sufficient resources, BA13, lack of PQ measurement, BA14, lack of PQ consultants, BA15, lack of PQ standards, and BA16, lack of PQ monitoring and database.

In order to identify which distribution network was affected by PQP barriers, a one-way between-groups analysis of variance was conducted to explore the impact of PQP implementation on LDNs, as measured by the level of PQP Awareness, PQP Top Management Attention, PQP Resources and PQP Involvement. LDNs were divided into three groups (DN1: Western Distribution; DN2: Southern Distribution; DN3: Eastern Distribution) as explained in table 6.24. Table 6.26 shows the descriptive results produced from the ANOVA test for PQP factors in terms of means, and standard deviation for each distribution network.

Table 6.26: Responses, Means and Standard deviation of PQP factors

PQP Implementation Factors	LDNs	Responses	Mean	Std. Deviation
PQP Awareness	DN1	159	3.64	0.634
	DN3	131	3.87	0.649
	DN2	107	3.72	0.709
	Total	397	3.74	0.666
PQP Top Management Attention	DN1	159	3.92	0.543
	DN3	131	4.10	0.580
	DN2	107	4.07	0.557
	Total	397	4.02	0.564
PQP Resources	DN1	159	2.81	0.893
	DN3	131	2.67	0.876
	DN2	107	2.99	0.919
	Total	397	2.81	0.901
PQP Involvement	DN1	159	3.94	0.485
	DN3	131	4.09	0.515
	DN2	107	4.03	0.521
	Total	397	4.01	0.508

Table 6.27 illustrates between-groups and within-groups sums of squares, degrees of freedom. The most important element in this table is the column marked Sig. The significant value indicated whether there is any significant difference between PQP factors among LDNs. The effect size is calculated based on Cohen consideration, who classified Eta squared as following 0.01 as a small effect, 0.06 as a medium effect and 0.14 as a large effect [234]. Eta squared can be calculated as follows;

$$\text{Eta squared} = \frac{\text{Sum of squares between groups}}{Total\ sum\ of\ squares} \qquad \text{equation (6.1)}$$

$$\text{PQP Awareness} = \frac{3.786}{175.389} = 0.021 \qquad \text{equation (6.2)}$$

$$\text{PQP Top Management Attention} = \frac{2.813}{125.934} = 0.022 \qquad \text{equation (6.3)}$$

$$\text{PQP Resources} = \frac{5.931}{321.258} = 0.018 \qquad \text{equation (6.4)}$$

PQP Involvement= $\frac{1.636}{102.085}$ = 0.016 equation (6.5)

All eta squared values for all PQP factors would be considered a small effect size based on Cohen consideration.

Table 6.27: List of PQP factors ANOVA Tests

PQP Implementation Factors		Sum of Squares	df	Mean Square	F	Sig.
PQP Awareness	Between Groups	3.786	2	1.893	4.346	0.014
	Within Groups	171.603	394	0.436		
	Total	175.389	396			
PQP Top Management Attention	Between Groups	2.813	2	1.406	4.501	0.012
	Within Groups	123.121	394	0.312		
	Total	125.934	396			
PQP Resources	Between Groups	5.931	2	2.966	3.705	0.025
	Within Groups	315.327	394	0.800		
	Total	321.258	396			
PQP Involvement	Between Groups	1.636	2	0.818	3.209	0.041
	Within Groups	100.449	394	0.255		
	Total	102.085	396			

Table 6.28 illustrates the post-hoc tests to point out, where the differences lie between PQP factors among LDNs after obtaining the significant values from the ANOVA table. If the Sig. value was equal to or less than 0.05 then the asterisks (*) in the column mean difference indicate that the three LDNs being compared are significantly different from one another at the $p< 0.05$ level with PQP factors.

Table 6.28: Post-Hoc Multiple Comparisons using the Tukey HSD Test

Dependent Variable	(I) Which Network do you work at?	(J) Which Network do you work at?	Mean Difference (I-J)	Std. Error	Sig.
PQP Awareness	DN1	DN3	-.228(*)	0.078	0.010
		DN2	-0.079	0.083	0.606
	DN3	DN1	.228(*)	0.078	0.010
		DN2	0.149	0.086	0.193

	DN2	DN1	0.079	0.083	0.606
		DN3	-0.149	0.086	0.193
PQP Top Management Attention	DN1	DN3	-0.183(*)	0.066	0.016
		DN2	-0.155	0.070	0.069
	DN3	DN1	0.183(*)	0.066	0.016
		DN2	0.028	0.073	0.924
	DN2	DN1	0.155	0.070	0.069
		DN3	-0.028	0.073	0.924
PQP Resources	DN1	DN3	0.140	0.106	0.383
		DN2	-0.178	0.112	0.252
	DN3	DN1	-0.140	0.106	0.383
		DN2	-0.317(*)	0.117	0.019
	DN2	DN1	0.178	0.112	0.252
		DN3	0.317(*)	0.117	0.019
PQP Involvement	DN1	DN3	-0.150(*)	0.060	0.033
		DN2	-0.084	0.063	0.377
	DN3	DN1	0.150(*)	0.060	0.033
		DN2	0.066	0.066	0.578
	DN2	DN1	0.084	0.063	0.377
		DN3	-0.066	0.066	0.578

** The mean difference is significant at the 0.05 level.*

The results of the post-hoc tests were explained respectively as follows;

- **PQP Awareness**

There was a statistically significant difference at the $p < 0.05$ level in PQP Awareness scores for the three LDNs [$F (2, 394) = 4.34$, $p = 0.014$]. Despite reaching statistical significance, the actual difference in mean scores between the groups was quite small. The effect size, calculated using eta squared, was 0.021. Post-hoc comparisons using the Tukey HSD test indicated that the mean score for DN1 ($M=3.94$, $SD=0.634$) was significantly different from DN3 ($M=3.87$, $SD=0.649$). However, DN2 ($M=3.72$, $SD=0.709$) did not differ significantly from either DN1 or DN3.

- **PQP Top Management Attention**

There was a statistically significant difference at the $p < 0.05$ level in PQP Top Management Attention scores for the three LDNs [$F (2, 394) = 4.50$, $p = 0.012$]. Despite reaching statistical significance, the actual difference in mean scores between the groups was quite small. The effect size, calculated using eta squared, was 0.022. Post-hoc comparisons using the Tukey HSD test indicated that the mean score for DN1 (M=3.92, SD=0.543) was significantly different from DN3 (M=4.10, SD=0.580), while DN2 (M=4.07, SD=0.557) did not differ significantly from either DN1 or DN3.

- **PQP Resources**

There was a statistically significant difference at the $p < 0.05$ level in PQP resources scores for the three LDNs [F (2, 394) =3.70, p= 0.025]. Despite reaching statistical significance, the actual difference in mean scores between the groups was quite small. The effect size, calculated using eta squared, was 0.018. Post-hoc comparisons using the Tukey HSD test indicated that the mean score for DN3 (M=2.67, SD=0.876) was significantly different from DN2 (M=2.99, SD=0.919). Moreover, DN1 (M=2.81, SD=0.893) did not differ significantly from either DN2 or DN3.

- **PQP Involvement**

There was a statistically significant difference at the $p < 0.05$ level in PQP involvement scores for the three LDNs [F (2, 394) =3.20, p= 0.041]. Despite reaching statistical significance, the actual difference in mean scores between the groups was quite small. The effect size, calculated using eta squared, was 0.016. Post-hoc comparisons using the Tukey HSD test indicated that the mean score for DN1 (M=3.94, SD=0.485) was significantly different from DN3 (M=4.09, SD=0.515). DN2 (M=4.03, SD=0.521) did not differ significantly from either DN1 or DN3.

In brief, a post-hoc Least Significance Difference (LSD) test was carried for the four PQP framework factors. The respondents agreed that PQP factors have significant effect on LDNs in terms of level of PQP Awareness, PQP Top Management Attention, PQP Resources and PQP Involvement. There were significant difference found among WDN1, SDN2 and EDN3, which faced some particular PQP barriers. WDN1 faces three factors; F1, lack of PQP awareness, F2, lack of PQP top management attention, and F4, lack of PQP involvement, whereas EDN3 faces F1, lack of PQP awareness, F2, lack of PQP top management attention, F3, lack of PQP resources and F4, lack of PQP involvement and SDN2 faces F3, lack of PQP resources. As a result, it can be said that LDNs have so far struggled to implement PQP effectively.

6.9.5.2 PQP Barriers Validity and Reliability

The 16 PQP barriers were further tested to measure if they are rotated and extracted under each of the four PQP barriers. The 16 PQP barriers were inter-correlated by an exploratory factor analysis (EFA) based on the principal component analysis (PCA) with Varimax rotation to discover the structure of the factor in the derived barriers. The data was measured in order to perform PCA for appropriateness of factor analysis. Factor analysis results output for the 16 PQP barriers are illustrated as follows:

- Factor analysis results are shown in Table 6.29 for the variables chosen to assess PQP Awareness Construct. This factor consists of 4 barriers (BA1-BA4), which were lack of staff awareness, skills and experience, lack of end users awareness, lack of customer cooperation and lack of long-term strategy and planning. The entire four barriers were distilled into a single factor and verify that all the items selected to measure (PQP Awareness) are statistically valid measures. The values of the load for these variables are all at moderate or higher, level and the explanation of these variables collectively can be 52.84% of the variance.

Table 6.29: Factor Analysis for PQP Awareness Constructs

PQP Barriers	Description	Item Loading	Cronbach's Alpha
	PQP Awareness	-	**0.769**
BA1	lack of staff awareness, skills and experience	0.813	
BA2	lack of end users awareness	0.741	
BA3	lack of customer cooperation	0.725	
BA4	lack of long-term strategy and planning	0.693	

Total Variance explained	52.84%
Measures of Sampling Adequacy	0.801
Bartlett's Test of Sphericity (Approx. Chi-Square	488.396
Degree of Freedom	10
P-value (Sig.)	<0.001

Inspection of the correlation matrix disclosed the presence of many coefficients of 0.3 and higher than the Kaiser-Meyer-Oklin (KMO). Measure of Sampling Adequacy value was 0.801, which exceeds the recommended value of 0.6 [231][199][206][232]. The Bartlett's Test of Sphericity for all 4 PQP awareness barriers was also highly significant (Chi-Square = 488.396 with 10 degrees of freedom, at $p<0.001$), reaching statistical significance in the correlation matrix [200]. This implies that the factor analysis of 4 PQP awareness barriers was appropriate and confirms that all the items were statistically significant, which are judged to be an excellent validation of factor analysis. Moreover, the reliability test of Cronbach's alpha for all 4 PQP awareness barriers is 0.77, which is above the cited minimums of Cronbach's alpha 0.70 [219], and it was considered to be high and acceptable alpha, giving evidence that the total Cronbach's alpha was judged to be reliable for the questionnaire.

- Factor analysis results are shown in Table **6.30** for the variables chosen to assess **PQP Top Management Attention Construct.** This factor consists of 5 barriers (BA5-BA9), which were lack of top management commitment, lack of network design, lack of distribution networks infrastructure, lack of conducting research and studies and lack of top management responsibility. All five barriers were distilled into a single factor, and it was verified that all the items selected to measure **(PQP Top Management Attention)** are statistically valid measures. The values of the load for these variables are all at moderate or higher, level and the explanation of these variables collectively can be **57.34%** of the variance.

Table 6.30: Factor Analysis for PQP Top Management Attention Constructs

PQP Barriers	Description	Item Loading	Cronbach's Alpha
	PQP Top Management Attention	-	**0.811**
BA5	lack of top management commitment	0.784	
BA6	lack of network designing	0.781	
BA7	lack of distribution networks infrastructure	0.765	
BA8	lack of conducting research and studies	0.738	
BA9	lack of top management responsibility	0.717	

Total Variance explained	57.34%
Measures of Sampling Adequacy	0.779
Bartlett's Test of Sphericity (Approx. Chi-Square	668.813
Degree of Freedom	10
P-value (Sig.)	<0.001

Inspection of the correlation matrix disclosed the presence of many coefficients of 0.3 and higher than the Kaiser-Meyer-Oklin (KMO). Measure of Sampling Adequacy value was 0.779, which exceeded the recommended value of 0.6 [231][199][206][232]. The Bartlett's Test of

Sphericity for all 5 PQP Top Management Attention was also highly significant (Chi-Square = 668.813 with 10 degrees of freedom, at p<0.001), reaching statistical significance in the correlation matrix [200]. This implies that the factor analysis of 5 PQP Top Management Attention barriers was appropriate and confirms that all the items were statistically significant, which are judged to be an excellent validation of factor analysis. Moreover, the reliability test of Cronbach's alpha for all 5 PQP Top Management Attention barriers is 0.81, which is above the cited minimums of Cronbach's alpha 0.70 [219], and was considered to be high and acceptable alpha, giving evidence that the total Cronbach's alpha was judged to be reliable for the questionnaire.

- Factor analysis results are shown in Table **6.31** for the variables chosen to assess **PQP Resources Construct.** This factor consists of 3 barriers (BA10-BA12), which were lack of training courses, education and support, lack of enough resources and lack of financial incentives. The entire three barriers were distilled into a single factor, and verified that all the items selected to measure **(PQP Resources)** are statistically valid measures. The values of the load for these variables are all at moderate or higher, level and the explanation of these variables collectively can be **51.01%** of the variance.

Table 6.31: Factor Analysis for PQP Resources Constructs

PQP Barriers	Description	Item Loading	Cronbach's Alpha
	PQP Resources	-	**0.731**
BA10	lack of training courses, education and support	0.742	
BA11	lack of enough resources	0.727	
BA12	lack of financial incentives	0.691	

Total Variance explained	51.01%
Measures of Sampling Adequacy	0.791
Bartlett's Test of Sphericity (Approx. Chi-Square	464.108
Degree of Freedom	15
P-value (Sig.)	<0.001

Inspection of the correlation matrix disclosed the presence of many coefficients of 0.3 and higher than the Kaiser-Meyer-Oklin (KMO). Measure of Sampling Adequacy value was 0.791, which exceeded the recommended value of 0.6 [231][199] [206][232]. The Bartlett's Test of Sphericity for all 3 PQP Resources was also highly significant (Chi-Square = 464.108 with 15 degrees of freedom, at p<0.001), reaching statistical significance in the correlation matrix [200]. This implies that the factor analysis of 3 PQP Resources barriers was appropriate and confirms that all the items were statistically significant, which are judged to be an excellent validation of factor analysis. Moreover, the reliability test of Cronbach's alpha for all 3 PQP Resources barriers is 0.73, which is above the cited minimums of Cronbach's alpha 0.70 [219], and was considered to be high and acceptable alpha, providing evidence that the total Cronbach's alpha was judged to be reliable for the questionnaire.

- ❖ Factor analysis results are shown in Table **6.32** for the variables chosen to assess **PQP Involvement Construct.** This factor consists of 4 barriers (BA13-BA16), which were lack of PQ measurement, lack of PQ consultants, lack of PQ standards and lack of PQ monitoring and database. The entire four barriers were distilled into a single factor and verify that all the items selected to measure **(PQP Involvement)** are statistically valid measures. The values of the load for these variables are all at moderate or higher, level and the explanation of these variables collectively can be **53.13%** of the variance.

Table 6.32: Factor Analysis for PQP Involvement Constructs

PQP Barriers	Description	Item Loading	Cronbach's Alpha
	PQP Involvement	-	**0.821**
BA13	lack of PQ measurement	0.796	
BA14	lack of PQ consultants	0.774	
BA15	lack of PQ standards	0.734	
BA16	lack of PQ monitoring and database	0.733	
Total Variance explained		53.13%	
Measures of Sampling Adequacy		0.837	
Bartlett's Test of Sphericity (Approx. Chi-Square		869.002	
Degree of Freedom		21	
P-value (Sig.)		<0.001	

Inspection of the correlation matrix disclosed the presence of many coefficients of 0.3 and higher than the Kaiser-Meyer-Oklin (KMO). The measure of Sampling Adequacy value was 0.837, which exceeded the recommended value of 0.6 [231][199][206][232]. The Bartlett's Test of Sphericity for all 4 PQP Involvement was also highly significant (Chi-Square = 869.002 with

21 degrees of freedom, at p<0.001), reaching statistical significance in the correlation matrix [200]. This implies that the factor analysis of 4 PQP Involvement barriers was appropriate and confirms that all the items were statistically significant, which are judged to be an excellent validation of factor analysis. Moreover, the reliability test of Cronbach's alpha for all 4 PQP Involvement barriers is 0.82, which is above the cited minimums of Cronbach's alpha 0.70 [219], and was considered to be a high and acceptable alpha, giving evidence that the total Cronbach's alpha was judged to be reliable for the questionnaire.

6.9.5.3 The relative importance index (RII) and rank of PQP Barriers

The relative importance index is a technique, which has been used widely in different types of questionnaire to rate each factor based on the weight given by the respondents. It is also one of the best approaches to rank the ordinal scale variables by the respondents and ranges based on Likert Scale from 1 to 5 [235]. However, it is very important to state, which significant barrier is most affecting the implementation of PQP. The relative importance index method (RII) is employed in this thesis to identify, which one of the sixteenth PQP barriers is most affected the implementation of PQP in three LDNs west, east and south after the significant level is obtained [235]. The relative importance index is calculated as:

$$RII = \frac{\sum w}{A \times N} \qquad \textit{equation (6.6)}$$

Where:

- W is the weight given to each factor by the respondents and ranges from 1 to 5
- A = the highest weight = 5 on Likert Scale from 1 to 5
- N = the total number of respondents

In addition, part four in the questionnaire was designed concerning research question five to assess the level of PQP implementation by assess the attitude of west, east and south distribution network respondents towards the barriers that effect on the implementation in LDNs.

What are the difficulties and barriers facing LDNs in implementing PQP?

The relative importance index (RII) and rank of PQP barriers, which are considered as the key factors affecting the implementation of PQP presented in table 6.33. Lack of PQ standards has been ranked the first factor affecting the implementation of PQP by the west distribution network respondents (RII) = 0.541 and east distribution network respondents (RII) = 0.543 respondents. However, this factor has been ranked as third by south distribution network respondents (RII) = 0.532. The overall rank for this factor among all factors with relative index (RII) = 0.538. It is noted that this factor identified as most important for west and east distribution network as they lack of PQ standards, which affect both the supplier and end user. Moreover, this factor has affected the end user sensitive equipments as well as the distribution network operators to assess the level of PQ. As a result, end user complaint regarding PQDs due to lack of PQ standards. Lack of staff awareness, skills and experience has been ranked the second factor affecting the implementation of PQP by east respondents (RII) = 0.542 and south distribution network respondents (RII) = 0.546. However, this factor has been ranked as third by west distribution network respondents (RII) = 0.525. The overall rank for this factor among all factors with relative index (RII) = 0.537. This factor is considered as a significant obstacle for LDNs staff, whereby they could not improve PQDs, satisfy end user, identified PQDs roots, increase their knowledge and skills, aware end user regarding PQ issues and the most important element their contribution in implementing PQP.

Table 6.33: Presented the relative importance index (RII) and PQP barriers ranking

Items	Barriers	West Network		East Network		South Network		Overall	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
BA1	lack of staff awareness, skills and experience	0.525	3	0.542	2	0.546	2	0.537	2
BA2	lack of end users awareness	0.447	8	0.481	5	0.459	10	0.462	8
BA3	lack of customer cooperation	0.518	4	0.523	4	0.562	1	0.534	3
BA4	lack of long-term strategy and planning	0.501	5	0.468	7	0.493	7	0.487	5
BA5	lack of top management commitment	0.471	6	0.435	9	0.458	11	0.454	9
BA6	lack of network designing	0.532	2	0.525	3	0.514	5	0.523	4
BA7	lack of distribution networks infrastructure	0.441	11	0.447	8	0.439	13	0.442	11
BA8	lack of conducting research and studies	0.443	9	0.432	10	0.515	4	0.463	7
BA9	lack of top management responsibility	0.423	13	0.412	13	0.462	8	0.432	12

BA10	lack of training courses, education and support	0.408	14	0.358	16	0.441	12	0.402	16
BA11	lack of enough resources	0.398	15	0.407	14	0.428	14	0.411	14
BA12	lack of financial incentives	0.456	7	0.421	11	0.461	9	0.446	10
BA13	lack of PQ measurement	0.392	16	0.406	15	0.424	16	0.407	15
BA14	lack of PQ consultants	0.442	10	0.474	6	0.502	6	0.472	6
BA15	lack of PQ standards	0.541	1	0.543	1	0.532	3	0.538	1
BA16	lack of PQ monitoring and database	0.427	12	0.415	12	0.426	15	0.422	13

As indicated in table 6.33, lack of customer cooperation has been ranked by the west respondents as the fourth factor with RII equal 0.518. It has been ranked by the east respondents as the fourth factor with RII equal 0.523 and has been ranked by the south respondents as the first factor with RII equal 0.562. The overall rank for this factor among all factors with relative index (RII) = 0.534. The three distribution network respondents considered this factor as an important due to the neglect of end user to cooperate with LDN management in order to improve PQDs and implement PQP. As a result, the end user are not satisfied about the bad PQ they utilize as well as their complaints are not taken seriously. Therefore, this factor affects directly on PQP implementation as they do not trust LDN department to take their suggestion into account, when measuring or improving PQDs. If customers are not cooperated as part of PQP implementation, the implementation will suffer from issues of considering end user satisfaction to estimate the real outcome expected from such programme. This result confirms what Grady and Noyola stated regarding PQP implementation, if customer cooperated, which will give necessary and sufficient results needed [73]. In addition, table 6.33 presented the relative importance index (RII) and rank of PQP barriers, which indicated the most affecting barriers on the implementation from 1 to 16, based on the three LDNs respondents respectively. The relative importance index (RII) and the rank closes to one is considered most important factors affecting on PQP implementation in three west, east and south LDNs. Therefore, from table 6.33, LDNs need to consider and evaluate each importance barrier based on its rank, which affecting on the whole programme implementation in order to make significant change on PQDs. This can be done by link all the four factors of PQP framework together in order to make dramatically change within time specified.

6.10 Modeling PQP Framework Using Multivariable Linear Regression

6.10.1 Multivariable Linear Regression of (CSFs) of PQP Awareness

Multivariable Linear Regression (MVLR) analyses were performed in this thesis to investigate; firstly, the relationship between the success factors derived from the literature and the level of PQ awareness within LDNs. Four predictor variables were used: (Customer Satisfaction **(CS)**, Management Commitment **(MC)**, Employee Participation and Training **(EPT)**, and PQ Disturbances Affecting Networks **(PQDANs)**) in order to assess their contribution to the outcome factor, which is PQ Awareness. The purpose of using multiple-Regression was to provide enough information about the model for PQP and the relative predictor variables that contribute to the model [196]. After the data obtained, Multivariable Linear Regression (MVLR) was chosen as a reliable and useful analysis tool for such a PQP framework [236]. Preliminary assumption tests were conducted again to check for multicollinearity and singularity, outliers, normality, linearity, homoscedasticity and independence of residuals, with no serious violations noted [197]. Moreover, both constructs validity and reliability instruments were used to test the constructs of the PQP in the model to ensure that they produced strong unities and expressed good measurement properties for all the items, as shown in table 6.3 and table 6.7. These tests were conducted by employing both factor analysis and reliability [237].

Principal Components Analysis (PCA) of the model constructs explained extremely rotated loadings in the factors structure, as represented in Table 6.7. There were some items excluded to improve the reliability loading [238]. The reliabilities of Cronbach's alpha in this study, ranged from 0.745 to 0.851, as shown in table 6.3, and all were well above the cited minimums of 0.60 [217] or 0.70 [219][221]. The factor analysis in PCA showed that all the factor communications loading pattern were rotated by each factor item. The items excluded were to improve the reliability, which were included in regression, because they do not change the regression patterns [207]. The Critical ratio or T-values indicated whether the predictor variables contributing to the model outcome are significant or not. In this model, all T values for all factors loading are significant, since all of them were above the suggested value, which 1.96 for the entire factor loadings [201][208].

Therefore, in order to arrive at statistically significant results, the survey was conducted in three LDNs based on five critical success factors for a PQP. These factors are management commitment, employees training and participation, customer satisfaction and PQ awareness and PQ disturbances. Each factor has its own variables, which were derived from the literature review, in order to determine the assumptions, which should exist in LDNs, in order to increase the level of PQ awareness. As a result, an acceptable model was developed based on these factors. It is clear that all these factors are significantly correlated, since all p values are less than (<0.05) and are substantially affected by the lack of awareness of the implementation of PQP in LDNs, as shown in Figure 6.17.

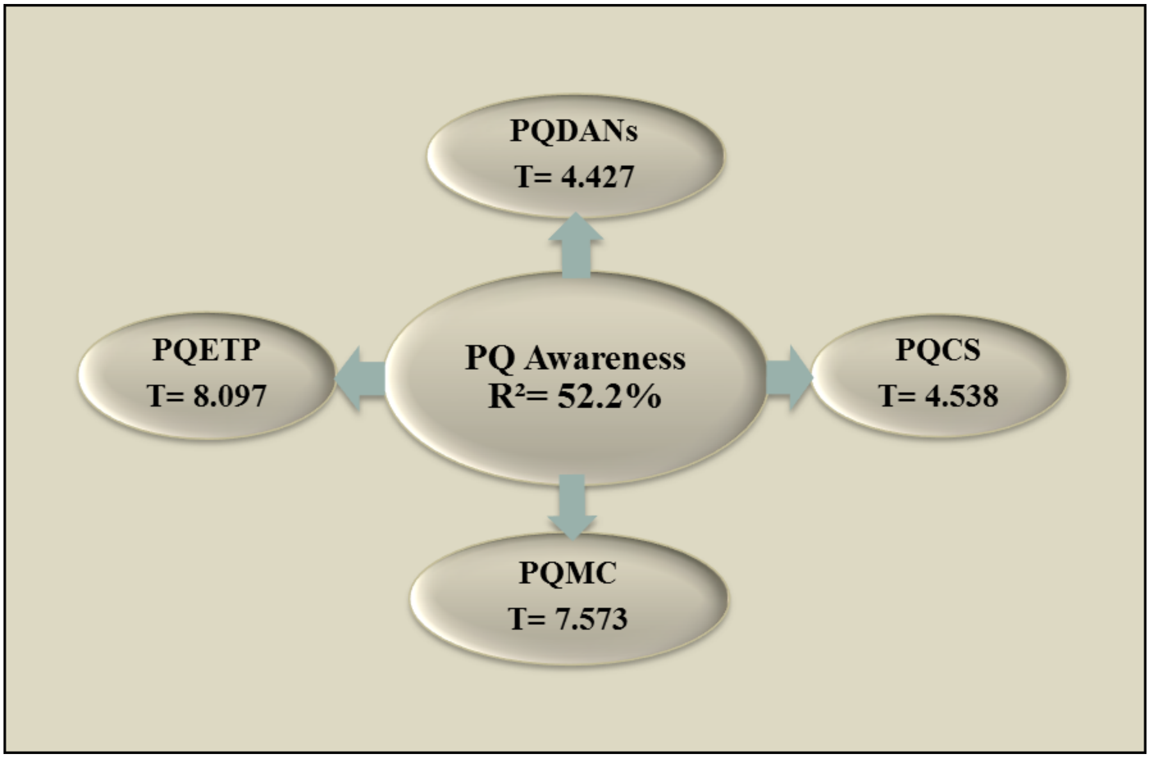


Figure 6.17: Research Model for PQ Awareness

Therefore, *"Good model fit is developed with significant path coefficients, acceptably high R^2 and internal consistency construct reliability being above 0.70 for each construct"* [209]. Multivariable Linear Regression output is generated below using the enter method, a significant model emerged (F/4, 351=95.989, $p < 0.0005$. Adjusted $R^2 = 0.522$. The significant variables contributed to the model are shown in Table 6.34:

Table 6.34: Regression results for PQ Awareness predictor factors

Constant PQ Awareness	B	SD .Error	β	T	P	R²	Collinearity Statistics	
	0.589	0.181		3.246	0.001	0.522	Tolerance	VIF
PQ. (CS)	0.139	0.031	0.202	4.538	0.000		0.691	1.449
PQ. (MC)	0.301	0.041	0.345	7.573	0.000		0.655	1.527
PQ. (EPT)	0.238	0.029	0.316	8.097	0.000		0.893	1.119
PQ.(DANs)	0.126	0.028	0.171	4.427	0.000		0.911	1.099

Table 6.34 and Figure 6.17 showed that the value of R^2 was 52.2% for this model, which indicated how much of the variability in the outcome was explained by the predictors, which are (customer satisfaction, management commitment, employee participation and training, and PQ disturbances affecting networks). Since all factors of the model were statistically significant ($p < 0.05$). This also indicated that the validity of this model is very good. As a result, this model can be accepted and applied to LDNs to increase the level of PQ awareness, and in order to implement PQP, since all the predictors increase by one unit (see β value), as these constructs explained 52% of PQ Awareness construct ($R^2 = 0.522$). Table 6.34 also illustrated that all the factors contributed to the model, since all p values were significant correlated and less than <0.05. The two factors that most highly contributed to the model are PQMC (β=0.345, $p < 0.05$), which means that this predictor makes the strongest unique contribution and explains 34.5% of the outcome factor [196], which is significantly positively affected by the level of PQ Awareness (T =7.573), when the variance is explained by all other predictor factors in the model. PQEPT (β=0.316, $p< 0.05$), which is significantly positively affected by PQ Awareness and has explained 31.6% of PQ Awareness factor (T=8.097), while (PQCS β=0.202, $p < 0.05$) which was significantly positively affected by PQ Awareness and has explained 20% of PQ Awareness factor (T=4.538), and PQDANs value (β=0.171, $p < 0.05$) which has significantly positive affected by PQ Awareness and has explained 17% of PQ Awareness factor (T=4.427).

As a result, the regression analysis explained the linear relationship between the outcomes, which was PQ Awareness, explained by model and the predictor factors. This confirmed the need to improve these factors, as shown in Figure 6.17. Therefore, these improvement factors should be considered by LDNs top management, for which both end users and engineers and technicians must be critically fully aware of PQ issues.

As a result of Multivariable Linear Regression analysis, an acceptable model is developed based on these factors. It is revealed that all these factors are significantly positively contributed, and have effect on the implementation of PQP in LDNs in terms of PQ awareness, as shown in Figure 6.17. Therefore, the implementation of this model framework is expected to provide faster feedback and more efficiently, if both top management and employee participation paid good and strong attention to it.

6.10.2 Multivariable Linear Regression of PQP Framework Implementation

Multivariable Linear Regression (MVLR) analyses were performed in this thesis to investigate secondly; the relationship between the PQP barriers derived from the literature and the implementation of PQP framework within LDNs. Four predictor variables were used: (PQP Awareness, PQP Management commitment, PQP Resources, and PQP involvement) in order to assess their contribution to the outcome factors, which is PQP Implementation. Preliminary assumption tests were conducted once more to check for multicollinearity and singularity, outliers, normality, linearity, homoscedasticity and independence of residuals, with no serious violations noted [197]. Moreover, both constructs validity and reliability instruments were used to test the constructs of the PQP in the model to ensure that they produced strong unities and expressed good measurement properties for all the items, as shown in tables 6.29 - 6.32. These tests were conducted, employing both factor analysis and reliability [237].

Principal Components Analysis (PCA) of the model constructs explained extremely rotated loadings in the factors structure, as represented in tables 6.29 - 6.32. The reliabilities Cronbach's alpha for the Four predictor variables of PQP barriers ranged from 0.731 to 0.821, as shown in tables 6.29 - 6.32, and all were well above the cited minimums of 0.60 [217] or 0.70 [219][221]. The factor analysis in PCA showed that all the factor communications loading pattern were rotated by each factor item. The critical ratio or T-values indicate whether the predictor's variables that contribute to the model outcome are significant or not. In this model, all T values for all factors loading are significant since all of them were above the suggested value, which is 1.96 for the entire factor loadings [201][208]. Moreover, Pallant stated that *"Standardised beta values indicate the number of standard deviations that scores in the dependent variable would change if there was a one standard deviation unit change in the predictor"* [196].

Therefore, answering research question six, and arriving at statistically significant results of PQP framework implementation. The four PQP framework factors each have their own variables, derived from the literature review, to determine the assumptions, which should exist in LDNs, in order to implement the PQP framework. As a result, an acceptable model was developed based on these factors. It is clear that all these factors are significantly correlated, since all p values are less than (<0.05) and are substantially affected by the implementation of PQP in LDNs, as shown in Figure 6.18.

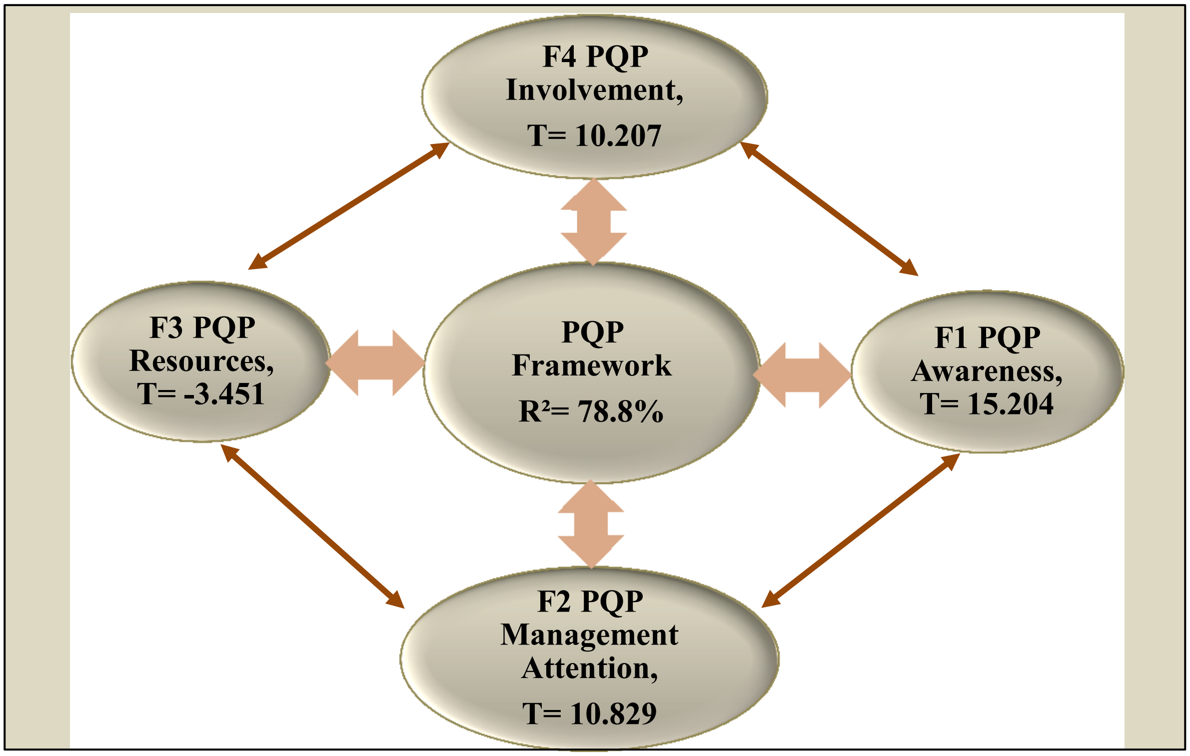


Figure 6.18: Research Model for PQP Framework Implementation

Therefore, *"Good model fit is developed with significant path coefficients, acceptably high R^2 and internal consistency construct reliability being above 0.70 for each construct"* [209]. Multivariable Linear Regression output is generated below using the enter method; therefore, a significant model emerged: = (F/4, 347=322.439, p < 0.0001. Adjusted R^2 = 0.788. The significant variables contributed to the model are shown in Table 6.35:

Table 6.35: Regression results for contributed factors of PQP Framework Implementation

Constant PQP Framework	**B**	**SD .Error**	**β**	**T**	**P**	**R²**	**Collinearity Statistics**	
	0.717	0.109		6.588	<0.001	0.788	Tolerance	VIF
F1 PQP Awareness	0.516	0.034	0.546	15.204	<0.000		0.474	2.112
F2 PQP Management Attention	0.201	0.019	0.314	10.829	<0.000		0.729	1.373

F3 PQP Resources	-0.065	0.019	0.099	-3.451	<0.001		0.740	1.351
F4 PQP Involvement	0.206	0.020	0.289	10.207	<0.000		0.763	1.310

Table 6.35 and Figure 6.18 showed that the value of R^2 was 78.8% for this model, which indicated how much of the variability in the outcome was explained by the predictors, which are (PQP Awareness, PQP Management commitment, PQP Resources, and PQP involvement). Since all factors of the model were statistically significant *($p < 0.05$)*. This also indicated that the validity of this model is very good. As a result, this model can be accepted and applied for LDNs to implement PQP, since all the predictors increase by one unit (see β value) as these constructs explained 78.8% of PQP implementation construct ($R^2 = 0.788$). Table 6.35 also illustrated that all the factors contributed to the model, since all p values were significant correlated at less than <0.05. The factors highly contributed to the model were F1 PQP Awareness (β=0.546, $p < 0.05$), which makes for the strongest unique contribution factor explaining the outcome of the model [196], and has significantly positive effect on PQP framework implementation and has explained 54.6% (T=15.204). F2 PQP Management Attention (β=0.314, *$p < 0.05$),* which has significant positive effect on PQP framework implementation and has explained 31.4% (T =10.829), when the variance is explained by all other predictor factors in the model. F3 PQP Resources (β=0.099, $p < 0.05$), which has significantly positive effect on PQP framework implementation and has explained 10% (T=-3.451), indicating that it made less contribution [196]. F4 PQP Involvement (β=0.289, $p < 0.05$), which has significant positive effect on PQP framework implementation, and has explained 29% (T= 10.207).

As a result, the regression analysis explained the linear relationship between the outcomes, which is PQP implementation, explained by model and the predictor factors, which are statistically significant contributions. This confirmed the need to improve these factors, as shown in Figure 6.18. Therefore, the implementation factors of PQP should be considered by top management, for which the three LDNs end users and engineers and technicians are critically, not fully aware of PQ issues, as explained in section 6.10.1. As a result of Multivariable Linear Regression analysis, an acceptable model was developed based on these factors. It revealed that all these factors significant positive contributors, and have an effect on the implementation of PQP in LDNs in terms of PQP Awareness, PQP Management commitment, PQP Resources, and PQP involvement, as shown in Figure 6.18. Therefore, the implementation of this model framework is expected to have faster feedback, and greater efficiency, if both top management and employee's participation paid good and strong attention to it by increasing the awareness level.

6.11 Summary

The contribution of this chapter was in explaining the steps of the data analyses used in this thesis. The results gained from this study were based on the questionnaire conducted in LDNs across 397 respondents. Initial analyses, after data preparation, were conducted to ensure that the data is normally distributed. Then data were scanned, cleaned, coded and entered into SPSS (Statistical Package for Social Scientists18.1). In part one, multiple techniques were used to measure the questionnaire instrument reliability and validity regarding Cronbach's alpha and factor loading. All the 6 PQP factors had a satisfactory level of reliability (0.806) and the internal consistence measures for each construct ranged between 0.745 and 0.851. The items were inter-correlated and the Eigenvalues of the unreduced inter-correlation matrix were computed using principal component analysis (PCA). Six factors were extracted, and explained 54.582% of the variance, and rotated to a simple structure by means of Varimax Rotation. Pearson's correlation coefficient was utilized to indicate the strength of association between CSFs of PQP factors. The correlations within the CSFs of PQP were tested to check the PQP implementation in LDNs. The test pointed out that all five factors were positive correlated. Therefore, this indicates that a PQP should be implemented among LDNs. Moreover, the level of implementation of PQP was the main focus to be investigated in this survey. Table 6.10 revealed the low level of PQP implementation among LDNs. These findings were not accidental as LDNs have not had adopted any of PQ standards, which would improve PQDs. This section was applied to answer the second research question: *what is the current state of PQ awareness and efforts regarding the implementation of PQP in LDNs?"*

MANOVA was designed to answer the fifth research question by examining whether or not any of the five CSFs of PQP were statistically significantly different within LDNs. This signified that, there were no statistical significant differences in employees' work position, educational level, experience, and responsibility along with all participants categories from all three networks, since the value of (P>0.05) and the levels of PQ awareness regarding the CSFs derived from the literature for PQP implementation.

Part two was designed to explore the level of implementation of PQPs, which were carried out in LDNs, and to answer the first research question. *What is the actual overall level of the PQDs, in terms of measurements, solutions and implementation regarding PQ awareness?*

There was a critical answer from the respondents with regard PQP implementation in three networks, which significantly would indicate that there no PQP was implemented in LDNs in the past, with approximately 51.9% to 56.6% of the respondents explained that in section 6.9.2. This can give an indication, that most of the engineers, technicians and head managers were not aware of PQ problems, as a result of not being aware of the concept of PQ. Moreover, One-way Analysis of Variance was conducted in this study to test whether or not there were any statistically significant differences between PQP barriers and three LDNs. It was revealed that Out of 16 barriers, 13 were statistically significant differences at the P value <0.05. The ANOVA results exposed that PQP factors have a significant effect on LDNs in terms of level of PQP Awareness, PQP Top Management Attention, PQP Resources and PQP Involvement.

In addition, Multivariable Linear Regression (MVLR) analyses were performed in this thesis to investigate, firstly, the relationship between the success factors derived from the literature and the implementation of PQP within LDNs. Four predictor variables were used: (Customer Satisfaction, Management Commitment, Employee Participation and Training, and PQ Disturbances Affecting Networks. As a result, an acceptable model was developed based on these factors. All these factors are significantly correlated, since all p values are less <0.05 and are substantially affected by the lack of awareness of the implementation of PQP in LDNs. Secondly, Multivariable Linear Regression (MVLR) analyses were also performed to investigate the relationship between the PQP barriers and the implementation of a PQP framework within LDNs. Four predictor variables were used: (PQP Awareness, PQP Management commitment, PQP Resources, and PQP involvement). It revealed that all these factors were positively significant and have statistical effect on LDNs to implement PQP. The regression analysis explained the linear relationship between the outcomes, which was PQP implementation, explained by the model and the predictor factors, which confirmed the need to improve these factors.

Other conclusions that have emerged from this chapter are that a PQ survey on LDNs was conducted in all three, west, east and south, networks. In addition, PQ causes and problems in LDNs were determined. Comparative tables between the three networks in terms of disturbances and main sources of problems were analysed. In response to this, new models for PQ solutions were developed and proposed for LDNs. The results showed that most PQ issues were due to lack of a management strategy, lack of awareness and knowledge on part of LDNs staff and customers. The rapid economic growth was a very significant factor causing huge events in GECOL after 1999. One of the points was that, it is clear there was no PQP awareness, which can at least match the sudden growth in the economy. It is revealed that lack of PQ awareness is the main issue. As a result, lack of awareness was found among the four main categories: Top management, Engineers, Technicians and End users. These are the people who are supposed to solve PQDs, or at least to be aware of the PQDs, as described in figure 6.11. These issues are seen as quite crucial and fundamental requirements before start mitigation PQDs. As a result, both end users complaints and attitudes are raised and caused significant reactions through faulty connection to the distribution networks, which impacted on the quality of electricity, and required both PQ guideline and datasets. The regression models were sufficiently representative to conclude that the relationship between the model and the dependent variables of PQ awareness and PQP factors are very strong and not incidental.

The next chapter (7) presents the second data analysis based on the qualitative study and findings used to examine the barriers of PQP implementation in LDNs.

Chapter Seven: Qualitative Data Analysis and Results

7.1 Introduction

This chapter explains the qualitative data analysis performed in this study, which revealed that the definition of PQ is still a new phenomenon among staff in LDNs. Therefore, given the lack of understanding of this term, there is a need to find an appropriate adoption model or framework for PQP to be implemented, so as to start making improvements in PQ. For this research, the PQP adoption model framework was developed based on an extensive review of the literature, comprising previous studies, reports, published papers, and documents, added to the results gained from analysis of both quantitative and qualitative data.

Qualitative data for this study was collected through face-to-face semi-structured interviews of EGCOL staff. Participants included LDN top managers, middle managers, engineers, technicians and employees in four departments, namely distribution, planning, training and customer services, which are relevant to PQP improvements. From the qualitative data, the researcher was able to understand and recognise participants' experiences, opinions and thoughts. This study's model and diagrams were developed based on participants' ability to identify the abstractions faced in building the appropriate PQP framework in LDNs. Appendix B shows the interview questions used in the qualitative study on PQP implementation. This qualitative data were processed and analysed in a methodical manner, as is summarised in the subsequent sections, where Section **7.2** explains the purpose of using qualitative data in this study, while Section **7.3** describes the current level of PQP implementation factors in LDNs. Section **7.4** illustrates the barriers facing PQP implementation, and Section **7.5** clarifies the benefits of PQP implementation, which would have positive impact on improving LDNs in terms of PQDs. Finally, Section **7.6** summarises the whole chapter.

7.2 Semi-structured interviews

PQP requires an investigative method to determine the critical success factors suitable for particular programme requirements. A qualitative method was used in this research for several reasons; firstly, the PQP concept is not well known in EGCOL, and therefore, existing frameworks cannot be adopted, because they do not provide the adequate and full investigation needed in the LDNs' case. The PQP model for LDNs was validated using both the quantitative (PQ survey) and qualitative approach (interviews) with EGCOL staff. The qualitative data were collected as open-ended narrative, without predetermined or standardised categories, as defined by Silverman, *"the ability to achieve a level of depth and complexity of information and gaining very detailed and comprehensive talk"* [239]. Qualitative analysis examines various groups of interviewees to categorise the common topics regarding the specific phenomenon [144].

Therefore, the purpose of collecting qualitative data is due to its diversity in establishing answers for research questions [144]. Generally, these procedures required converting data, such as interview notes, audiotapes, into partly processed data (transcripts), which are then coded and subjected to one of a number of analysis schemes [152]. Weber and Bryman and Bell defined content analysis as *"powerful data reduction technique is a procedure for the categorisation of verbal or behavioural data, for purposes of classification, summarisation and tabulation many words of text into fewer content categories based on explicit rules of coding"* [142][240].

As part of this, the questions were designed in sections with clear statements to enhance the interviewees to provide answers for each factor. Collis and Hussey, Sarantakos and Leedy, and Ormond stated that when designing the interview questions, the researcher should take some rules into account [241-243]. The rules are as follows:

- Explain the aim of the interview to all interviewees
- Make the interview questions simple and shorter
- Organize questions in sections
- Asking one question at a time
- Asking relevant questions only
- Avoid asking complicated questions
- Avoid asking the interviewees embarrassing questions

The analysis has involved the researcher dealing with collected data by listening to tapes, typing the text and reading transcripts. This was done in order to identify the existing issues, concepts, beliefs, and themes by which the data could be examined, referenced and rearranged, according to the appropriate part of the study framework. It was also to find associations between themes with more explanations for the findings, which could be compared with the findings from the quantitative analysis [240][175]. The outcome of the qualitative analysis is supported by quotations from interviewees, and by the outcomes from the quantitative analysis to provide a clear vision of PQP difficulties in LDNs.

Miles and Huberman stated that *"Qualitative data analysis is more subjective than quantitative data, is anecdotal and relies heavily on the researcher's knowledge and experience to identify patterns, extract themes and interpretation of findings"*[144][240]. Moreover, this approach enabled the researcher to gain in-depth views and experiences from knowledgeable interviewees involved in PQP improvements.

After collecting the data, transcription and coding into NVivo 9 software to support developing the coding system for qualitative data analysis, the next step prepared for further analysis. According to Patton, "analysis is the process of bringing order to the data, organising what is there into patterns, categories and basic descriptive units, interpretation involves attaching meaning and significance to the Analysis explaining descriptive patterns and looking for relationships and linkages among descriptive dimensions" [244]. The interview analysis for this study revealed that qualitative data supported the results gained from the quantitative analysis and proved, why there was a clear lack of PQ awareness in implementing PQP and the issues, which LDNs faced and still face. Table 7.1 shows the number of interviewees, who participated in the qualitative study, along with their department. Moreover, Appendix J explains how interviewee characteristics were coded for the qualitative data analysis based on each department, interviewee category and position, and questions for each PQP factor.

Table 7.1: Interviewees and departments characteristic

Interviewee Categories	Customer Department	Planning Department	Distribution Department	Training Department
Head Manager	0	1	0	1
Middle Manager	2	9	8	6
Engineer	0	1	6	0
Employees	2	0	2	6

7.3 Implementation Factors of Power Quality Programme (PQP)

The qualitative data analysis is clearly explained in the following sections;

7.3.1 Factor (1) – Power Quality Programme (PQP)

The PQP is the first and most significant factor chosen to assess how top management and staff bear their commitment to, and support for implementing PQP. Their commitments are to understand PQ definition, and the difficulties and benefits of implementing PQP. It was clear that without establishing a clear vision of these factors, which have significant effect on LDNs, then any efforts aimed at improving PQ issues will be a waste in both time and resources. Table 7.2 shows PQP barriers, which affect LDNs in implementing the PQP framework, and the significant effect of each barrier on each department.

Table 7.2: PQP framework effect by barrier on each department

PQP Barriers	Customer Department	Planning Department	Distribution Department	Training Department
1 : Lack of Infrastructure	0%	36.17%	46.29%	17.54%
2 : Lack of Customer Awareness	2.57%	18.22%	56.19%	23.02%
3 : Lack of Enough Resources	0%	10.33%	11.65%	78.01%
4 : Lack of Long Term Strategy	4.55%	29.46%	17.83%	48.16%
5 : Lack of Management Commitment	0.42%	29.32%	26.45%	43.81%
6 : Lack of Networks Designing	4.11%	55.53%	26.13%	14.23%
7 : Lack of PQ Measurement	2.13%	49.41%	43.74%	4.73%
8 : Lack of PQ Standards	0%	61.65%	19.63%	18.72%
9 : Lack of PQ Training Courses	0%	15.15%	3.72%	81.13%
10 : Lack of Regular Maintenance	0%	45.79%	27.97%	26.25%
11 : Lack of Staff Awareness	0.73%	32.1%	38.54%	28.63%
12 : Lack of Top Management Responsibility	0%	80.42%	19.58%	0%

Table 7.2 illustrates the most common PQP barriers, which affect LDNs in implementing the PQP framework. As can be seen, the four departments, which are supposed to implement PQP, are affected by the twelve PQP barriers. The level of each barrier and its effect on each department are identified by the interviewees. In general, the table shows that all PQP barriers (they are all above 15%) seriously affect LDNs progressing to implement a PQP.

One of the clear points is that there was no PQP awareness, which can at least match the significant increase in PQP barriers. In response, there was a significant need to implement a PQP framework. It is revealed that the lack of the following: PQ awareness, long term strategy, customer awareness, training courses, accommodating economic growth, network design and infrastructure, sufficient resources, staff awareness, top management responsibility and commitment, and PQ standards, are the main issues in LDNs regarding PQP implementation. The twelve PQP barriers were found in the four main departments involved in PQ improvements: planning, distribution, training and customer departments. These departments should be aware of the crucial and fundamental requirements, as well as the top priority factors needed before starting to implement a PQP. Moreover, each department should evaluate each barrier and identify strengths and weaknesses, and what it needs to tackle as high priority.

7.3.1.1 Power Quality Definition (PQD)

Five variables were related to question one regarding the concept of PQ. These were investigated, and summary statistics from the analysis are presented in table 7.3.

Table 7.3: Mean and SD of (PQD) Factor variables

Factor	Item No	Description	Mean	S.D	Overall Mean
X2.1:Definitions(D)	X2.1.7	D/Reliability and Availability	4.20	0.922	4.03
	X2.1.8	D/Satisfy Customers	4.10	0.922	
	X2.1.9	D/Reduce Losses	4.17	1.053	
	X2.1.10	D/Customers Awareness	**3.46**	1.151	
	X2.1.11	D/Increase Efficiency	**4.26**	0.846	

Descriptive analysis of responses regarding the definition of PQ shows that the mean level of Power Quality Definition is **4.03** on the five-point Likert Scale, where 1=Strong Disagreement, and 5=Strong Agreement. This signifies a high level of understanding of the concept of PQ, which is a result of the high level for both its components and PQP implementation. PQ referred to reliability and availability scored a mean level of (4.20), satisfying customers (4.10), reducing losses (4.17), customer awareness (3.46), and increasing efficiency (4.26). The result of the qualitative analysis supported the quantitative analysis, as shown in table 7.3.

All quantitative and qualitative results confirmed that the concept of PQ has been successfully understood by EGCOL staff categories, in order to implement PQP in LDNs within the relevant departments. Moreover, this indicated that the staff understood the concept of PQ, and will be able to implement PQP without any difficulties, if they plan to improve PQDs. As a result, the PQ definition was referred to four categories:

7.3.1.1.1 PQ Definition Associated with Reliability and Availability

Approximately 35.58% of the interviewees stated that the purpose of improving PQDs is to ensure the reliability and availability of the power supply. This means reliability all the time, without any interruption, and availability without any outage or poor power factor. One employee from the distribution network planning section defined PQ by stating that:

"PQ means power should be continuity and reliability all the time and without any interruption to supply consumer with good voltage and without voltage drop to protect the end users equipment to satisfy consumers".

Another five participants from the planning and standards department have a similar definition of PQ, associated with reliability; one stated:

"PQ means the power supplied to consumers should not have any disturbances such as voltage drop, flicker and harmonics and reliable all the time, which it should not be more or less than the acceptable level".

7.3.1.1.2 PQ Definition Associated with Customer Satisfaction

Approximately 39.47% of the interviewees stated that the purpose of improving PQDs is to satisfy customer requirements. These requirements are based on the barriers, which should be overcome in terms of PQP improvements. On the other hand, these requirements include what the end users should do to enable the company to implement these requirements. The first requirement is the voltage level, which should not go below or exceed the specified standards; as one of manager in the distribution system said:

"PQ means the stability of power supplied to consumer with good quality without any interruption and it should be within the standards to satisfy the end users".

Another manager in the protection section said:

"Of course this is the company priority which attempt to improve its picture to its customers in order to satisfy the customer by supplying them continuity power within the limit standards and without any variation to operate their equipment effectively".

This definition is similar to what GUL identified [71]. On the other hand, one of the planning and research department managers stated that:

"PQ means good and clean service should be distributed to consumers with high quality and without any interruptions based on each consumer load and type and it should be compatible with consumer's needs and have very high efficiency in order to satisfy them".

7.3.1.1.3 PQ Definition Associated with Increased Network Efficiency

Approximately 18.77% of the interviewees stated that the purpose of improve PQDs is to increase the network efficiency. This means that there should be no deviation in voltage, current and frequency. Most answers regarding PQ definition in terms of increasing the efficiency of the network were similar to the following:

"PQ means increase the power efficiency to be distributed to consumers at the acceptable level of voltage and quality to increase its efficiency to operate their equipment without any damage. So as a result this would help reducing PQDs by solving all the problems face of distribution network such as power interruption, voltage sag, voltage swell, fluctuation, flicker and power factor to increase the quality in terms of environment and economic".

7.3.1.1.4 PQ Definition Associated with Power Quality Standards

Approximately 42.65% of the interviewees stated that the purpose of improving PQDs is to establish PQ standards, which would facilitate implementing PQP. One planning research manager defined PQ as:

"PQ means good service should be distributed to consumers with high quality and without any interruptions based on each consumer load and compatible with consumers needs so it should not be more or less than the acceptable level by considering the voltage to be within PQ standards to satisfy them".

Three employees from the training department have similar views regarding PQ standards; one Quoted:

"I think PQ is very important for all end users to operate their devices without any interruption

and it should not be over or under voltage which cannot operate the devices, and it also should be compatible with all the national and international standards such as IEEE or IEC at very high level before distributed to end users".

In brief, the majority of the interviewees, including department managers, engineers and technicians and employees working at EGCOL, were knowledgeable enough regarding PQ definition. They understood what PQ really means, in terms of definition according to the international terminology. This indicated that there were high levels of awareness of the concept of PQ in different staff positions in all departments participating in this study.

PQ definition is a very important aspect to be understood before starting the implementation of PQP in LDNs. Moreover, the level of awareness regarding this term was very high, which indicated that they should have a very high level of both experience and skill to deal with PQDs. Therefore, they should be eager, where these improvements should take place in LDNs, to tackle any existing problems preventing PQP implementation. This should include staff awareness, customer awareness, training courses, long term strategy, good planning, power quality measurements, and top management responsibility regarding PQP. Thus, without adequate knowledge, awareness, planning, design, preparation, training, power quality standards, clear strategy, and most importantly, top management support to perform this programme, PQDs cannot be improved, and their severity will affect all consumers. This lack of PQ will cause damage to equipment and increase network losses. Therefore, the more time spent on education to raise the awareness of staff and end users of the importance of PQ, the less the losses and equipment damage caused by PQDs.

In addition, the effort of improving PQDs in each department depends on the level of awareness of the top manager and staff of each department. They should share the responsibility of solving these issues, and pay more attention to the importance of PQ as part of tackling PQDs. Moreover, making the end users aware of how important it is to deal with the company in solving PQ problems. Therefore, PQP in LDNs requires both patience and discipline by top management and staff to admit what knowledge they had in the past regarding PQ issues, and what existing problems they face, in order to continue learning more in the future to avoid these obstacles, especially, as their level of awareness of PQ definition was very high.

7.3.2 Factor (2) - Customer Satisfaction (CS)

Customer Satisfaction (CS) is the second significant factor selected for assessing PQP implementation within LDNs. This factor includes customer complaints, satisfaction, needs, improvement, and awareness regarding power quality. As a result, the purpose of implementing PQP is to improve PQDs, and so satisfy consumers. Therefore, CS is a key factor, to which LDNs can adapt and determine end user requirements. In this way, they may deal appropriately with consumer complaints regarding PQDs affecting equipment. Therefore, without full participation by all employees and all departments in considering CS, any efforts at implementing PQP will be a waste of time and resources. Five variables related to this factor were investigated, and analysed; summary statistics are presented in table 7.4.

Table 7.4: Mean and SD of (CS) Factor variables

Factor	Item No	Description	Mean	S.D	Overall Mean
X2.2:Customers Satisfaction (CS)	X2.2.12	CS/Customer Complaint	**2.69**	1.039	**2.47**
	X2.2.13	CS/Customer Satisfaction	2.31	.963	
	X2.2.14	CS/Customers' Needs	2.66	1.063	
	X2.2.15	CS/Customers Improvement	2.44	1.015	
	X2.2.16	CS/Customer Awareness	**2.28**	.871	

Descriptive analysis of participant responses relating to the customer satisfaction factor shows that on the five-point Likert Scale, the mean level of this factor is **2.47,** where 1=Strong Disagreement, and 5=Strong Agreement. This signifies a low level of customer satisfaction as part of implementing PQP. This resulted from the low level of customer awareness related to PQ issues, and the negligence of the customer department in responding to customer complaints. Therefore, this overall result arises from low mean scores in the areas of customer complaints **(2.69),** customer satisfaction **(2.31),** customer need **(2.66),** customer improvement **(2.44),** and customer awareness **(2.28)**. The results of qualitative analysis supported the data gained from the quantitative analysis shown in table 7.4.

All quantitative and qualitative results confirmed that PQP has not been successfully implemented, because PQDs were not solved. This was due to the low level of customer awareness of PQ definitions, which caused PQDs due to the lack of customer satisfaction and the negligence of customer department in responding to customer complaints. Consequently, end users connected illegally to the network. For this reason, LDN departments should consider customer complaints regarding PQDs, and to increase customer awareness and ensure their needs are satisfied. As a result, customers will be encouraged to cooperate and become involved in PQ improvements, as part of PQP implementation. The qualitative analysis shows that both the distribution and customer departments do not pay much attention to their customer's complaints. The results were supported by almost all the participants in these two departments, which indicated a low level of customer focus.

The majority of interviewees indicated that both departments always dealt with customer complaints, as the line is very long or the loads are increased, with no further evaluation if these problems were due to other reasons. Moreover, there is no quick response to PQDs in the network reported in consumer complaints. As a result, the distribution networks do not deal with customer complaints, for example, by sending a specific team to measure PQDs that the consumer complained about, analyse the causes, or investigate the solution that can be implemented to minimise existing problems. Therefore, the maintenance section should conduct some measurements to analyse and understand the root of the problem regarding customer complaints, and prevent recurrence by finding the appropriate solution.
Hence, the company should conduct studies and measurements of each problem separately, to prevent complaints from the consumers. One engineer from the distribution department recommended that:
"All the departments have a copy of the company strategy and I think the end users should be involved to understand what is going on of improvements regarding PQ, to satisfy them as result they will have good reaction to cooperate with company to improve PQDs".

Therefore, when PQ is lower than standards, customers will feel that their complaints are being neglected. This will lead them to react negatively, for example, by connecting to the network illegally. Moreover, the company should take these reactions into account to avoid any problem arising in the future, in the same way, due to dissatisfaction end users. One engineer from the distribution and planning networks departments explained that:

"Approximately 35% of consumers who illegally connected to the network caused PQ issues. As a result, this reaction is due to complicated procedure when company does not consider their

complaints regarding PQ issues" [71].

Therefore, there is a significant relationship between dissatisfied consumers, and the causes of PQDs. However, there is another reason, which is the high cost of electricity. This also led customers to react negatively by connecting illegally to the network, in order to reduce the huge amount they pay. They will then cause PQDs to other consumers, who are legally connected. Therefore, customer satisfaction is one of the indicators that can be adapted to measure PQ levels. Furthermore, consumer awareness is also a very significant aspect associated with improvements in PQDs. The lack of customer awareness is also caused by customer culture, which is considered one of the causes of PQDs; most consumers cannot wait, and follow the procedure that the company sets to satisfy them. An engineer from the distribution and planning networks department concluded that:

"Lack of consumer's culture is one of the obstacles we suffer because it is very difficult to deal with them regarding PQ improvements. I think this resulted due to lack of awareness, which customer department always attempt to take action regarding their complaints to satisfy them but they did not cooperate with the department to meet their needs".

For this reason, increased customer awareness of, and concern about PQ, is a vital element in customer satisfaction. In this respect, attracting and engaging the consumer is a science, and the company should improve its methods, to achieve the results it wants. This can be done using a variety of methods, such as the media, press, leaflets and Internet, in order to increase customer awareness.

On the other hand, end users who live outside the distribution scheme are one of the reasons causing PQDs, due to illegal connection. This resulted from the complicated procedures followed by the company when consumers want supply power, making it difficult to connect them in a very short period. As a result, the consumer will react negatively and cause both PQDs and commercial and technical losses, due to the negligence of the customer department in meeting customer needs. Therefore, how end users connect to the network illegally should be considered by the company, because these issues happen when the company does not cooperate with consumers. One engineer from the distribution and planning department said:

"The company always has quick solutions to satisfy the consumers and I think most of the solutions were not related to what consumer's complaint about or customer needs. Therefore,

the problem will become worse than before and customer will not be satisfied".

In spite the fact that approximately 45% of consumers contributed in large part to causing PQDs by connecting to the network illegally, customer services employees were not experienced enough in dealing with consumers in a polite way. Handled properly, the consumer may become satisfied, even with the consequences when they cut the power due to unpaid bills. Therefore, in some cases, those technicians reconnecting customers illegally are unaware of the consequences resulting from this connection, and do not identify the phase to which they should connect, because they do not consider the loads distribution. This causes PQDs and consumers will start to complain. One manager from the distribution safety area section stressed that:

"I think to satisfy consumers and respond to their complaints, the maintenance section should conduct regular measurements by involve the consumers to measure all their loads to ensure that all the loads are distributed equally and are not based on one phase or transformer".

This will identify any problem before it reaches customers, and ensures customer satisfaction in that their needs are being met. Moreover, if voltage levels are good, this will give an indicator that power can be delivered to all end users without problems. However, if it is not to the expected standards, it should not be distributed to customers, unless PQDs are solved, which can avoid any customer complaints.

The majority of employees stated that if consumers utilise good voltage and all the types of loads are operated within PQ standards this would lead consumers to be satisfied. Conversely, consumers will complain about any PQDs they face. Therefore, customer complaints are the only the way used to identify customer satisfaction, where improving PQDs is not based on regular measurements or studies. This confirmed that the lack of employee awareness affected customer satisfaction, in that there was no further evaluation of existing distribution networks with measurement of PQDs, but an approach based on customer complaints rather than long term strategy.

LDN employees should be concerned with responding to consumer complaints, and should be involved in satisfying consumer needs, by increasing customer awareness making them familiar with PQDs. As a result, the purpose of improving PQ is to satisfy consumers. Therefore, reaching a high level of customer satisfaction is one of the key challenges and an objective for LDNs to achieve. For this reason, LDNs have to identify what are the outstanding problems regarding PQ, which need improvement.

Consumers may only judge if power quality is good or bad. Therefore, accommodating or exceeding customer requirements by the distribution networks needs to focus on designing the network to classify each consumer type and load. Moreover, it needs to meet the increased demand on all end users to avoid any negative reaction that could result from complicated procedure. All departments involved in improving PQ must focus on all the obstacles and problems that contributed to the perceived value on customer satisfaction.

7.3.3 Factor (3) - Management Commitment (MC)

Management Commitment (MC) is the third critical factor chosen in this study to see how it influences PQP implementation in LDNs. This factor is relevant to top managers, middle managers and engineers, who should support PQP implementation, under the headings of: Identifies the Causes, Responsibility, Planning Good Strategy, Recommendations and Studies, Ensure Security and Quality and International or National PQ standards. Therefore, without direct support given through MC, then any efforts at implementing PQP will be a waste of time and resources. Six variables related to this factor were investigated, and the analysis provides summary statistics, which are presented in table 7.5.

Table 7.5: Mean and SD of (MC) Factor variables

Factor	Item No	Description	Mean	S.D	Overall Mean
X2.3: Management Commitment(MC)	X2.3.17	MC/Identifies The Causes	2.23	1.060	**2.24**
	X2.3.18	MC/Responsibility	**2.03**	1.102	
	X2.3.19	MC/Planning Good Strategy	2.35	1.087	
	X2.3.20	MC/ Recommendations and Studies	**2.70**	.937	
	X2.3.22	MC/Ensure Security and Quality	2.12	1.052	
	X2.3.23	MC/International or a National Benchmarks	2.06	1.076	

Descriptive analysis of the MC factor shows that the mean level of this question is **2.24** on the five-point Likert Scale, where 1=Strong Disagreement, and 5=Strong Agreement. This signifies a low level of top management commitment as a part of implementing PQP, which resulted from the low level in both its components and the implementation of PQP. This overall result arises from low mean scores in the MC headings of: Identifies the root causes **(2.23),** Responsibility **(2.03),** Planning Good Strategy **(2.35),** Recommendations and Studies **(2.70),** Ensure Security and Quality **(2.12),** and International or National standards **(2.06).** The results of qualitative analysis supported the data gained from the quantitative analysis, as shown in table 7.5.

All quantitative and qualitative results confirmed that PQP has not been successfully implemented, because of absence of MC. This was due to management's lack of understanding of their responsibility, which is to be involved in improvements to the distribution network and the relevant departments. Moreover, this indicated that top managers did not appreciate the importance of having PQP, let alone any difficulties that might face them, if they planned to resolve PQDs. Therefore, the lack of top management knowledge and awareness had led to PQP not being implemented in LDNs.

In order to implement PQP in LDNs, top management needs to understand, and also have sufficient knowledge and awareness regarding PQP, to be able to support this programme effectively. The majority of participants in this research indicated that top management encouragement is seen as one of the most crucial factors, required to complete and facilitate the full implementation of PQP, by setting a clear strategy with obvious objectives, and involving all departments, which have a stake in improving PQ issues. Currently, the relevant departments have not conducted specific studies regarding PQP implementation, nor have they identified the level of difficulty by setting specific objectives based on each department's proposed strategy; one respondent argued:

"Of course the top management willing to implement PQP, but there are many studies and suggestion in last few years regarding PQ did not have gain the expected feedback, because most of strategies are come from the top management and most of the strategies are made by them. Moreover, they see PQP as small project and that is why they always ignorance it. Therefore, there are some difficulties which resulted by lack of clear strategy due to lack of concentration on visibility studies led the distribution networks to step backward of not complete the implementation of PQP".

One engineer from the distribution network planning section said:

"There are many projects but all of them are not matching each other because there is no clear strategy to combine all these projects to be in one goal in order to implement PQP. Therefore, all the concentration was how to reduce the technical and the commercial losses without

concentrating on improving PQ problems. Moreover, PQ department has just established".

Top management bears the main responsibility for PQ problems, as they must have a clear strategy to diagnose and solve PQ problems, and setting goals in the company strategy. One engineer from the power and planning department indicated that:
"There is a desire from the company to implement all the suggestion studies but because there is no a clear strategy yet due to lack of management commitment awareness. Therefore, it is responsible because most of the managers are changed from time to other and most of the old decisions or strategies are not completed".

There should be clear and long term strategy, which should include all the possibilities and solutions to help in improving PQ, even though managers may change. Indeed, the company sometimes begins to implement a strategy, and then stops without giving staff the reasons. Moreover, some problems can be tackled, but the lack of clear strategy still exists among some managers due to lack of awareness in some departments.
Top management should be the first to bear the responsibility for implementing PQP within a long term strategy, which is drawn up for the entire department involved in implementation. Moreover, they should increase their awareness and knowledge levels to be able to identify the root causes of the problems; by conducting some studies to ensure the security and quality of PQP implementation by following both international and national standards. Two managers from the training and the customer service departments have similar responses, and stated that:
"Top management is responsible to implement PQP. Therefore lack of long term strategy to improve PQ is missed. For example, there are very old generation plants have operated since 1970 and these affect PQ, which distributed to customers especially in summer time, where large numbers of end users operate air conditioning at the same time. As a result, many power interruptions caused to customer in many different areas".

Therefore, lack of top management awareness is another reason, which caused PQ problems, because there are not enough resources to implement PQP and improve distribution networks. However, there was no clear plan to tackle these issues. As a result, the strategy should be implemented step by step and all studies and projects standards are subject to quality control, if the company wants to have good PQP implementation.

In addition, another problem was caused by lack of clear strategy, there is no general scheme planned by the top management of the distribution networks, to tackle the difficulties faced in PQP implementation, such as new projects, which would accommodate the increased demand to improve PQ issues by preventing the end users taking electricity illegally. Thus, EGCOL is 100% responsible for solving PQ issues, because it is only the supplier who generates, transmits, and distributes power to consumers. Moreover, it receives funds annually from the government for development projects [120]. As a result, upgrading the existing distribution networks by adding new extra transformers to connect new customers legally, will reduce the impact of poor PQ, and complete PQP implementation; as one of the technicians in the customer complaint section stated:

"The top management does not bear their responsibility to control the increase demand on electricity, and this is caused by lacking of the government scheme because citizens can build or construct new houses or projects outside the scheme. Therefore, this will made it very difficult to control the network and implement PQP due to lack of distribution system strategy of not accommodated them".

Therefore, the majority of respondents indicated that top management responsibility is essential to support and meet the requirements of PQP implementation. They proposed some elements forming part of top management's responsibilities;

- To set clear strategy
- To raise end users' awareness
- To compare PQS to equipment standards
- To conduct studies on new technology
- To evaluate feedback for each project
- To have a proper team to understand the problem roots
- To involve all employees in any strategy
- To train employees regarding PQ issues

On the other hand, a few respondents stated that the distribution department has a new strategy, due to start in 2012. This included all requirements needed to implement PQP to improve its networks and PQ is part of its strategy. The project will be implemented in cooperation with the Swedish consulting firm, Breuer. This confirms that one of the difficulties facing PQP implementation is lack of staff awareness, including experience, culture, and skills.

One of top management's responsibilities is the ability to identify the roots of any problem, which might face implementation through one of the factors stated above. Therefore, the purpose of setting a clear strategy is to help categorise each task based on priority to avoid any unexpected results that could delay complete implementation. One of the planning standards department managers said that:

"The root for any problem cannot be identified because it is depends on the head manager if he interested in known the root, which caused the problems, and then it will have important concentration. For the reason that the staff do not care about the root of the problems and they just change the broken equipment by new equipment".

Lack of responsibility is one top management error, in that they do not give enough support to employees to follow up the problem roots through diagnosis and analysis. On the other hand, some top managers are interested in knowing the root causes of problems. However, it is sometimes difficult to find staff with enough background and knowledge related to these problem roots. Indeed, one of the difficulties facing PQP implementation is lack of staff awareness, including skills, experiences, and knowledge.

Therefore, one of the top management commitments is to conduct researches and studies, and provide enough equipment to analyse any problem. Moreover, the majority of the interviewees described some actions, which the top management should perform as part of their responsibility for PQP implementation, by controlling electronic equipment which are not compatible with PQ standards. Moreover, to meet increased demand with proper design of distribution networks, according to each consumer type. One of the planning, study and research managers said that:

"I think controlling the open marketing, where large number of the electronic equipment imported, because it is cheap and without high efficiency. As a result, this has impact on PQ due to its sensitivity to power supply variation".

One of the important things, to which top management must pay attention, is to set the strategy for all unexpected increases in both demand and economic growth. This may be achieved by considering normal growth with mega-projects that take account of any sudden increases. This would help the distribution networks categorise all types of consumers by type of load, into small and large residential, small and large industrial, and agricultural. Indeed, the company must take into account the types of the consumer when designing new networks or upgrading

existing ones. As a result, PQP can be implemented properly given that one problem area is the lack of proper network design. One of the planning high voltage managers said that:
"I think the distribution system concentrate on two things, which are the main priority both the demand increase and the economic growth and all the resources are spend on that rather than concentrating on improving PQ issues. Therefore, there should be such master plan including the load forecast and the development projects to know the prediction of the demand at all the levels in the network and to meet the peak demand for the next few years".

Therefore, a lack of top management culture of addressing PQ is one of the difficulties facing PQP implementation, i.e. good management will result in good PQ, and if top management does not have the sense of responsibility this means PQ would be at low level, which will be reflected on end users' expectations. As one of the engineers from the training department pointed out:
"For example, when the company implements some projects regarding distribution networks, the decision is based on the head manager of the department without sharing the decision with the engineers and mid managers to study the consequences, which will affect the network by causing PQ problems".

From the qualitative analysis of the four departments, it is clear that the top managers in these departments were not very involved in supporting PQP implementation. The lack of clear strategy, responsibility, studies and researches, identifying the problem roots and PQ standards to implement the whole programme have caused a low level of PQ among the distribution networks. All respondents from these departments stressed that PQP implementation cannot be completely successful without the direct participation of all staff, and with top management support. Thus, the absence of employee participation regarding PQP implementation could have a negative result for the departments involved, regarding PQD improvements.
In the end, it was clear that top management in these departments did not pay sufficient attention to building enough awareness, knowledge, planning, preparation studies, strategy, and standards to support PQP implementation. As one engineer said:

"*The typical management has affected on the employee's performance, therefore if there is a typical management, the employees will be also typical and if there is no typical management the employees will be careless".*

Therefore, the success factors of PQP implementation in each department reflect the style of the respective manager.

7.3.4 Factor (4) - Employees Participation and Training (EPT)

Employees Participation and Training (EPT) is the fourth critical factor selected to assess PQP implementation in LDNs. Therefore, employee participation and training was chosen to measure employee awareness and knowledge levels regarding PQDs. Moreover, it also measures their participation in any strategy regarding PQP implementation. Employee participation and training, includes the following variables; Survey or Feedback Techniques, Sufficient Training, Employees Suggestion, Employees Strategies, Appropriate Qualifications, and Employees Involvement. As a result, without full participation by all employees and all departments, then any efforts of implementing PQP will be wasted. Six variables related to this factor were investigated and the summary statistics of the analysis are presented in table 7.6.

Table 7.6: Mean and SD of (EPT) Factor variables

Factor	Item No	Description	Mean	S.D	Overall Mean
X3.1Employees Participation and Training (EPT)	X3.1.24	EPT/Survey or Feedback Techniques	**2.62**	1.147	**2.22**
	X3.1.25	EPT/Sufficient Training	2.21	1.173	
	X3.1.26	EPT/Employees Suggestion	2.29	1.120	
	X3.1.27	EPT/Employees Strategies	2.15	1.097	
	X3.1.28	EPT/Appropriate Qualifications	**2.01**	1.035	
	X3.1.29	EPT/Employees Involvement	2.05	1.092	

Descriptive analysis of the employee participation and training factor shows that the mean level of this factor is **2.22** on the five-point Likert Scale, where 1=Strong Disagreement, and 5=Strong Agreement, which is quite low. This low level was due to a lack of training courses related to PQ issues needed to support PQP implementation.

The values for the means of participant responses for the variables were quite low, namely Survey or Feedback Techniques **(2.62),** Sufficient Training **(2.21),** Employees Suggestion **(2.29),** Employees Strategies **(2.15),** Appropriate Qualifications **(2.01),** and Employees Involvement **(2.05)**. These qualitative results supported the data gained from the quantitative analysis, as shown in table 7.6.

All quantitative and qualitative results confirmed that PQP was not successfully implemented, because PQDs were not solved due to lack of PQ awareness, in terms of definitions and disturbances, of both engineers and technicians. Hence, there should be training courses to increase the level of awareness and knowledge of staff, to be able to measure and analyse power quality disturbances, as a part of PQP implementation.

Approximately 47.93% of the interviewees indicated that there were no training courses regarding PQ. This was due to some factors, which prevented such courses to be run to improve PQDs. The factors below indicated why there were no training courses on PQP implementation;

- Lack of clear strategy regarding PQ
- Employees are not qualified for PQ training courses
- Lack of evaluation of courses
- Training courses are not related to staff background
- Lack of sufficient resources
- Lack of tools
- Lack of related material
- Lack of good locations
- Lack of healthy facilities and centres
- Lack of incentives regarding training courses
- Lack of a training team for PQ courses

There was no long term strategy to focus on all the employees' requirements, and gain the expected results from the training course regarding PQ. As a result, there are not enough resources to run training courses for any subject, which also lacks clear strategy. One manager from the training department stated that:

"The training in general is useless; because the majority of the employees who had training courses were not benefited from these courses because most of them are unqualified for such training courses. Therefore, some managers are concentrating just on quantity without looking for the quality of these courses. For example, there are some departments who want large number of employees to have training courses with no strategy or objectives. However, we have not run training courses regarding PQ yet".

Therefore, training courses would increase engineers' and technicians' skills and experience, for them to be aware and able to understand the problem roots regarding PQDs. Moreover, if there are no technician teams trained properly, ready to solve these problems, and know the problem roots, this will lead to more PQDs based on previous action. Therefore, as much as the technician teams are trained well in appropriate courses regarding PQ issues, the less PQ problems occurred. One employee stated that:

"When some PQ problems happened, the company runs training courses for specific people, who can understand and aware of these issues to deal with its roots in the future".

Positive training courses regarding PQ would facilitate PQP implementation. However, this depends on the type of training courses that are given to qualified employees. However, if training courses are given to unqualified employees, PQ will not be improved. Moreover, the training courses should include all practical, technical, psychological and cultural materials. Therefore, evaluating the feedback before, during, and after the training courses will help categorise employees, according to their ability to learn new skills and gain knowledge regarding PQ. As a result, employee's attention is also important which can gain good information of knowledge and increase their skills.

On the other hand, if training courses are forced on staff, and are not related to staff experience or background, this will have negative effect, and staff will not benefit. One employee from the training department said:

"There are some managers who award some employees with no background about the course, which will be attended because sometime they send large number but at the end of the training courses only 100 employees who benefit from these courses. Therefore, there were almost 15% of the employees who had training courses regarding PQ issues and benefited from them".

The training courses regarding PQ should be given to the employees based on each department's requirements. Therefore, if engineers or technicians attended good training courses regarding PQ issues, this could help in resolving PQDs. Nonetheless, it is not the only key factor for resolving all the problems, but is part of preventing them from recurring. One expert from a training centre said:

"I think if training courses are given by qualified professional and experts, this would help improving the employee's skills and knowledge regarding PQ, which will positively help to

improve PQ issues. For example, if the problems are 50% by training the employees regarding PQ issues the percentage will reduce to 30%. I would say that training is very important aspect to improve any product".

Lack of sufficient resources prevented the company from conducting PQ training courses due to the large expanse of LDNs. This made it difficult for the company to measure and assures its services. However, the LDNs need to have enough resources, as well as rules, clear strategy, incentives and good staff, and to improve the performance of employees, in order to overcome PQ problems, internally and externally, which can lead to implementing PQP.

Therefore, there was a lack of resources regarding PQ training courses, because the company did not concentrate on these resources, such as venues and training centres, and does not care about them, in terms of importance. This is a very huge issue in fact, since training is an essential aspect in any company. Therefore, an employee from the training department pointed out that:

"The fundamental step for any department is training if the company have successful training courses that mean it is successful company and it can tackle any PQ issues".

One area of lack of sufficient resources is that equipment are very old and not up to the level of the work, and so do not meet training needs. Indeed, the company has devices to analyse power supply problems, but there are no specific tools to analyse PQ problems. One engineer from the distribution planning networks department emphasised that:

"The training department should use advanced technology when training the staff, because that will led them to cope with the latest technology regarding PQ issues and it should include modern approaches such as equipment, material, healthy, and good facilities by concentrating on both methods theory and practical to gain better results".

Moreover, the absence of employee feedback regarding training courses is because there are not enough resources to cover all these needs. Indeed, most training courses were not conducted at company locations, as some are not good in terms of healthy environment and facilities.

Conversely, if the company gives training courses as a routine, this would not bring benefits to either the company or employees. Therefore, there should be some incentives given to employees, as part of encouragement of better performance. In this respect, the financial side is very important to incentivise employees to give good performance, and so solve any problems in an effective and efficient way. One engineer in the training department highlighted that:

"The training courses are very important for any organisation or company. Therefore, the most company which give training courses to its employees is the general electrical company of Libya because the numbers of employees who are given training courses reach sometimes to 10.000 employees yearly. However, in last period when we revised the benefits and the cost of these courses we found that there was no employee's feedback in term of knowledge and awareness regarding PQ".

Therefore, training courses are essential aspects in tackling PQDs, and any related issues regarding PQP implementation. Nevertheless, no teams had been trained properly to solve PQDs. This is because EGCOL still have some deficiencies in not providing training courses in PQ. Indeed, to solve any problem, a team should be properly trained. This would cost the company, when it hires external consultants to either diagnose problems or train employees. Thus, if teams are trained properly, their awareness and knowledge level will become very high, and they will be able to deal with PQ issues.

It was found that, in terms of educational qualifications, approximately 52.4% of LDNs staff holds a high diploma degree, which is considered the minimum education qualification. In order to deal with PQ events, this level of education would enable them to cope with the current level of severity of PQ and the latest technology. Understanding or familiarity with PQP implementation is needed among all employees across the four departments, which are involved in implementing PQP in the three distribution networks. Engineers and technicians need to be better educated and trained to be able to deal with PQ issues, and find urgent and appropriate solutions to reduce disturbances.

In brief, the employees in LDNs are well educated; however, for higher PQ awareness levels, they need to be better trained and motivated. This can increase participation in PQP implementation and provide improvements regarding PQDs for LDNs.

7.3.5 Factor (5) - Power Quality Disturbances Affecting Networks (PQDANs)

PQ disturbances affecting networks (DANs), is the fifth essential factor selected to assess PQP implementation. Therefore, one of the main research questions of this study was to investigate what is the actual overall level of PQDs, in terms of causes, standards, measurements and solutions, needed to improve PQDs and to satisfy future needs. Moreover, how these disturbances are considered in terms of PQP implementation. PQDs include transients, surge, unbalance, harmonics, low power factor, over voltage, under voltage, voltage sags and voltage swells. Each disturbance has its own characteristic, which causes PQ issues on either end user electronic equipment due to lack of awareness or illegal connection. Moreover, it is caused by poor power supply due to reasons, such as lack of PQ standards, lack of utility awareness, lack of PQ measurements, lack of proper distribution networks design and lack of clear strategy, which did not accommodate the increased demand and led consumers to react badly by connecting to the networks illegally. Therefore, without solving these disturbances and without having sufficient support from distribution networks departments, and then any efforts of implementing PQP will be wasted. Seven variables are related to this factor, where PQDs were investigated, and the analysis provided the summary statistics presented in table 7.7.

Table 7.7: Mean and SD of (DANs) Factor variables

Factor	Item No	Description	Mean	S.D	Overall Mean
X4.3:Disturbances Affecting Networks (DANs)	X4.3.50.4	DANs/Transient, Surge and Unbalance	2.84	1.301	2.86
	X4.3.50.5	DANs/Harmonics	**2.75**	1.298	
	X4.3.50.6	DANs/Low Power Factor	2.81	1.295	
	X4.3.50.7	DANs/Over Voltage	2.78	1.297	
	X4.3.50.8	DANs/Under Voltage	**3.08**	1.181	
	X4.3.50.9	DANs/Voltage Swell	3.01	1.447	
	X4.3.50.10	DANs/Voltage Sags	2.77	1.091	

Descriptive analysis of PQDs factors showed that the mean level for responses on this question is **2.86** on the five-point Likert Scale, where 1= Very little, and 5= Very Much. This signifies a high level of PQDs as a part of implementing PQP, which resulted from the high level for both its components and the causes of the factors, which led to lack of PQP implementation. High level of transient, surge and unbalance **(2.84),** low level of harmonics **(2.75),** low level of low power factor **(2.81),** low level of over voltage **(2.78),** low level of under voltage **(3.08),** low level of voltage sags **(3.01),** and low level of voltage swells **(2.77).** The result of qualitative analysis supported the data gained from the quantitative analysis as shown in table 7.7.

All quantitative and qualitative results confirmed that PQP was not implemented successfully, because PQDs were not solved due to lack of awareness of both PQ definitions and disturbances by engineers, technicians and end users. Hence, there should be training courses regarding PQ for the staff, to increase the level of awareness and knowledge in order to conduct PQ measurements on a regular basis, to be able to measure and analyse PQDs as a part of PQP implementation. Moreover, this indicated that top managers did not support staff in increasing their skills, in order to understand and be aware about the importance of implementing PQP. As a result, lack of top manager's knowledge and awareness of the involved departments had led to not implemented PQP in LDNs due to low level of PQDs. Therefore, to conduct PQ measurement, existing factors associated with PQ measurements, such as ***lack of customer awareness and cooperation, lack of networks designing, lack of PQ measurements, lack of top management attention and lack of staff participation*** should be tackled, as shown in Figure 7.1.

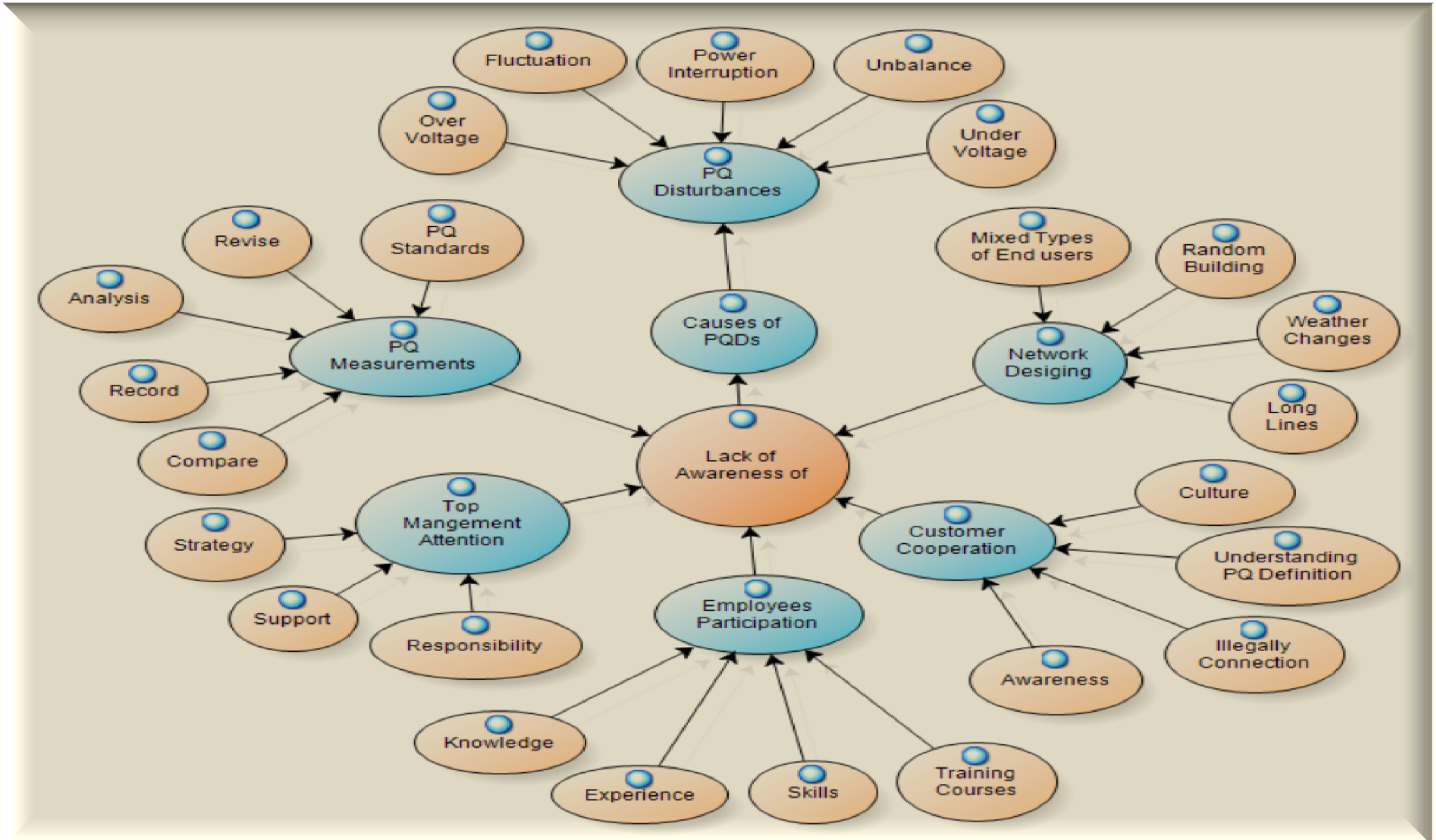


Figure 7.1: Tree node of PQP Barriers from Qualitative data analysis

Therefore, improving PQDs and achieving this objective as part of PQP implementation, is influenced by the willingness of distribution networks to tackle the mentioned factors that still exist. PQP cannot be implemented successfully, unless the mentioned factors are addressed.

7.4 Barriers to Implementing a Power Quality Programme (PQP)

It was clear from the qualitative analysis of the interviews that no PQP was implemented in LDNs. The results showed that EGCOL top management do not pay enough attention to their departments and staff, in setting up a long term strategy to improve PQDs that face end users and distribution networks on a regular basis. This was due to some difficulties, which still exist and make the process of implementing PQP complicated and slow. Accordingly, this section is developed to examine the fifth research question, namely:

- *What are the difficulties and barriers facing LDNs in implementing PQP?*

Figure 7.1 shows that there were about ten difficulties, which prevented a PQP from being implemented:

- Lack of clear strategy
- Lack of customer awareness
- Lack of accommodating economic growth
- Lack of electronic equipment
- Lack of equipment standards
- Lack of network design
- Lack of sufficient resources
- Lack of staff awareness
- Lack of top management responsibility
- Lack of PQ standards

7.4.1 Qualitative Data Analysis Results

The twelve difficulties were discussed in the interviews, and are similar to those obtained from the questionnaire. These results indicated that LDNs have not implemented PQP. It also showed that top management has not given enough attention, support, commitment and responsibility to setting up long-term strategies to implement PQP. Therefore, LDNs lose around LD 464 million annually due to poor PQ, and the failure to implement PQP [120]. Table 7.8 shows PQP barriers derived from qualitative data analysis.

Table 7.8: PQP Barriers from Qualitative data analysis by interviewee respondents

Items	PQP Factors	Barriers	Head Managers	Middle Managers	Engineers	Technicians
BA1	Lack of PQP Awareness	Staff awareness, skills and experience	4.5%	69.85%	12.64%	13.01%
BA2		End users awareness	2.85%	56.26%	20.38%	20.51%
BA4		Long-term strategy and planning	3.9%	60%	17.18%	18.92%
BA5	Lack of PQP Top Management Attention	Top management commitment	7.56%	56.68%	17.91%	17.84%
BA6		Network designing	2.32%	71.44%	16.12%	10.12%
BA7		Distribution networks infrastructure	17.64%	50.1%	16.93%	15.33%
BA9		Top management responsibility	6.12%	76.75%	17.13%	0%
BA10	Lack of PQP Resources	Training courses, education and support	16.53%	44.35%	3.72%	35.4%
BA11		Enough resources and financial incentives	2.53%	58.26%	7.5%	31.71%
BA13	Lack of PQP Involvement	PQ measurement	0%	95.27%	0%	4.73%
BA15		PQ standards and PQ consultants	3.08%	83.28%	2.91%	10.73%
BA16		PQ monitoring and database	8.81%	64.18%	16.67%	10.34%

In addition, most of members of staff involved in improving PQDs are middle managers, 52.4% of who held high diploma qualifications, which are considered the minimum educational level. This means that they are not highly knowledgeable or sufficiently aware to cope with the current severe level of PQ. Moreover, this level of education would not enable them to understand and participate in implementing PQP. Almost 38% of engineers and technicians have between 6 and 15 years of experience, but lack awareness and skills. They should be better taught and trained, before they can tackle PQDs.

7.4.2 Barrier (1) Lack of Clear Strategy

The first difficulty found in PQP implementation in LDNs was the lack of strategy. Indeed, some respondents referred to it as a very significant element in this respect. As a result, most of the projects, which attempted to establish PQP, failed due to lack of clear and long term strategy, to determine the benefits of implemented PQP. Thus, time should be spent on planning and preparation, and to provide a clear picture of what LDNs need from such a programme to eliminate any obstacle or confusion that might face implementation objectives in the future. In the words of one engineer from the network planning department:

"The difficulty, which LDNs face is lack of general strategy, where there is lack of location to implement new station and to improve the existing networks As a result customer not cooperated with the company. Therefore, lack of having clear strategic scheme to deal with all these problems is missed".

Another manager confirmed that:

"There should be a clear strategy for these improvements along with its priorities to solve the whole problems instead temporarily solution based on the demand and increased capacity. Thus, if there is long term strategy everything will be clear and the targets will performed by all the staff".

Therefore, the first action, which LDNs should take, is to identify what they have experienced, regarding the difficulties in PQP implementation in the past, and the most crucial factors that need to be improved, in drawing a clear strategy based on these requirements and so start to achieve objectives. Hence, they should spend more time on education and training courses, which would improve the awareness levels of engineers and technicians. As a result, end users awareness level will be increased too, and then they can cooperate with the company, which would help smooth PQP implementation based on the long term strategy of all departments.

7.4.3 Barrier (2) Lack of Customer Awareness

The second difficulty found delaying PQP implementation is lack of customer awareness. The quantitative analysis findings revealed that one of PQ causes is the lack of customer awareness. Approximately 39.33% of the interviewees confirmed that lack of customer awareness is one of the critical factors impacting on PQP implementation. This factor was classified into four categories as shown in figure 7.2.

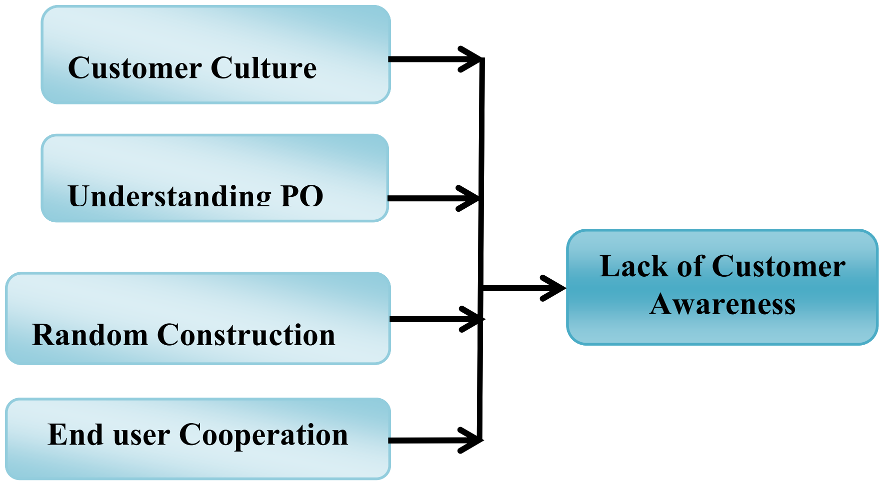


Figure 7.2: Lack of Customer Awareness

7.4.3.1 Lack of Customer Culture

- Lack of customer culture when the company want to conduct some measurements and these measurements from the consumer's side; the difficulty lies in existing consumer mentality, as some of them do not like to have devices in their home to measure PQ; this result from lack of PQ awareness.
- Lack of proper customer culture, whereby causing PQDs to other legitimate end users, connected by the company.

7.4.3.2 Lack of Understanding PQ Definitions

- Lack of consumer awareness in understanding PQ definition is one of the main causes of PQDs. Therefore, as electronic equipment increases, this will affect PQ.

7.4.3.3 Random (unplanned) Construction

- End users are not aware of PQ issues; therefore they randomly construct new houses without considering the company because, there is no long term strategy by the company to avoid these issues and design supply schemes for new residential areas.
- The consumers who live outside the scheme connect to the network without waiting for the company to do that for them. Thus, they are responsible due to illegal connection, and cause both commercial and technical losses, as well as PQDs.

From the above points, it was clear that lack of customer awareness is one of the difficulties facing EGCOL in implementing PQP. Therefore, without tackling these issues, the process of carrying out a further programme will be impossible, unless these obstacles are solved. The way that the end users connect to the network illegally should be considered by the company and by the law, because these issues happen regularly, especially when the company does not cooperate with them.

7.4.3.4 Lack of Customer Cooperation

- Customers do not cooperated with the company to solve existing problems. Therefore, almost all of the projects stopped, because there is no cooperation from the consumer side to implement new stations to improve the networks.
- End users connect to the network illegally cause overloads on the network, by connecting to one phase illegally, and without realising that this will cause both commercial and technical losses, which produce PQDs.

These problems were identified in the areas outside the scheme. One engineer from the distribution planning network department highlighted that:

"The responsibility is caused by both the supply and consumer, the supply should provide good PQ since it generated and the consumer' electronic equipment should have high quality and do not disturbance the supply. Therefore, what the company has done for its consumers to be satisfied and what the consumers have operated by not affect the power supply".

Accordingly, one engineer from the distribution and planning department stated:
"*It is very difficult to aware all consumers because most of them not complaint about bad PQ they utilised even if is less than PQ standards".*
Therefore, the problem still exists and was not solved due to lack of consumer awareness and culture. Customers do not cooperate with the distribution network department, and because of lack of awareness, they buy very cheap non-linear equipment that does not meet the PQ standards that the company set.

7.4.4 Barrier (3) Economic Growth

The third difficulty found delaying PQP implementation is economic growth. The company still faces two problems associated with economic growth, especially after the period of 1999, represented in more new construction projects and increased demand on electricity, at a rate of roughly 8% yearly. Subsequently, there was a leap in the country, and it was one of the significant barriers of not implementing PQP, as one of the managers said that:

"I think the biggest problem the company always does face is there are many projects but all of them are not matching each other or there is no clear strategy to combine all these projects to be in one goal and improve PQDs".

Consequently, if the company has the desire to complete PQP implementation, it should control these increases by designing new schemes, which would accommodate the increased demand and cooperate with the infrastructure ministry, to have a full picture with the whole company' strategy, along the same line, after tackling all the difficulties mentioned above. Therefore, increases in demand and economic growth will continue in the future. However, the company can adapt both the earlier solutions, which will lead to complete implementation of PQP, as economic growth is one of the difficulties still facing improvements in PQ issues.

7.4.5 Barrier (4) Lack of Equipment Standards

The fourth difficulty impacting PQP implementation is lack of equipment standards. EGCOL conducted several new projects, which are in progress, to develop distribution networks. Nonetheless, these projects were not matched to each other to be compatible with the distribution networks specification, due to the different equipment standards of each company, as one of the planning and standards manager said:

"The conditions, which should be followed for who construct new projects are not exactly same as what they agreed about it in the contract. Therefore, the difficulty is in Multi-companies which the company deals with to import new equipment, sometimes are cheap and do not meet the standards of the existing distribution network equipment".

The company should cooperate with device specification department at the border gates cross the country to control the market through enforcement of legislation on device specifications by preventing installation of these equipment in its distribution networks, unless the specification are revised, this was pointed out by another planning and standards engineer:

"PQ also means the quality of equipment used to generate, transmit and distribute the power".

Moreover, the consumers should stop importing any electrical or electronics equipment, which is not compatible with PQ standards. One manager from the planning and standards department said:

"The end users sometimes buy electrical or electronic devices, which are very cheap and this as a result will cause PQDs if their specifications are not match PQ standards".

Therefore, the difficulty of meeting both the distribution networks and the end users equipment standards has affected PQP implementation, as one of the engineers said:

"The problem was that PQ has specific standards but these standards are not unified for its equipment and this is very important to have good quality. The designing standards and installation standards are different and all these will have impact on PQ".

7.4.6 Barrier (5) Lack of Distribution Network Design

The fifth difficulty of PQP implementation is lack of network design. The qualitative analysis revealed that some obstacles were associated with network design as stated below, and this affected PQP implementation. PQDs are not solved, because the network is mixed. Therefore, to solve any problems, it required isolating each consumer based on type and load to find the appropriate solutions. However, LDNs map is very huge, which cannot control all problems and it is also due to number of distribution lines driving far away for long destination. Therefore, it difficult to make some logical and final solutions because the solutions will be limited to the resources provided. The assistance manager of the planning general department pointed out that:

"One of the most problems face the company is that customers live far away and they have to connect them to the network. For example, there are some areas which connected to the network from long thousands of kilometres to four or five houses only and far away from each other. Therefore, if the company connect each one individually this would cost a lot and PQ will not be at the acceptable level for those consumers".

As a result, end users are constructing new houses randomly without considering the company, because there is no long term strategy by the company to avoid these issues. For example, the maintenance team want to conduct PQ measurements in specific area; barriers are found that prevent them from doing so due to random building.

One point is that the rapid increase in new developments projects and the increased demand in electricity, as well as new houses built randomly by end users, are all factors that cause overload of the distribution networks. These factors prevent the company from accommodating these increases, and implement a PQP to distribute good PQ. Moreover, there is no long term strategy to improve PQ issues. For instance, the company connects end users, who live in remote locations, but at the same time does not improve PQ for end users, who live in cities. One engineer from the distribution planning department stated that:

"Weather change is one of some reasons caused PQ problems especially in country side areas, where some of consumers settled in agriculture areas randomly and live far away. The problems occurred when the temperature is very high in summer season, where large number of consumer uses air conditioning. As a result, this caused low power factor, which consumers complained about it in terms of bad PQ, which affect and damage their devices".

The Libyan distribution department needs to have clear vision of designing the distribution networks based on each consumer type and load. Thus, teams for both regular maintenance and measurements should be considered, when tackling any problem or when investigating any power supply issues. Moreover, the lack of urban planning, where there are not enough suitable sites to build new distribution stations to accommodate the increases in demand. In addition, consumers should cooperate with the company in that manner and without any argument, when PQ measurements are needed and by record any illegal connection seen by other end user in order to increase the level of PQ. Moreover, it requires reorganising and revising the random building in and out the schemes in order to solve PQDs. Moreover, Libyan distribution department needs to have clear objectives in terms of working with the local planning authority to ensure enforcement of building rules and prevent random building, and earmarking sub-station sites to cope with PQP implementation.

7.4.7 Barrier (6) Lack of Sufficient Resources

The sixth difficulty of PQP implementation is the lack of sufficient resources. Having enough resources is vital for any company, which needs to cope with its current situation by improving existing equipment and upgrading networks for better PQ performance. Resources are also needed for both the maintenance of the existing networks, new projects and run training courses regarding PQP. This can help employees understand PQDs, and they may be able to have a full view regarding PQP implementation. One of the managers of the planning and cost estimation department said that:

"One of the difficulties, which face the company to make more improvements on the distribution networks, is lack of resources. As a result, many projects are discontinued, which they supposed to be a part of PQP implementation. Moreover, there are huge technical and financial losses caused by the consumers due to not paying their bills and by connect illegally to the networks. Therefore, the refund should be gained from the end users consumption is missed".

7.4.8 Barrier (7) Lack of Staff Awareness

The seventh difficulty in PQP implementation is lack of staff awareness, which is a very critical factor in implementing PQP. Thus, without staff awareness, knowledge, experience, skills, attention and culture, any programme would fail to be completed. The qualitative analysis revealed that most staff, working in planning, distribution, training and customer departments, where this study was conducted, are not aware of the importance of having a PQP.

In the first part of section one in this chapter, approximately 34.11% of employees were knowledgeable regarding PQ definition. This gave an indication that they were able to understand the concept of PQ. However, in this part of PQP implementation, the employees were one of the difficulties, which faced implementing PQP. Therefore, in order to have complete implementation, staff should have high level of responsibility by developing their skills and knowledge regarding PQDs, to become a part of this programme and continue further improvement to reach the acceptable level needed. For this reason, the qualitative analysis results revealed that lack of staff awareness fell into four categories, as shown in Figure 7.3.

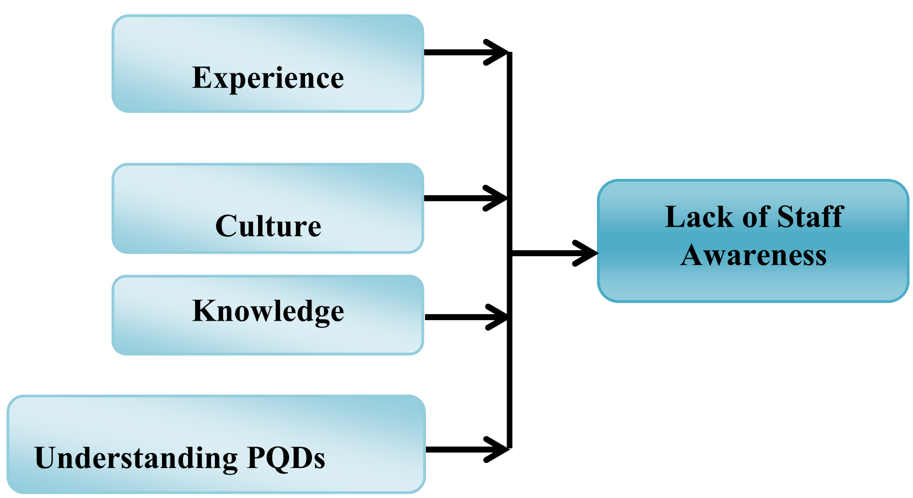


Figure 7.3: Lack of Staff Awareness

7.4.8.1 Lack of Employees Culture

One manager in the planning standards department stated that:

"The first difficulty is the employee's culture, who should aware of such problems. The solution depends on the staff themselves if they have desire to find the appropriate solutions. Moreover, the way which the company trains the employees is very old and it is not accommodated with the new technology. Therefore, the employees need to have enough time to understand the programme' objectives".

On the other hand, consumers have the right to complain regarding PQDs due to the terms in the contract, yet staff are not patient and do not deal with consumers politely. Therefore, this is one of the cultural reasons, which led consumers to react negatively and connect to the network illegally, because some employees do not deal with consumers politely. As a result, staff should work with the end users politely to solve all the PQDs. Indeed, the distribution network will either be affected by consumer reactions, or will benefit from consumer satisfaction.

7.4.8.2 Lack of Staff Experience

One manager of distribution and studying operation department said that:

"I do not know because I do not have enough knowledge regarding PQ. However, the company transfers all the problems to consulting Breuer, to solve almost all the serious problems due to inability to solve them by its staff, because there is no qualified staff, who can go and look deeply into these issues and also because there was no PQ department".

Staff are always blamed for not implementing any programme due to their lack of skills or experience. Nevertheless, the first thing is that in size, the distribution networks are huge, given that only one company generates, transmits and distributes power through different distribution networks in the country. Therefore, PQP awareness should start from top management, then employees and then the consumer. As a result, they will be able to understand PQ definition and PQ disturbances to solve existing problems.

7.4.8.3 Lack of Understanding PQ Problem Roots

The manager of the protection department highlighted that:

"PQ terminology is not known in the company so much. Therefore, there are few staff, who known it. However, the majority of staff, who should deal with customer's complaints regarding PQDs, does not know this term to solve its problems and to satisfy consumer".

Another engineer from the planning and standards department stated that:

"In most cases the staff do not understand the problem root regarding any PQDs. Therefore, staff duty is just how to get the power back without understanding the real issues which caused the problem. It also not compared to both equipment standards and PQ standards to avoid any faulty diagnosis".

Therefore, wrong estimation or measurements would cause serious problems in distribution networks, and affect the strategy of PQP implementation. Furthermore, most top managers and staff, who are responsible for repairing problems, as a quick reaction, will always install new equipment. Therefore, they do not follow up the reason that led to this problem and find its roots.

7.4.8.4 Lack of Staff Knowledge

Lack of staff knowledge is another aspect causing PQDs, due to the employee's culture, because this term is not known very well, and there is lack of awareness among the employees themselves. Moreover, the company transferred all the problems to a consulting firm, Breuer, to solve almost all the serious problems due to the inability to solve them using its staff. Therefore, due to the lack of employees training courses, both engineers and technicians do not have enough skills and experience to deal with the PQ problems.

Most employees, who had attended training courses, did not achieve an acceptable level, while some employees were careless and did not benefit from these courses. Therefore, the lack of a positive employee culture can be found. However, there are differences among employees, those not willing to learn new technologies, and others, who would benefit from new information and improve their skills regarding PQDs. Therefore, PQ problems should be tackled by those employees, involved in the company strategy, and cooperating with the customers for better PQ solutions.

7.4.9 Barrier (8) Lack of Top Management Responsibility

The eighth difficulty in PQP implementation is lack of top management responsibility. Top management responsibility and awareness levels are one of success factors, which lead any electrical utility to implement PQP successfully, by setting out a clear strategy for all staff involved in resolving PQ problems. The qualitative analysis revealed that the majority of the interviewees refer to lack of top management responsibility as the significant factor, which prevents PQP implementation in LDNs.

Therefore, four barriers were associated with the lack of top management's responsibility, which were ***lack of administrative structure, lack of manager culture, lack of studies and researches, and lack of top management attention.*** As mentioned earlier, the qualitative study was conducted in four departments, which were supposed to share their responsibility of improving PQ issues. Therefore, if these departments did not cooperate with each other and position one clear strategy and set direct objectives, then any attempt to improve the distribution networks will be a waste of time and effort. They should be coherent and have obvious requirements; to tackle any difficulties that may face them in implementing PQP. Hence, top management support is considered as one of the key success factors, which would facilitate any difficulties, and includes awareness and attention by conducting some studies, and making the administration structure not complicated, and provide more training courses regarding PQP implementation. Therefore, the interview data revealed that successful PQP implementation has to be endorsed by the top management. In the subsection below, some of the interview responses state why there was lack of top management responsibility, as shown in Figure 7.4.

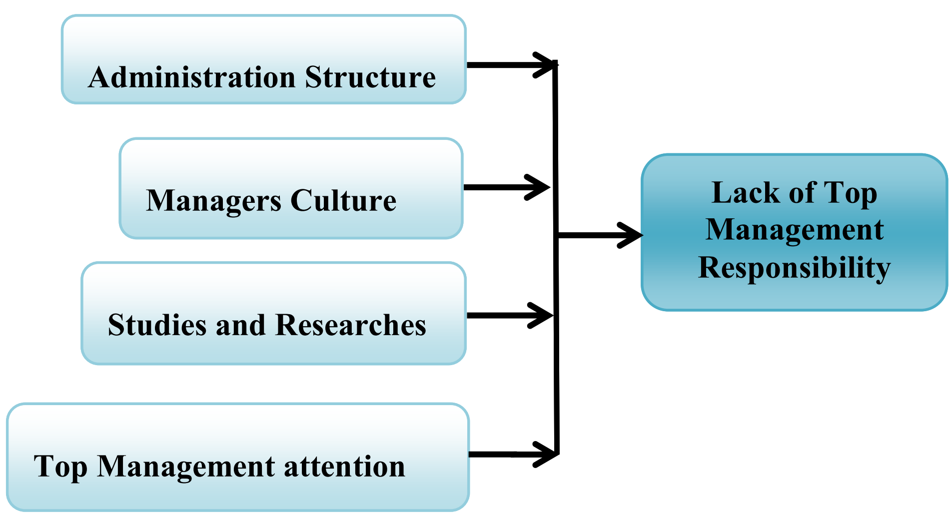


Figure 7.4: Lack of Top Management Responsibility

7.4.9.1 Lack of Administrative Structure

- The difficulties which the company faces are in administrative structures. Therefore, any new programme cannot achieve its objective, due to administrative complications, especially given the huge map of the country.

7.4.9.2 Managers Culture

There is a lack of appropriate mentality among top managers. For example, the company implements some projects to distribute the power to citizens based on the head manager's decision without considering the resulting consequences, which will affect the network by causing PQ problems. The company faces another problem with decision makers, because they consider these projects as not very important. Therefore, it is very difficult to convince them about the severity of the problems if these projects are not implemented.

7.4.9.3 Lack of Studies and Researches

The company should have a serious vision about all the increases to prevent these problems from recurring in the future, and improve PQDs to satisfy customers by making more effort on that. Therefore, there are many new projects have a part of improving PQ issues but the problem always in implementation. As a result, this will made the improvements very difficult to be finished on the schedule period. One engineer from the distribution and planning networks department emphasised that:

"According to my experience, the technical department is responsible in general of causing PQ problems, because there are huge technical faults due to lack of studies when implementing new project or station".

The problem starts from the planning department. Planning good strategy and good implementation are essential, because if planning engineers have designed a good scheme by including all the problems, such as voltage drop and interruption, then any problem will be tackled. Moreover, if the company conducts studies and researches instead concentrating on the interruptions and technical issues in the network by setting some priority objectives, then these difficulties could also be tackled.

Thus, if there is no good planning, the implementation would not be good and PQDs will not be resolved. Moreover, one of the interviewees stated that: *"It is very difficult to ensure PQ before it is delivered to consumer, because almost 45% of consumers outside the scheme"*. Therefore, in those areas outside the scheme, most consumers are illegally connected to the network. This would cause PQ issues due to random building, which has a serious impact, because they increase their loads, which are different from what they sign with the company in the contract. One management commitment problem is highlighted by the training department manager:

"The intermediary is one of the things, which caused PQ problems. In order to satisfy and provide good PQ to some very important people, who live in specific areas, the maintenance team cut the electricity on some consumers, who did cause PQDs. Therefore, ignoring the end users and without any consideration for such maintenance would affect their equipment. This will lead the consumer to behave badly by connect illegally to the network because the problem is not in the area that the company cut the electricity down".

7.4.9.4 Lack of Top Management Attention

One of the difficulties is that there is no serious attention from the top management to improve the network. Therefore, if the company has implemented PQP, the benefits will be very high and PQ issues will be addressed. Moreover, there is a monopoly on administration by some managers, who stay in their position for more than ten years without making changes or giving technicians and engineers the chance to attend training courses to improve their skills. With such lack of attention, new technology developing all the time is missed, especially those new technologies that help in PQ improvement.

7.4.10 Barrier (9) Lack of Power Quality Measurements

The ninth difficulty in PQP implementation is lack of PQ measurements. The reason as one planning standards department engineer said: *"There are many equipment operated, which out of age and very old, which led to cause PQ disturbances. Moreover, the measurements devices are available but the results are not revised to determine the real reasons due to lack of staff experience".* As a result, there is no quick response to some PQDs in the network to avoid any consequences could result of not replying. Planning department manager stated that:

"Most of consumer PQ problems are voltage drop and interruption, but it could be other problems under and over voltage, unbalance flicker, fluctuation. Therefore, the company always

deals with these problems as the line is very long or the loads are increased without conduct PQ measurements if these problems caused by another reasons".

This statement has been agreed by the majority of the distribution standards department staff.

Therefore, PQ measurements should be conducted on a regular basis to monitor, and analyse PQDs on the customer side, which can be compared and revised to PQ standards. As a result, final reports would help find the appropriate solutions based on each disturbance characteristic.

Moreover, there should be monthly measurement planning to predict and measure the network for any improvements. PQ measurement tools may be used on a very narrow scale, in case any sudden problems appeared. Measurements can then be taken immediately to identify the problems root. For example, the southern network suffers from PQ issues constantly, regarding low power factor. The maintenance department has installed capacitor banks as one of the solutions to improve power factor. Nonetheless, the consumers still complained about poor power factor. The problem is that the southern network is connected by a long transmission line from the main generation plants in Khums in the north. Therefore, one of the solutions, which southern distribution network should implement, is to add generation capacity to help this network overcome such PQ problems.

7.4.11 Barrier (10) Lack of Power Quality Standards

The last difficulty in PQP implementation is lack of PQ standards. The qualitative analysis revealed that approximately 32.59% of interviewees agreed that: *"there were no specific PQ standards have been adopted through LDNs to improve PQDs".* Moreover, roughly 39.47% of the respondents were not knowledgeable on PQ standards. The reason is that each of the four departments has its own standards, which were not similar and were not followed in improving the networks. However, the new equipment, which the company bought to improve the distribution networks did not match the specifications of the existing equipment in the networks. Additionally, the company must control the private sector, which imports equipment without checking if they are compatible with PQ standards or not.

LDNs should impose PQ standards on departments, to be followed in each project and also by all consumers. Furthermore, PQP implementation requires a specific agreement between the departments involved in improving PQDs. Therefore, this agreement should follow international standards, such as IEEE and IEC standards, to identify the characteristic of PQDs to be known in such a way that can be revised and compared among both the end users and staff. In addition, the distribution system should conduct studies to compare the equipment standards that the consumers use and compare them to each load type in terms of specification. Therefore, PQDs are revised and compared to IEEE or IEC PQ standards, because if each PQD is compared to these standards; as a result the end users will be satisfied. Moreover, as one of the managers from the standards section said: *"if there are PQ standards mentioned in the contract based on PQDs then each consumer can know what his /her duty is"*. Another engineer from the planning and standards department highlighted that:

"PQ standards are very important to the consumer especially the big customers and the small customers, because there are many new projects are under construction in many different areas regarding distribution networks by many different companies, but all are under EGCOL standards".

However, from the economic perspective, if customers used equipment, which has good quality and is compatible with PQ standards, this will be a guarantee that the equipment life time will be longer.

Briefly, PQP implementation plays a significant role in improving PQ issues. The purpose of implementing this programme is to achieve the strategy objectives set by all departments, associated with completing and developing PQP in LDNs. However, if LDNs do not take into account the implementation difficulties mentioned above, this will lead to unexpected consequences for both the departments involved in PQ improvements and end users' satisfaction.

In conclusion, lack of PQ standards is another problem that the company still suffers therefore; the equipment should have very good standards and quality, because there is a different between existed equipment in distribution networks and the new equipment, which are based on the company standards not the EGCOL standards. Distribution networks should follow up the installation standards when install new equipment. Therefore the standards studies and planning department should revise these and compared them with EGCOL equipment standards and PQ standards.

7.5 Benefits of Implementation of Power Quality Programme (PQP)

The qualitative analysis of the interviews revealed that there will be extremely significant benefits for LDNs if PQP is implemented. The outcomes obtained from the interview data classified these benefits to three categories; employees, consumer, and distribution networks, as shown in Figure 7.5.

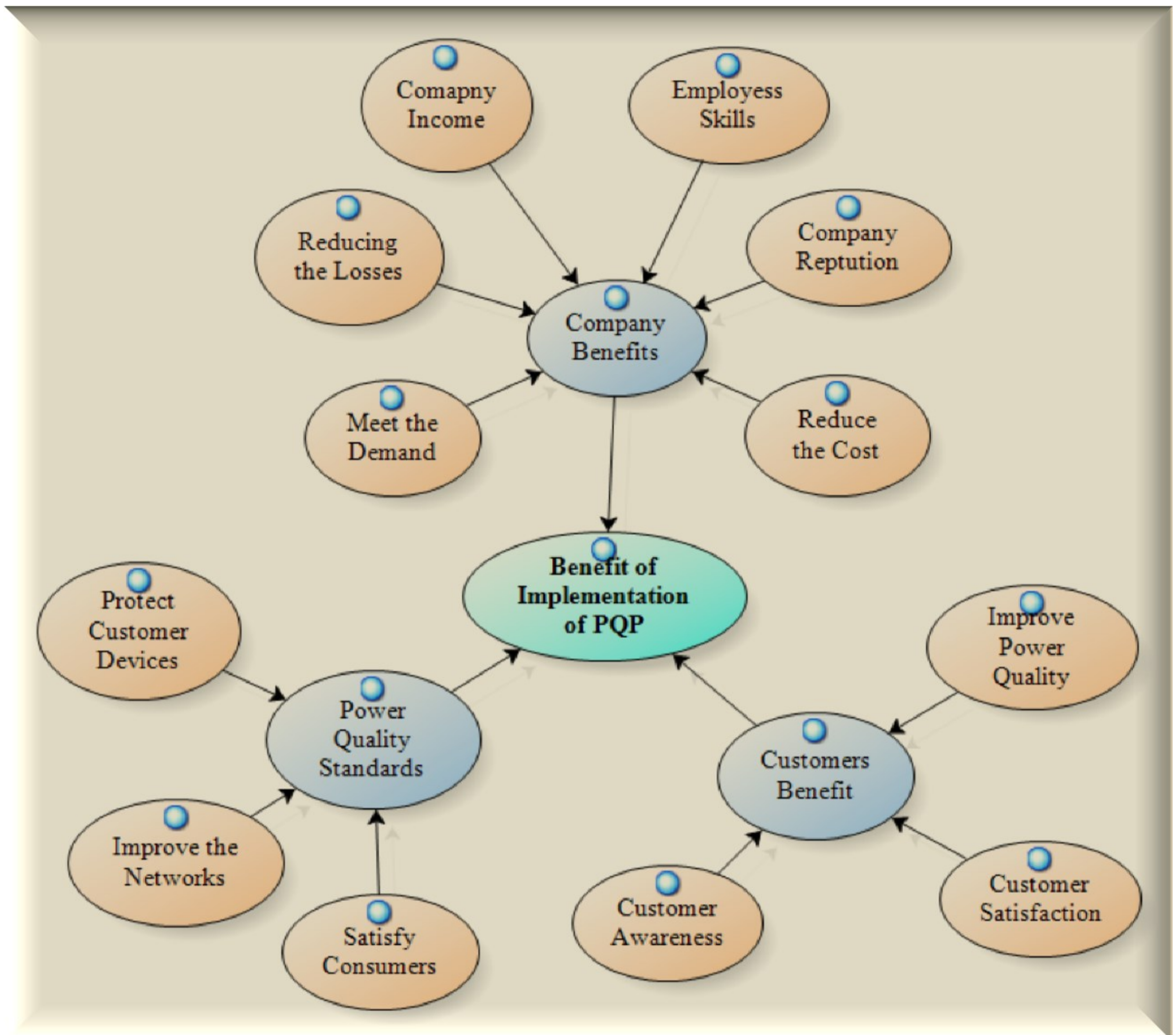


Figure 7.5: Benefits of PQP Implementation according to Qualitative Analysis

7.5.1 Benefits (1) Distribution Networks

The qualitative results revealed that approximately 30.19% of interviewees stated that the benefit of PQP implementation would increase the distribution networks income, which was lost from the commercial losses caused by consumers, who illegally connect to the distribution networks. Therefore, once PQDs were tackled and supply monitored according to PQ standards, this will lead to increased financial income, and improve the projects, which faced the difficulties mentioned above, and prevented PQP implementation. Moreover, the amounts spent on repair and maintenance will be reduced. As a result, the company's reputation will be improved, because as high as PQ becomes good and meets all the standards, the cost per kWh will be reduced.

On the other hand, PQP implementation will help the distribution networks to accommodate the increased demand to meet the end user's needs. It also increases employee skills through providing PQ training courses, as one of difficulties is lack of employee's awareness. This is due to lack of sufficient facilities and venues where employees can have training courses, as part of PQP implementation.

The qualitative data also revealed that one of the most important benefits of implementing PQP is to reduce the technical losses in the distribution networks. Therefore, improving PQDs, having satisfied customers, and unified standards for all distribution networks equipment and PQ standards, will reduce the technical losses. One of the engineers said:

"I think the first benefit is that improve PQDs because there are some loads produce harmonics. Therefore, reduce the technical losses in the networks; this will lead to improve the power factor because this cause huge amount of losses in distribution networks especially in summer season".

7.5.2 Benefits (2) Customer Satisfaction

The qualitative analysis revealed that another benefit of PQP implementation is increase customer satisfaction. This was proved by roughly 39.46% of the managers, engineers and technicians, who participated in the interviews. Furthermore, PQDs will be improved and the customers will not complain about bad PQ, which affects their equipment due to power interruptions. Moreover, customer satisfaction reduces the compensation that the company pays to consumers, as their devices are affected by poor PQ. As a result, this will help increase company income, which will contribute to the distribution network completing PQP implementation, as one of the difficulties is lack of sufficient resources.

On the other hand, customer awareness will increase, which is very important to cooperate with the company in implementing PQP as one of the difficulties is lack of customer awareness. Besides, one of customer's service department managers said that:

"The implementation of PQP would help customer to increase their awareness level regarding PQPs and start recognise the importance of it when they buy new equipment".

7.5.3 Benefits (3) PQ Standards

The third benefit of PQP implementation is to provide PQ standards. PQ standards are very important for distribution networks to monitor and compare against PQDs. This benefit is one of the significant requirements needed to complete PQP implementation. One of the engineers in standards department said:

"If there are PQ standards mentioned in the contract based on PQDs, then each consumer can know what his /her duty is".

Therefore, the qualitative data analysis revealed that the interviewees divided the importance of PQ standards into four categories; where PQ standards are important:

- To protect customer devices.
- To satisfy customers.
- To improve the distribution networks.
- To revise PQDs.

The qualitative analysis results indicated that approximately 76.35% of the interviewees stated that PQ standards are very important to protect customer devices, whereas roughly 27.51% of the interviewees referred to satisfying customers. This gives clear evidence that customer complaints will be reduced if there was a PQ standard in the contractual terms. Therefore, as long as PQDs are revised and compared to PQ standards, the consumers will not complain regarding poor PQ, and will be satisfied. One of the distribution area managers said:

"PQ standards are important to customer, who has sensitive equipment that can affect by any variation in power supply. Therefore, PQ will not be interrupted and the voltage will not be dropped".

Thus, standards are very important, because if they are met and compared to international standards, the consumer will be satisfied. One of the planning and cost estimation managers said:

"PQ standards are very important for customers because they are willing to utilise good PQ with continuity all the time. As a result, this will lead them to be satisfied based on the quality of the electricity. Therefore, customer's satisfaction is very important and it can help them to cooperate with the company".

Furthermore, PQ issues will be based on how good these standards are in preventing any over or under voltage and to avoid any interruption, which could result from other customers, if they connect to the same line. As a result, PQ standards will benefit the consumer more than the company, because it protects them from any deviation. As one distribution and planning network manager said:

"There are minority of consumer, who aware about PQ problems and they look at PQ standards as very important, and it should not be less than its standards. Moreover, almost all of the consumer devices are electrical and electronic equipment. Therefore, PQ issues are caused by non-linear loads. They are very sensitive to PQ deviation such as fluctuation, harmonics and so on. As a result, when the end users know these standards, they can buy their equipment based on the limitation that the company set".

However it is very important to improve PQ. Moreover, when these standards are followed by the company, this will provide many benefits, such as stability, reliability, and PQ in all LDNs.

7.6 Summary

This chapter presented the second method of data analysis. Qualitative analysis was conducted using both content analysis and direct quotation to investigate the level of PQP implementation in LDNs. It was also used to explore and investigate the barriers and benefits of PQP within Libyan distribution systems. It contributed by providing an insight into the overall efforts needed to implement and validate a PQP implementation framework and the main reasons underlying its failure. The purpose of using a qualitative study was also to find the most critical factors, which can be adopted to start implementing PQP and compare them with the results gained from the quantitative analysis, to ensure that there is no difference between the results from both analyses and confirm the need for these factors to be improved as an essential requirement of the programme. Moreover, the combination of using both results of quantitative and qualitative analysis is to start developing a PQP framework for LDNs to adopt, in order to improve networks performance and competitiveness in face of economic growth challenges in the future.

LDNs have to consider all the mentioned factors, which will help in improving PQ issues as the level of awareness will be increased. Therefore, by implementing PQP and moving from the studies and recommendations, this can lead to implement a PQP practically.

This chapter also revealed poor PQP implementation in LDNs, because they were not moving from the suggested strategies to realistic performances. According to the qualitative analysis, this gap will continue if PQP is not implemented. In fact, there are some difficulties which the company tried to tackle; nonetheless, it is still delayed in completing the implementation of a full programme. The difficulties are categorised in four main PQP barriers, which were determined from this study, namely; lack of awareness (lack of staff awareness, skills and experience, lack of end users' awareness, lack of customer cooperation, lack of long-term strategy and planning); lack of top management attention (lack of top management commitment, lack of network designing, lack of infrastructure for distribution networks, lack of continuing research and study, lack of top management responsibility); lack of resources (lack of training courses and support, lack of financial resources, lack of enough incentives); lack of power quality involvement (lack of PQ measurement, lack of PQ consultants, lack of PQ standards, lack of PQ databases).

The result of the qualitative analysis supported the data gained from the quantitative analysis, as shown in tables 7.3-7.7. Therefore, all quantitative and qualitative results confirmed that a PQP has not been successfully implemented. Indeed, PQDs were not solved due to the low level of customer awareness and customer satisfaction, as well as the negligence of the customer department in responding to customer complaints. Moreover, top managers were not supporting implementation due to a lack of understanding of their responsibility, and lack of PQ awareness for both engineers and technicians.

It was clear that establishing a clear vision of these factors, while having the direct support derived from management commitment, full participation by all employees and departments to consider consumers satisfaction will have a significant effect on LDNs. However, without solving PQDs and sufficient support by distribution network departments, then any efforts of improving PQ issues and implementing PQP will be waste of both time and resources.

In addition, approximately 75% of the interviewees stated that there was no PQP implemented in the past. Therefore, one of the main challenges in implementing PQP is to link all the implementation difficulties of PQP with both its objectives and strategies. As a result, this study suggests that a regular evaluation of PQP programme difficulties should be performed to identify the hidden reasons associated with, and causing poor implementation. On the other hand, the qualitative data analysis validated the developed PQP framework, by identifying the main factors in PQP barriers. It was revealed that lack of PQ awareness is the significant factor, which affects LDNs in not implementing PQP and causes the twelve PQP barriers respectively.

The next chapter (8) will introduce the findings, discussion and proposed framework of PQP for LDNs that is validated using both the qualitative and quantitative data analysis

Chapter Eight: Findings, Discussion, and Proposed PQP Framework for (LDNs)

8.1 Introduction

The purpose of this study to identify the critical success factors (CSFs) that would make a major impact on PQP implementation in LDNs, and which could be applied and adopted internationally. The results of the literature review were presented in chapters 2 and 3. These helped the researcher in identifying the research problem and stating the actual needs of a PQP, in terms of employee training, management planning, and customer satisfaction. A PQP is essential to address PQDs and distribute good PQ across EGCOL distribution networks. This study also investigated the main critical factors underlying PQP, which lead to PQDs in LDNs. Six CSFs were selected by the researcher as fundamental to a complete conceptual framework for exploring PQP implementation in LDNs. Both quantitative and qualitative methods were used in this study, and data were collected and analysed, to answer the research questions. Therefore, this chapter presents the research findings gained from the two previous chapters in more details.

Section 8.2 summarises the general demographic characteristics of the survey sample and interviewees. Sections 8.3 presents the findings related to the research questions from the quantitative and qualitative surveys. Section 8.4 describes the whole framework, and roadmap of each phase respectively. These can be used as a template to support and improve other distribution utilities, in similar circumstances regarding PQ issues, in understanding and analysing the factors causing PQDs. Finally, Section 8.5 summarises the chapter.

8.2 General Demographic Characteristics of the Sample

Data were collected from a questionnaire survey of 397 participants, divided into 159, 131, and 107 respondents from west, east, and south networks, respectively. The respondents were head and middle managers, engineers, technicians and other employees, who worked in LDN departments, and rated 81% of the total responses. Approximately 51.9% to 56.6% of the respondents were not aware whether any PQP had been implemented across the three networks. In contrast, roughly 26.7% indicated that a PQP had been implemented two years before, while around 7.4% stated that a PQP had been implemented three months prior to this survey. Therefore, the respondents gave a critical answer regarding PQP, which indicated significantly that no PQP had been implemented in LDNs in the past; the majority of respondents (56.6%) pointed that out. This may indicate that most engineers, technicians and head managers were not aware of PQ problems. However, approximately 26% of respondents knew about PQ problems as a result of being aware of power quality definition, as shown in figure 6.10.

The majority of respondents (52.4%) hold a high diploma degree (the minimum qualification in Libya). Almost 38% of respondents have between 6 to 15 years' experience in the three networks. This implies that most respondents are able to provide adequate and accurate data for the researcher to assess the level of PQ across the three networks. More than 55% of respondents were department managers, who had been with their networks for more than 10 years. According to the distribution of respondents, 35.3% of department managers and engineers worked in the repair & maintenance department, 32.7% in the operations department, and nearly 20% in the design department, as shown in figure 6.8. This indicates that these department managers should be knowledgeable about the history of PQDs, as explored in this survey.

8.3 Part One: Findings Related to Critical Factors in PQP Implementation

8.3.1 Research Question One

- *What is the actual overall level of the PQDs, in terms of measurements, solutions and implementation regarding PQ awareness?*

8.3.1.1 Power Quality Disturbances (PQDs)

Table 6.8 shows that the factor, relating to PQDs affecting LDNs, has a positive and statistically significant relationship with all other five factors regarding the PQP CSFs. This factor consists of 10 parameters, namely transient, surge, unbalance, harmonics, low power factor, over voltage, under voltage, outage, voltage sags and swells. All the questions were distilled into a single factor, verifying that all the items selected to measure PQDANs are statistically valid and statistically significant, which supported the factorability of the correlation matrix [200]. The Cronbach alpha score for the factor PQDANs is 0.851, and it explains 7.51% of the total variance.

One of the reasons why a PQP was not implemented successfully is that PQDs were not resolved. This was due to lack of awareness of both PQ definitions and disturbances by engineers, technicians and end users. Hence, training courses regarding PQ should be given on a regular basis, to increase the level of awareness and knowledge, enabling staff to measure and analyse PQDs as part of PQP implementation. Moreover, this indicates that top managers did not support staff in increasing their skills, or understand the importance of implementing a PQP.

Various levels of PQDs occurred in the three networks. Long interruption was considered the most significant, accounting for approximately 43.6% of PQDs in the three networks. The four equipment types causing the most PQDs in the three networks are shown in figure 6.13. Approximately 24% of respondents point to air conditioning as the top cause of PQDs in the three networks. Roughly 19% of respondents indicated that electric motors were second in causing PQDs. Consequently, because of the huge industrial areas connected to them, PQDs were generated in west and east networks. Voltage sags and swells are other disturbances, considered to be highly significant, representing 39% of all disturbances, and occurring often in the three networks, as shown in figure 6.13. Around 35.3% of the respondents point to low power factor as one of the disturbances causing PQDs. Roughly 37.6% of the employees referred to under voltage as one of the most frequent disturbances, occurring constantly and specifically in the west network. The increase in PQDs, when compared to past measurements, points to economic growth as the main factor, which increased after 1999, where a huge number of scattered houses, and private small agricultural projects were developed randomly. Figure 6.16 shows the factors causing most PQDs in LDNs. Approximately 17% of the respondents indicated that the excessive use of electronic equipment is considered the most significant factor causing problems in the three networks. Around 16% of the respondents opined that taking electricity illegally is the second factor causing PQ issues. Moreover, figure 6.13 shows PQDs in the three distribution networks based on participants' reponses.

8.3.1.1.1 Causes of PQDs in the Western Distribution Network

- ❖ Large numbers of air conditioning units are used, affecting the network efficiency in terms of quality.
- ❖ Heavy loads are mainly used in this network, and consequently, voltage sags were generated due to motors starting. These problems occur especially in the summer season, when the temperature is very high. Mixed welding plants and heavy duty motors in residential areas is another factor causing PQDs.
- ❖ Excessive use of electronic equipment, which is uncontrolled, i.e. the specification may not be compatible with PQ standards.

8.3.1.1.2 Causes of PQDs in the Eastern Distribution Network

- ❖ Digital electronic equipments are one of the main causes of PQDs in this network. It is seen that lack of understanding or a known PQ definition has brought significant disturbances for both end users and suppliers.

- ❖ The scattered privately-owned small agricultural projects, which need to be supplied with electricity. Many of these are in many different remote locations, where the suppliers face a difficult situation in connecting them and provide high PQ level.

- ❖ Many large projects were implemented by the government to support the Libyan economy, which depended on domestic production seven years ago. These projects are implemented constantly, but are not planned for in the company's strategy.

- ❖ Large numbers of heavy water pumping loads use large induction motors. Even though, new transfer stations were built, the problems still reoccurred due to the sharp rise in these projects, as well as the scattered new infrastructure projects after 1999.

8.3.1.1.3 Causes of PQDs in the Southern Distribution Network

- ❖ The southern network is only fed from one side by Alkhoms generation plants. As a result, the end users on this network are connected via different substations by long transmission lines, as shown in figure 3.9.

- Heavy loads such, as the Great Man-Made River Projects and private agricultural projects with huge pumping plants, caused problems for this network. As a result, PQDs started where these projects were added to this network, and were not part of the planned network capacity, which was implemented after 1999. Figure 8.1 shows PQDs in the three networks.

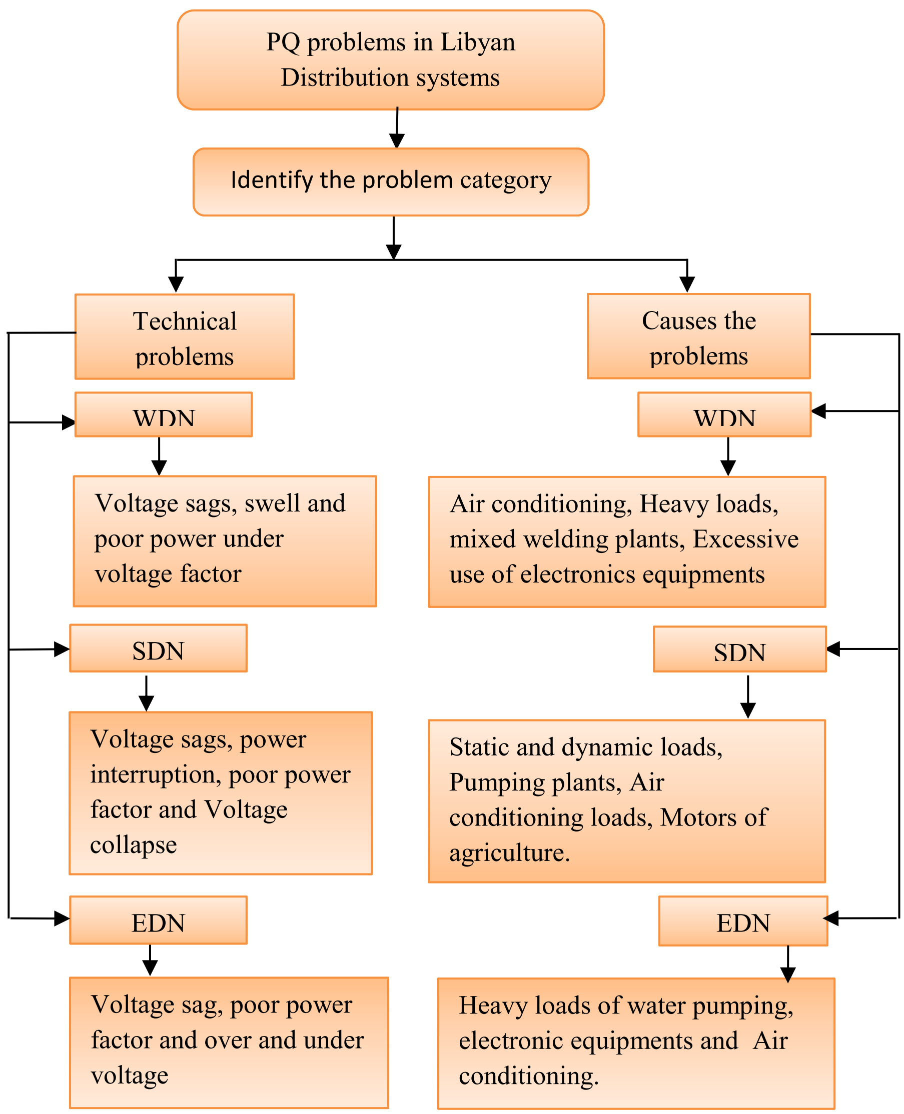


Figure 8.1: PQ Disturbances and Causes in LDNs

Figure 8.1 shows the most common PQ problems in the three networks, west, south and east.

Each network has its own source of PQDs. From figure 8.1, voltage sags and swells are seen as the most significant disturbances occurring in the three networks. This is due to heavy use of loads, such as air conditioning in the three networks; welding plants in the west network, and motor starting loads, such as water pumping, in both south and east networks. Disturbances from electronic equipment occurred in both west and east networks. In brief, PQDs occurred significantly in the three LDNs, west, east and south, due to six crucial factors;

- Lack of PQP implementation arising from lack of management strategy to cope with all increases in generation and transmission systems.
- Lack of PQ standards to be followed by the company for any evaluation or comparisons with PQDs recorded, if they are to be used in future in the Libyan distribution system.
- Lack of employee experience and skills resulting in lack of PQ awareness, and inability to deal with PQDs.
- Lack of customer awareness of the PQ concept leading to excessive use of non-linear loads and sensitive equipment.
- Lack of management planning for the design of proper distribution networks, given the presence of mixed welding plant and heavy duty motors in residential areas.
- Unregulated import of electronic equipment without imposing any standards, since 1999, due to open market.

8.3.2 Research Question Two

- *What is the current state of PQ awareness and efforts regarding the implementation of PQP in LDNs?*

The current levels of PQP implementation in LDNs, and the difficulties that face them in PQP implementation are identified below:

- From statistical analysis of the data collected from 397 respondents in LDNs, table 6.9 shows the mean scores, standard deviation and level of PQP implementation in LDNs. Moreover, the results of qualitative analysis of data, gathered from head managers, middle managers, engineers and technicians working in four departments related to PQP implementation, supported the results gained from the quantitative analysis. This indicated that PQP was not successfully implemented in LDNs due to lack of PQ awareness among top managers, staff and end users. This was the main and critical obstacle to understanding the significant outcome to be achieved, if a PQP is implemented.

- From the quantitative analysis in table 7.4, and from analysis of the interviews (see section 7.3.2), customer satisfaction was found to be a key factor. The company needs to adopt this factor in setting their requirements for dealing with consumer complaints regarding PQDs affecting equipment. Therefore, without the full participation of all employees and departments in considering consumer satisfaction, then any efforts in implementing PQP will be a waste in time and resources. Therefore, the PQP was not successfully implemented, because PQDs were not solved due to a low level of customer awareness of PQ definitions, resulting in PQDs. This is due to lack of customer satisfaction and the negligence of the customer department in responding to customer complaints. Hence, this relation between lack of satisfaction and lack of awareness leads the consumer to connect illegally to the network. For this reason, LDN departments should consider customer complaints regarding PQDs, and also increase customers' level of awareness and satisfy customer needs. As a result, customers will cooperate and become involved in PQ improvements, forming part of PQP implementation.

- From the quantitative analysis in table 7.5, and from analysis of the interviews (see section 7.3.3), the PQP was not successfully implemented, because MC was not sufficient to support this implementation. This was due to a lack of understanding of their responsibility, which is to be involved in distribution network improvement and to fully involve the relevant departments. This indicates that top managers do not understand the importance of implementing a PQP, or appreciate the difficulties they might face, if they plan to improve PQDs. As a result, lack of top management knowledge and awareness led to PQP not being implemented in LDNs. In order to implement PQP, the top management needs to understand PQP and have sufficient knowledge and awareness, to be able to support this programme effectively. Therefore, the majority of participants in this research indicated that top management encouragement is one of the most crucial factors, required to facilitate the full implementation of PQP. Top management must set clear strategy and obvious objectives, and should involve all relevant departments in addressing PQ issues.

- ❖ From the quantitative analysis in table 7.6 and from analysis of the interviews (see section 7.3.4), PQP was not successfully implemented, as PQDs were not solved. This was due to lack of PQ awareness in terms of definitions and disturbances among the engineers and technicians. Hence, training courses should be given to increase the level of awareness and knowledge of staff, who must be able to measure and analyse PQDs, as a part of the PQP implementation. Approximately 47.93% of the interviewees stated that there were no training courses regarding PQDs. This was due to a number of factors, preventing such courses from being run, as shown in section 7.4.

- ❖ From the quantitative analysis in table 7.7 and from analysis of the interviews (see section 7.3.5), resolving PQDs and achieving its objective as part of PQP implementation, is influenced by the distribution networks to tackle the following factors, which are *Lack of customer awareness and cooperation, Lack of networks designing, Lack of PQ measurements, Lack of top management attention and lack of staff's participation,* that still existed and increased PQDs. Therefore, PQP cannot be implemented successfully unless the mentioned factors are addressed.

- ❖ From section 7.3.1 it was clear that there was no PQP implemented to measure PQDs. This absence of implementation is due to lack of management commitment. Only 26%

of engineers, technician and head managers were aware of PQ problems as illustrated in figure 6.10. Approximately 51.9% to 56.6% of the respondents did not know if there was PQP implemented. This was due to management lack of commitment to having a clear strategy to build awareness, and train staff, in order to satisfy customers.

- ❖ The economic factor is the main aspect, which led to PQ problems in these networks. The improved economic conditions since 1999 led to significant and rapid urban growth, represented in wide-scale construction of homes, hospitals, schools, universities and industrial sites, etc. These new development projects were needed to meet the population needs every year, worsened by the lack of government strategy during the political, economic and trade blockade of Libya between 1990 and 1999.
- ❖ The blockade put EGCOL in a worse situation, whereby they could not build, renew or upgrade any infrastructure due to lack of resources. Therefore, citizens built houses randomly without any planning, which resulted in PQDs. The blockade forced the Libyan economy to become critically unstable.
- ❖ After 1999, when the blockade was lifted, many goods and products were imported to Libya, among them electronic equipment. There was no control on the import of electronic devices; this made the situation worse, because their specification was not compatible with PQ standards, even though EGCOL had a plan to improve PQ. Likewise, most infrastructure projects were based on high technologies, consisting of sensitive tools. Therefore, when the blockade was lifted, and the number of electronic equipment increased, so did the number of complaints; the company was suffering PQ issues, because of lack of staff awareness of PQ.

- ❖ Deregulation of importing electronic equipment without any controls began after 1999. As a result, these non-linear equipments were used rapidly by customers in both residential and the industrial sectors. Later on, when the number of users increased every month, so did the number of complaints to LDNs, due to the bad PQ they received. Therefore, due to the lack of understanding of the concept of PQ by customers, management and staff at the EGCOL, these complaints are still increasing as they are not being considered. Hence, the problems of PQ were aggravated and started to increase across the three LDNs.

- The interview results were similar to the results gained from the survey, as is shown in table 7.8. Approximately 75% of the interviewees stated that there was no PQP implemented in the past. The lack of PQP was due to two important factors; firstly, the staff did not have enough knowledge and awareness of the PQ concept and problems. Moreover, about 75% of interviewees stated that the lack of training courses that could keep them updated on the problems related to PQ. This was also due to use of sensitive equipment by end users from all sectors. Interviewees blamed them for not being helpful in reducing PQDs, and work together to improve PQ. As a result, end users were not aware of PQ issues or definition.
- The majority of respondents in both quantitative and qualitative analysis refer to lack of PQ standards, where the customer must follow these standards. This affects the network in the excessive use of non-linear loads. Secondly, there was no clear strategy in the economic factor, where the Libyan government was not organised, in the sense of informing EGCOL about new strategy, regarding new economic projects. This led to huge problems, where a large number of projects were constructed, without considering the capacity of the distribution networks.

8.3.3 Research Question Three

- *What are the most significant success factors of implementing a PQP regarding PQ awareness within LDNs in EGCOL?*

The PQ survey was designed to ask the respondents to state their opinions and attitudes regarding the current level of PQP implementation in LDNs. There were forty three items based on six factors, which were ordered according to their importance in PQP implementation with a significant loading above 0.4, as shown in table 6.7. These factors explained a total of 54.58% of the overall variance, and were ranked as follows:

- Customer Satisfaction

- Management Commitment
- Employee's Participation and Training
- Customer and Company Awareness
- Power Quality Disturbances

8.3.3.1 Customer Satisfaction

From table 6.8, it can be seen that the customer satisfaction factor has a positive and statistically significant relationship with all five PQP factors. This factor consists of 5 variables, 12-16, which are customer complaints, customer satisfactions, customers' needs, improvement for customers and customer awareness. All five questions were distilled into a single factor, and it was verified that all the items selected to measure PQCS are statistically valid and reached statistical significance level, supporting the factorability of the correlation matrix [200]. The Cronbach alpha scores for the factor, PQCS, is 0.811 and explains 10.17% of the total variance. The purpose of implementing PQP in LDNs is to improve PQDs in order to satisfy the consumers. This means that customer satisfaction is a key factor, which the company can adopt to determine their requirements in dealing with consumer complaints regarding PQDs. As a result, without full participation by all employees and departments to consider consumers satisfaction, then this will lead to a waste in time, resources and efforts of implementing PQP. Therefore, customer satisfaction had a strong impact on PQP implementation in order to improve PQDs. Moreover, LDNs need to consider customer complaints seriously by conducting measurements or studies to identify the level of customer satisfaction, and to improve PQDs. Therefore, reaching a high level of customer satisfaction is one of the most essential challenge objectives for LDNs to achieve. For this reason, LDNs have to identify what are the most outstanding problems regarding PQ for customer needs as part of improvement.

8.3.3.2 Management Commitment

From table 6.8, it can be seen that the management commitment factor has a positive and statistically significant relationship with all other factors (5) regarding power quality programme. This factor consists of 7 variables, 17-23, which are: identifies the causes, inaccurate managerial decision, planning good strategy, following the recommendations and studies, ensure security and quality and international or national benchmarks. All six items were distilled into a single factor, and it was verified that all the items selected to measure PQMC are statistically valid and reached statistical significance level, which supporting the factorability of the correlation matrix [200]. The Cronbach alpha score for factor PQMC is 0.841, which explains 9.61% of the total variance. Therefore, without direct support through management commitment, then any efforts of implementing PQP will be a waste in both time and resources.

In order to implement PQP, top management needs to understand and have sufficient knowledge and awareness regarding PQP to be able to support this programme efficiently. The majority of participants in this research indicated that top management encouragement is seen as one of the most crucial factors, facilitating the full implementation of PQP, by setting clear strategy with its obvious objectives, and involving all departments relevant to improving PQ issues. Therefore, top management should be the first to bear responsibility for implementing PQP in a long term strategy, drawn from all departments involved in PQP implementation. Moreover, they should increase their awareness and knowledge levels to be able to identify the causes of the problems root, and conduct some studies to ensure the security and quality of the PQP implementation by following both international and national standards.

8.3.3.3 Employees Participation and Training

From table 6.8, it can be seen that the Employees Participation and Training factor has a positive and statistically significant relationship with the other five factors regarding PQP implementation. This factor consists of 6 variables, 24-29, which are survey or feedback techniques, sufficient training, employee's suggestions, employee's strategies, appropriate qualifications and employee's involvement. All six variables were distilled into a single factor, and it was verified that all the items selected to measure PQEPT are statistically valid and reached statistical significance level, which supported the factorability of the correlation matrix [200]. The Cronbach alpha score for factor PQEPT is 0.806, and explains 8.21% of the total variance. Without full participation by all employees and departments, then any efforts of implementing PQP will be a waste of time and resources. Approximately 47.93% of the interviewees stated that there were no training courses regarding PQDs. This was due to lack of awareness of PQ definitions and disturbances for both the engineers and technicians. Hence, there should be training courses to increase the level of awareness and knowledge for the staff, to be able to measure and analyse PQDs, as part of PQP implementation.

It revealed that the majority of respondents (52.4%) held the educational qualification of high diploma degree, considered the minimum education level. In order to deal with PQ events, this level of education would enable them to cope with the current level of PQDs severity. Therefore, training courses would increase the engineers' and technicians' skills and experience, to be aware and be able to understand the problem roots regarding PQDs. Moreover, if there is no good technician team trained properly and ready to solve these problems and know the problem roots, this will lead to more PQDs based on previous action. Therefore, evaluating the feedback before, during, and after the training courses will help categorise those employee, who have the ability to learn new skills and knowledge regarding PQ issues. Nonetheless, it is not only the key factor in stopping all the problems, but also prevents them from recurring. LDNs staff are well educated, however they needed to be trained further and have the motivation, which would increase the awareness level of PQ and participation in PQP implementation and achieving improvements for LDNs.

8.3.4 Research Question Four

- *Are there any statistically significant differences between the level of PQ awareness regarding employee characteristics, in terms of position, education, responsibility and experience within LDNs, and the success factors derived from the literature needed for implementation of a PQP for satisfying future needs?*

The four main effects of MANOVA (work position, education level, work experience and work responsibility were examined in three LDNs. The MANOVA results signified that, there were no statistically significant differences in employees' work position, educational level, experience, and responsibility in the combined dependent variables along with all participants from all three networks, since the value of ($P > 0.05$), and the levels of PQ awareness regarding the CSFs derived from the literature of PQP implementation in LDNs, included Customer Satisfaction, Management Commitment, Employees Participation and Training, Customers and Company Awareness, and PQ Disturbances. These findings support the research question four, as shown in table 8.1.

Table 8.1: The impact of demographic characteristics on PQP Factors

MANOVA Test			
Distribution Network	Employees' Characteristics	PQP Factors	P Value
West Network	Work Position	Not significant	0.344
	Education Level	Not significant	0.419
	Work Experience	Not significant	0.297
	Work Responsibility	Not significant	0.306
East Network	Work Position	Not significant	0.327
	Education Level	Not significant	0.075
	Work Experience	Not significant	0.923
	Work Responsibility	Not significant	0.244
South Network	Work Position	Not significant	0.162
	Education Level	Not significant	0.365
	Work Experience	Not significant	0.308
	Work Responsibility	Not significant	0.661

On the other hand, in order to find the significant answer concerning objective five, which is to identify the most important and significant factors to assess PQP implementation within LDNs, which could be applied and adapted internationally. In response, the relative importance index method (RII) was used to identify the relative importance of each critical success factor (CSF) in west, east and south distribution networks, as shown in table 8.2.

Table 8.2: The results of the relative importance index and the rank of the CSFs affecting PQP implementation

CSFs	**West Network**		**East Network**		**South Network**		**Overall**	
	RII	**Rank**	**RII**	**Rank**	**RII**	**Rank**	**RII**	**Rank**
PQ. Customers Satisfaction	3.149	5	3.229	5	3.171	5	3.186	5
PQ. Management Commitment	5.661	3	5.438	2	5.398	3	5.499	3

PQ. Employees Participation and Training	4.431	4	4.501	4	4.355	4	4.429	4
PQ. Awareness	6.493	1	6.691	1	6.626	1	6.603	1
PQ Disturbances	5.679	2	5.357	3	6.078	2	5.704	2

Table 8.2 illustrates the most important CSFs, which significantly affected PQP implementation according to each west, east and south distribution network current level. These are 1) PQ awareness, 2) PQ disturbances, 3) PQ management commitment, 4) PQ employee's participation and training and 5) PQ customers' satisfaction. According to LDNs, it seems that PQ awareness was the most important factor, which delayed the implementation of PQP, as it was ranked first among all CSFs, with relative index (RII) = 6.493 for west distribution network, 6.691 for east distribution network, and 6.626 south distribution network. This agreement between all three distribution networks may be referred to lack of PQ awareness among LDNs top management to implement PQP effectively. Consequently, this can confirm that the ranked importance factors of all five CSFs of PQP are positive, and statistically significant among west, east and south distribution network, since the p-values (Sig.) are less than 0.05 using Pearson's Coefficient (r), as shown in table 6.8. Moreover, table 6.33 and figure 6.17 showed that the value of R^2 is 52.2%, which indicated that the extent of the variability in the outcome was explained by the predictors of all five PQP CSFs and affected by the level of PQ awareness. Appendix K presents the relative importance index for all the 41 PQP CSFs in the west, east, and south LDNs.

8.3.5 Research Question Five

Part four in the questionnaire was designed to address research question five, and assess the level of PQP implementation by assess the attitude of west, east and south distribution network respondents towards the barriers that effect on the implementation in LDNs.

What are the difficulties and barriers facing LDNs in implementing PQP?

In Section 6.9.5.1, One-way ANOVA was conducted, which showed that out of 16 PQP barriers, 13 were statistically significantly different at the P value <0.05, as illustrated in table

6.25. In addition, table 6.28 illustrates the post-hoc tests to point out, where the differences lie between PQP factors among LDNs after obtaining the significant values from the ANOVA table. Moreover, in section 7.4, both figure 7.1 and table 7.8 illustrated that the qualitative data analysis revealed some difficulties, which still exist and prevented the process of implementing PQP. In response, table 8.3 presented the overall relative importance index (RII) and the rank of the 16 PQP barriers based on four factors of the PQP framework. The barrier has been ranked as 1, indicating the highest effect barrier on PQP implementation and respectively up to barrier 16, which indicates less effect on PQP implementation. However, the 16 PQP barriers have been affecting LDNs to implement PQP successfully among the three distribution network, which still suffer severe PQDs due to lack of top management recognizing the importance of implementing PQP. Table 8.3, summaries the relative importance index (RII) and the ranking of the 16 barriers to PQP implementation.

Table 8.3: The relative importance index (RII) and rank of barriers affecting PQP implementation in LDNs

Items	**PQP Barriers**	**Overall**	
		RII	**Rank**
BA1	lack of staff awareness, skills and experience	**0.537**	**2**
BA2	lack of end users awareness	0.462	8
BA3	lack of customer cooperation	**0.534**	**3**
BA4	lack of long-term strategy and planning	0.487	5
BA5	lack of top management commitment	0.454	9
BA6	lack of network design	0.523	4
BA7	lack of distribution networks infrastructure	0.442	11
BA8	lack of conducting research and studies	0.463	7
BA9	lack of top management responsibility	0.432	12
BA10	lack of training courses, education and support	0.402	16
BA11	lack of enough resources	0.411	14
BA12	lack of financial incentives	0.446	10
BA13	lack of PQ measurement	0.407	15
BA14	lack of PQ consultants	0.472	6
BA15	lack of PQ standards	**0.538**	**1**
BA16	lack of PQ monitoring and database	0.422	13

It clear that from table 8.3 that the three PQP barriers most affecting LDNs are PQ standards, staff awareness, skills and experience and customer cooperation. LDNs top management needs to consider these factors first, before moving to other barriers due to their importance in preparing and alerting both staff and end user about the importance of implementing a PQP framework effectively and to tackle the existing barriers, LDNs still face.

8.4 Part Two: PQP Framework for Libyan Distribution Network

8.4.1 Research Question Six

In order to implement PQP successfully for LDNs, the framework should be appropriate to the current level of LDNs. The PQP framework for this study was developed based on the extensive literature reviews and EGCOL documents, paper, reports and archives. It was also based on the research results gained from both quantitative and qualitative data analysis. The results revealed that no PQP was implemented. This absence of implementation is due to lack of PQ awareness by top management, which does not have a clear strategy to raise awareness and train staff in order to solve complaints and satisfy customers. Therefore, research question six states;

> *What type of PQP implementation model framework should be developed in order to guide LDNs in improving PQDs and what are the requirements involved in the implementation of PQP?*

In response, the outcome of this study showed that the top management of EGCOL do not give enough attention to their departments and staff, to set up long term strategy to improve PQDs that face end users and distribution networks on a regular basis. This was due to some difficulties, which still exist and made the process of implementing PQP complicated and slow, as explained in section 7.4. Hence, PQP implementation requires great attention from top management that can help the distribution networks to achieve their goals in converting the studies and recommendations into practice by implementing a PQP practically. Moreover, there were about ten difficulties, as shown in figure 7.1 and table 7.8, which had prevented this programme from being implemented.

In order to have a complete implementation to perform this programme, the following factors needed to be considered by LDNs:

PQP implementation is influenced by:

- having long term clear strategy
- increasing customer awareness
- accommodating economic growth
- equipment standards
- design good distribution networks
- providing enough resources
- staff awareness
- top management responsibility
- PQ standards
- PQ measurements

Resolving PQDs and achieving the objective, as part of PQP, is influenced by the distribution networks, which tackle these factors that still exist. Therefore, PQP cannot be implemented successfully, unless the abovementioned factors are addressed.

On the other hand, table 6.10 revealed a low level of PQP implementation in LDNs. Hence, Multivariable Linear Regression (MVLR) analyses were performed in this thesis; firstly, section 6.10.1 illustrates the relationship between the CSFs derived from the literature and the level of PQ awareness within LDNs. It was clear that lack of PQ awareness has significantly positively effect on the CSFs of PQP, Customer Satisfaction, Management Commitment, Employee Participation and Training, and PQ Disturbances Affecting Networks, as shown in figure 6.17. Secondly; section 6.10.2 illustrates the relationship between the PQP barriers derived from the literature and PQP implementation framework within LDNs. It was clear that PQP implementation in LDNs has been affected in terms of PQP Awareness, PQP Management commitment, PQP Resources, and PQP involvement, as shown in figure 6.18. Hence, it is crucial to develop the PQP framework to guide LDNs in tackling all the outstanding factors that still exist and prevent implementing PQP. Figure 8.2 shows the proposed PQP framework flowchart.

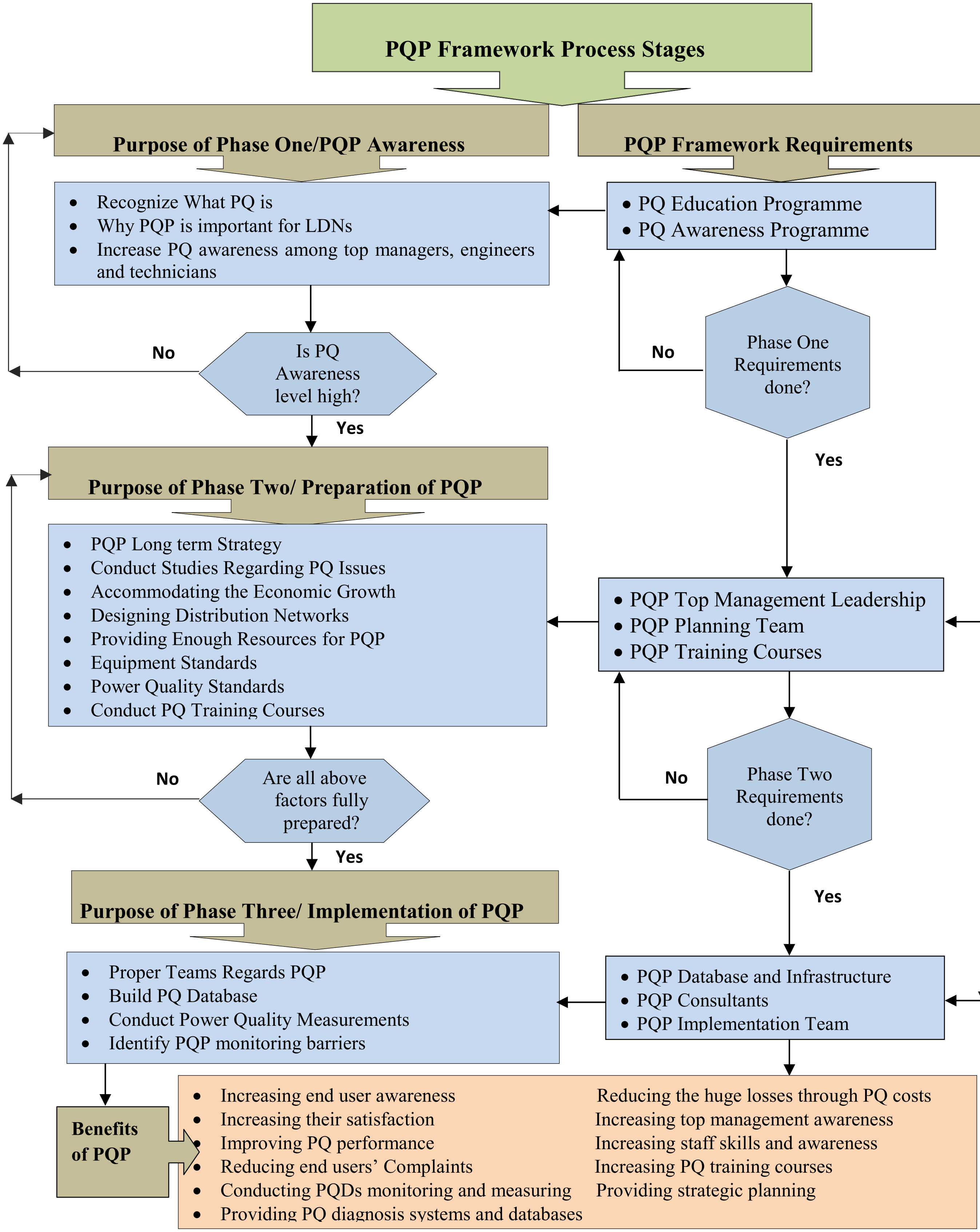


Figure 8.2: Flow chart of PQP framework Roadmap

8.4.2 Research Question Seven: the Roadmap for PQP Framework and Requirements

The prior questions and the proposed success factors from both the literature and the pilot stage led to answering the seventh research question;

> *How PQP framework can be implemented, and what are the stages involved in the roadmap process and what are the outcomes should be gained after implementing PQP framework followed each process stage of the roadmap?*

PQP implementation will enable LDNs to step forward, to tackle any PQ problems by setting a clear and long term strategy, with the most crucial objectives, by involving all the departments and staff, who have direct relation and responsibility for addressing PQDs. Approximately 63.37% of participant responses were that no PQP was implemented in the past due to twelve significant difficulties, which were mentioned above and prevented the company from concentrating or focusing on improving PQ issues. Thus, LDNs should have an explicit strategy to improve PQ issues existing in its networks. It was clear from the qualitative analysis of EGCOL departments that top management in these departments concentrated very much on supplying power to consumers rather than concentrating on quality.

Furthermore, there were no clear objectives or attention to support PQP implementation by top management. This lack of obvious vision is due to some difficulties still facing EGCOL in increasing the awareness level of PQP, and to set out further requirements to complete this programme in order to improve PQDs and to increase the level of awareness for all end user types, as explained in section 7.4. In addition, some of these difficulties require the end users to cooperate with the company in order to overcome them and provide good level of PQ for them as well. Notwithstanding, employees were also part of these difficulties by focusing on how to satisfy their managers, and ignoring customer satisfaction. Consequently, customers reacted badly, and caused significant PQDs. Unluckily, the majority of EGCOL staff in different departments, which are involved in improving PQ, have no influence to make their suggestions regarding any strategy would improve PQDs. The qualitative analysis results showed that lack of implementing PQP, was due to some difficulties, which still exist and made the process of implementation very complicated and its progress very slow.

8.4.2.1 Phase One: Power Quality Programme (PQP) Awareness

The purpose of phase one in the PQP framework is fundamental, in increasing the level of awareness regarding PQ among staff. This phase involves motivating top management to be eager and enthusiastic to start implementation of the programme based on staff's level of knowledge and awareness after understanding the importance of PQP and its features. Top management must pay more attention to reaching a high level of understanding, and so prepare clear objectives, along with a clear strategy for successful implementation of the PQP.

8.4.2.1.1 Why PQP is important for Libyan Distribution Networks (LDNs)

Top management and LDNs staff should understand the importance of PQ. Lack of awareness could result in utilities still suffering from PQ problems caused by the industrial, domestic and commercial sensitive equipment. Overall, as long as the concept of PQ is misunderstood by both the EGCOL staff and customers, then the severity of PQ issues will increase every day due to fact that the demand on power will be doubly increased [73][110].

PQ definition is a very important aspect to be understood before starting PQP implementation in LDNs. Moreover, the level of awareness regarding this term should be very high, which should indicate that they have reached a very high level of both experience and skill to deal with PQDs. Furthermore, staff from all departments should understand this concept and possess awareness and knowledge to resolve PQDs. Therefore, they should start implementing a full programme, where these improvements should take a place in LDNs, to tackle any existing problems that prevent PQP implementation. This includes staff awareness, customer awareness, training course, strategy, good planning, PQ standards and measurements, and top management responsibility regarding PQP. Thus, without adequate knowledge, awareness, planning, designing, preparation, training, PQ standards, clear strategy, and most importantly top management support to perform this programme, PQDs would not be improved. Indeed, their severity will affect all consumers, where lack of PQ will damage equipment and increase the network losses. Therefore, as more time is spent on education to make staff and end users aware of the importance of PQ, the less the losses and equipment damaged caused by PQDs.

The effort of resolving PQDs in each department depends on the level of awareness of the head manager and staff, who are share the responsibility to solve these issues and pay more attention regarding PQ definition. As a part of resolving PQDs, they must make the end users aware of how important this term is, and encourage them to cooperate with the company in solving PQ problems. Therefore, PQP in LDNs, requires both patience and discipline by top management and staff to admit what knowledge they had in the past regarding PQ issues, and what existing problems they still face, in order to learn more and more in the future to avoid these obstacles, as their level of awareness of PQ should be very high.

The PQP implementation framework plays a significant role in improving PQ issues. The purpose of this programme is to achieve the strategies and objectives set by all departments, associated with completing and developing PQP in LDNs. However, if they do not take into account the implementation difficulties, mentioned above, this will lead to unexpected consequences for all departments, involved in PQ as well as end user satisfaction. Therefore, one of the main challenges in implementing PQP is to link all the implementation difficulties of the programme with both its objectives and strategies. Hence, this study suggests that a regular evaluation of programme difficulties should be performed to identify the hidden reasons associated with, and causing poor implementation.

8.4.2.1.2 Top Management awareness

Top management awareness is one of the most prominent success factors, which leads any electrical company to implement PQP successfully, by setting a clear strategy for all employees, involved in improving PQ problems, with the purpose of improving the distribution networks. The qualitative analysis revealed that the majority of interviewees pointed to a lack of top management awareness as the significant factor, which prevents PQP implementation.

Therefore, four barriers were associated with the lack of top management's responsibility, which were ***lack of administration structure, lack of manager's culture, lack of studies and researches, and lack of top management attention***. As mentioned in chapter seven, the qualitative study was conducted in four departments, which are supposed to share the responsibility for improving PQ issues. Therefore, if these departments did not cooperate with each other, and position one clear strategy and set direct objective, then any initiative to improve the distribution networks will be waste of time and effort, because they should be coherent and have obvious requirements, to tackle any difficulties could face them in implementing PQP. Hence, top management support is considered one of the key factors, which would facilitate any difficulties and includes awareness and attention in conducting some studies, making the administration structure uncomplicated and providing more training courses regarding PQP implementation. Therefore, interview data exposed that successful PQP implementation is linked to top management attention.

8.4.2.1.3 Staff Awareness

Staff awareness is another crucial factor of PQP. Thus, without staff awareness, knowledge, experience, skills, attention and culture, any programme would fail. The qualitative analysis revealed that most of the staff, who work in planning, distribution, training and customer departments, where this study was conducted, are not aware of the importance of implementing PQP. Approximately 34.14% of employees were knowledgeable regarding PQ definition. This indicated that they were able to understand the concept of PQ. However, in section 7.3.4 of PQP implementation, they were one of the obstacles, which face implemented PQP. Therefore, in order to have a complete implementation, the staff should have high level of responsibility by developing their skills and knowledge regarding the latest PQ technology, to be a part of this programme and continue further improvement to reach the acceptable level needed. Moreover, PQ terminology is not known in the company, so much so, that few staff know about it. Indeed, the majority of staff, who should deal with customer complaints, do not recognise this term, and fail to solve disturbances and satisfy consumers. Therefore, the staff only focus on restoring power supplies without understanding the real issues causing the problem, or checking equipment standards to PQ standards to avoid any further faulty diagnosis.

As a result, wrong estimation or measurements would cause serious problems in distribution networks, and affect the PQP implementation strategy. Furthermore, the first thought of almost all head managers and staff, responsible for resolving the problems is to install new equipment. They do not follow up the causes of this problem or seek to find its roots. Therefore, the PQ awareness programme should start from top management, after that the employees, and then the consumer. As a result they will be able to understand PQ definition and disturbances, and are able to solve problems. The expected output of phase one is as following:

- Top management and staff become aware of PQP.
- Top management and staff understand the importance of PQP.
- Top management and staff start to prepare for PQP implementation

8.4.2.2 Phase Two: Preparation of PQP

Phase two is performed in conjunction with phase one. After top management becomes aware and understands the importance of PQP, then this phase will drive the distribution networks to start preparing for PQP implementation. Phase two involves preparation for PQP, which contains seven crucial requirements. The most important requirements of this stage is that top management must set a clear and long term strategy to continue building up the PQP to become part of the LDNs' culture. One of top management's responsibilities is to develop and meet the needs of this phase, and so reach a high level of PQP implementation across its networks. This step symbolizes the most critical factors of this framework, and requires both top management commitment and employee participation for PQP implementation in LDNs, as key factors for success.

8.4.2.2.1 Strategy

Strategy is a very significant requirement needed to implement a PQP. As a result, most of the projects, which attempted to establish PQP, failed due to lack of clear and long term strategy. Thus, time should be spent on planning and preparation to provide a clear picture of what the company needs from such a programme to eliminate any obstacle or confusion that might face the implementation objectives in the future. Therefore, the first action that LDNs should take is to identify what they have experienced, about the difficulties of PQP implementation in the past, and what are the most crucial factors that need to be improved to draw a clear strategy based on these requirements and start to perform their objectives.

8.4.2.2.2 Conduct Some Studies Regarding Power Quality Programme (PQP)

Top management should conduct some studies and researches to investigate the causes of PQDs. The four departments should conduct intensive programmes in different aspects to study the real situation of distribution networks. However, this depends on the results, which will be gained from the PQP awareness progress and how far these results are completed and evaluated. Therefore, these results should come from a realistic analysis of the real problems, which the company suffers from. It is impossible to adapt other electrical utilities solutions and implement them for LDNs, because each system has different causes and effects. Moreover, LDNs have their own characteristics, which are quite different to other distribution systems in the world. Therefore, if the company conducts serious studies and researches instead of concentrating on the interruptions and technical issues in the networks by setting some priority objectives, then these difficulties will be tackled. Therefore, the maintenance section should conduct regular measurements to analyse the researches and studies results to understand the problem root regarding customer complaints, and so prevent it recurring, by finding the appropriate solution.

8.4.2.2.3 Economic Growth and Network Design

LDNs still face two problems associated with economic growth, especially after 1999, which saw an increase in new construction projects and increased demand on electricity of roughly 8% yearly. After 1999, there was a leap in the country, which was also one of the significant barriers of PQP not being implemented. The distribution networks should control these increases by designing new schemes to accommodate the increased demand, and cooperate with the infrastructure Ministry, to have a full picture of the whole company's strategy, in the same line, after tackling all the difficulties mentioned above. Therefore, both increases in demand and economic growth will not stop in the future. Moreover, the qualitative analysis revealed that there were obstacles associated with the network design, which also affected

PQP implementation.

Libyan distribution departments need to have clear vision of designing the distribution networks based on each consumer type and load. Thus, both teams of regular maintenance and measurements should be considered when repairing any problem, or when investigating any power supply issues. In addition, the consumer should cooperate with the company without any dispute. Moreover, resolving PQDs requires reorganising and revising the random building, in and out of schemes. Besides, Libyan distribution departments need to have clear objectives to cope with PQP implementation without any obstacle facing that. Therefore, in order to implement PQP, the distribution department should build and upgrade new transfer stations, which would help in resolving PQDs by having one standard for all equipment and networks.

One of the important things, which top management should pay attention to, is to set strategy for all the unexpected increases arising from both demand increase and economic growth. By considering the normal growth with mega-projects for any sudden increases, which this would help the distribution networks categorise all types of consumers by type of load, such as large and small customers, residential, small and large industrial, and agricultural. However, the company must take into account the types of the consumer in consideration when designing and upgrading the networks.

8.4.2.2.4 Sufficient Resources

Enough resources are an essential aspect to cope with the current situation by improving the existing equipment and upgrade the networks for better performance of PQ. Furthermore, the resources are needed for both the maintenance of the existing networks, new projects and run training courses regarding PQP. This can help the employees to understand PQDs, and they can be able to have full view regarding the PQP implementation. Therefore, one of the difficulties, which face the company to make major improvements on the distribution networks, is lack of resources. As a result, many projects are discontinued, which they supposed to be a part of PQP implementation. Moreover, there are huge technical and financial losses caused by the consumers due to not paying their bills and by connect illegally to the networks. Therefore, the refund, which should be gained from the end users consumption, is missed.

8.4.2.2.5 Equipment Standards

The qualitative data analysis revealed that the distribution department has conducted several new projects, which are under way to develop its networks. Nonetheless, these projects were not matched to each other, to be compatible with the distribution networks' specification, due to different equipment standards in each company's specifications. The company should control the market by preventing installation of such equipment in their distribution networks, unless the specifications are revised. Moreover, consumers should stop importing any electrical or electronic equipment, which are not compatible with PQ standards. Therefore, the difficulty of meeting both the distribution networks and end users' equipment standards has affected PQP implementation.

The distribution network should adopt unified standards for all equipment. This would improve power quality problems. Therefore, accommodating all the equipments, which the company imports within the exact specifications for all networks, will guarantee that all these equipment are compatible with each other in terms of PQ. Moreover, the distribution networks must set one unified designing standards. This will also categorise the consumers based on each type and load. The distribution network department should keep maintenance the station by replaces new tools after measurements taken and analysis.

8.4.2.2.6 Power Quality Standards

The qualitative analysis revealed that approximately 32.59% of the interviewees said that there were no specific PQ standards in LDNs to improve PQDs. Moreover, roughly 39.47% of the respondents were not knowledgeable regarding PQ standards. Indeed, each of the four departments has its own standards, which are not similar and were not followed to improve the networks. New equipment, which the company buys to improve the distribution networks does not match the specifications of existing equipment. Additionally, the company must control the private sector, which imports equipment without checking if it is compatible with PQ standards or not. The company should impose PQ standards on these departments, to be followed in each project and by all consumers. Furthermore, PQP implementation requires specific agreement between the departments involved in resolving PQDs. Therefore, this agreement should follow the international standards such as IEEE and IEC standards to identify the disturbances characteristic of PQ to be known in such a way that can be revised and compared. As a result, the end users will be satisfied because PQDs are compared to these standards. In addition, the distribution system should conduct some studies based on the equipment standards that the consumers use and compare them to each load type in terms of specification. However, from the economic side, if the customers use equipment, which have good quality and compatible with PQ standards, that is mean there will be such guarantee that the equipment' lifetime will be longer.

8.4.2.2.7 Conduct Training Courses

Training courses regarding PQ is an essential factor to increase staff skills and awareness to deal with PQ problems. It appears that staff do not have enough knowledge regarding PQ definition and disturbances. Therefore, this is one of the difficulties facing LDNs to implement PQP. This was due to lack of conducting PQ training courses. The distribution systems at LDNs need to improve their engineers' and technicians' skills, and experience by conducting more training courses to deal with PQ issues and find the appropriate solutions for their customers in order to satisfy them. This can be done by rewarding engineers, who attend specific training courses regarding PQ, and should be related to distribution networks. Therefore, engineers and technicians should spent more time on education and training courses based on advanced approaches in training programme to cope with recent technologies to achieve better results, which would improve the awareness level. As a result, end users awareness level will do so [88]. This will help them to cooperate with the company, which would help PQP implementation smoothly based on the strategy of all departments. The expected output of phase two is as following:

- Top management comprehends the need for long-term strategy to accommodate economic growth and design the distribution networks based on each consumer type.
- Top management provides enough resources and PQ standards.
- Employees at all levels become aware of the importance of PQP, and are involved in power quality improvements and strategies.
- Both top management and staff have the same vision and are willing to solve PQDs.

8.4.2.3 Phase Three: Implementation of PQP

Phase three is the implementation stage, which would allow LDNs to determine both the weaknesses and obstacles facing the measurement of PQ. The previous two phases were designed to prevent the outstanding problems from recurring. The goal of implementing the PQP framework is to increase the level of awareness in practice, and operate the PQP framework practically with great attention from top management. It also focuses on, and satisfies end users' needs, by considering their complaints in an everyday process. PQ improvements should be conducted by proper teams to measure and analyse PQDs through building a PQ database to monitor, measure, analyse, and compare measurements to PQ standards.

8.4.2.3.1 Proper Teams Regarding PQP

One of the main objectives of implementing PQP is to train and provide proper teams ready and qualified to solve PQDs in order to satisfy customers. Moreover, training courses should include practical, technical, psychological and cultural sides. Therefore, evaluate the feedback before, during and after the training courses will help categorise each employee based on skills and knowledge regarding PQ. Moreover, if there is no good technician team trained properly and ready to solve problems and know the problem roots, this will lead to more PQDs based on previous action. Therefore, the more the technician teams are well trained regarding PQ, the less PQ problems occurring. Preparing and implementing the second phase, will lead to proper teams regarding PQ issues.

EGCOL still has some deficiency in not providing training courses regarding PQ, as well as other training courses, and is not able to solve any problem. This cost the company as it will have to employ external consultants for either diagnosing the problems or training employees. Thus, if there are properly trained teams, their awareness and knowledge level will become very high, and then they will be able to deal with PQ issues. However, this depends on the type of training courses that are given to qualified employees and the requirements of the second phase.

8.4.2.3.2 Customer Satisfaction

One PQP implementation purpose is to improve PQDs in order to satisfy consumers. Therefore, customer satisfaction is a key factor, which the company is willing to reach to determine the requirements to deal with consumer complaints regarding PQDs. Moreover, descriptive analysis of the customer satisfaction factor shows that the mean level of this factor is 2.47 on the five-point Likert Scale. This signifies a low level of customer satisfaction as a part of PQP implementation, which was due to a low level of customer awareness related to PQ issues, and the negligence of the customer department in responding to customer complaints. Hence, one of the expected objectives of PQP implementation by LDN departments is to consider customer complaints regarding PQDs, and increase customers' level of awareness, to become familiar with PQD features and meet their needs. As a result, they will be able to cooperate and be involved in PQ improvements, as a part of PQP implementation.

Therefore, reaching a high level of customer satisfaction is one of the essential challenges and objectives for LDNs to achieve after PQP implementation. LDNs have to identify what are the most outstanding problems regarding PQ, as part of guideline improvement for customer needs. Hence, increased customer awareness concerning PQ is an extremely important element in achieving customer satisfaction. Indeed, attracting consumers has become a science and the company should improve its methods to achieve the expected results. This can be done by using several methods, such as the media, the press, leaflets and Internet, in order to increase customer awareness.

8.4.2.3.3 Build a PQ Database

Building the PQ database is very significant for any distribution system. This database can be developed after the two phases are completed. This will help the distribution networks record PQDs, which will help in the evaluation of power supply deviation on a regular basis and compare these to PQ standards. Therefore, PQ measurements should be conducted on a regular basis to monitor, and analyse PQDs on the customer side, which can be compared and revised to PQ standards. As a result, final reports would help find the appropriate solutions based on each disturbance characteristic. Moreover, there should be monthly measurement planning to predict and measure the network for any improvements. Using PQ measurement tools on a very narrow scale, because in case any problem happened, the measurements will be taken immediately.

However, management planning and expert experience are also important for searching for PQDs in terms of good quality of electricity. As a result, databases for accurate analysis and better solutions can be built. One solution in avoiding any PQ issues is an "emergency plan". This would help LDNs avoid any PQDs [75][19]. This plan includes data, which can be reviewed, revised and tested regularly. It is also suggested that there should be more records on the most susceptible equipment. This can help in identifying the severity of these disturbances and its sources, which should be compared to PQ standards. Moreover, PQ datasets needed to compare the events of PQ captured with PQ standards, as a result to be compared with electronic equipment classifications.

8.4.2.3.4 Conduct Power Quality Measurements

The measurement section should conduct PQ measurement on regular basis to identify the critical loads, which have a major impact and cause PQDs. This can be done by installing some measurement devices to measure the supply quality, and recode any PQ parameters to be revised and compared to PQ standards. A PQP needs to be implemented at the distribution networks to provide all the success factors needed to monitor and record PQDs. This can help the control board to identify where PQ issues most occurred and determine their sources. As a result, both commercial and technical losses can be reduced in the networks, and this will improve PQDs. However, this will not be achieved unless engineers and technicians have good training courses. As a result, the distribution networks should deal with customer complaints, for example, by sending a specific team to measure PQDs that the consumer complains about, to be analysed in terms of causes and what kind of solution can be implemented to minimise existing problems. The distribution networks department should conduct both studies and measurements for each problem separately, to prevent any complaints from the consumers. The output of phase three is as following:

- After the implementation of three phases of PQP framework, LDNs should have reached a high level of PQ awareness, increased employee participation, sustained power quality improvements, while the most important element is end user satisfaction.

8.4.2.4 Benefits of PQP Framework Implementation

PQP framework requirements and its key success factors, which were presented in sections 4.2 to 4.9, are very important, because of their influence on PQP benefits. The benefit(s) of implementing PQP can be seen as positive at different levels: LDNs, staff including top managers, engineers, technicians, employees, and end users. Most of the PQP framework presented in chapters 2 and 4 emphasises some specific recommendations and requirements in order to obtain significant benefits and tackle existing obstacles to PQP framework implementation. Therefore, the mean level of PQP benefits indicates whether or not LDNs will gain significant outcomes after PQP is implemented successfully following the roadmap process for each phase. In response, participants were asked to judge how far one of 11 PQP possible benefits (BN) would be achieved by implementing PQP within Libyan distribution systems. The 11 PQP expected benefits are listed in table 8.4. All factors were designed in a five-point Likert scale format (1= not sure; 2=negative; 3= moderate; 4= positive; 5= very positive). The response scale of the survey was divided into three levels of outcome, where (1.51 to ≤ 2.50 was negative, 2.51to ≤ 3.50, moderate and, 3.51to ≤ 5 positive).

Table 8.4: List of Means Level of PQP Benefits

Item	PQP Benefits	DN1	DN2	DN3	Overall
BN1	Increasing the end users awareness	3.84	3.96	3.45	3.75
BN2	Increasing the end users satisfaction	3.91	3.56	3.54	3.67
BN3	Improving PQ performance	3.65	3.68	3.54	3.62
BN4	Reducing the end users complaints	3.51	3.52	3.68	3.57
BN5	Monitor & Measuring PQ disturbances	3.48	3.48	3.82	3.59
BN6	providing PQ diagnosis system and database	3.73	3.56	3.67	3.65
BN7	Reducing the huge losses of PQ cost	3.52	3.48	3.69	3.56
BN8	Increasing the top management awareness	3.76	3.88	3.82	3.82
BN9	Increasing the employee skills and awareness	4.25	3.31	3.75	3.77
BN10	Increasing PQ training courses	3.43	3.68	3.73	3.61
BN11	Providing strategic planning	3.48	3.66	3.61	3.58

The overall outcomes of implementing the PQP presented in figure 8.2 and table 8.4, which would have a positive impact on LDNs after implementing the PQP framework can be tangible, such as increasing end users' awareness, increasing their satisfaction, improving PQ performance, reducing end users' complaints, monitoring and measuring PQDs, providing PQ diagnostic systems and databases, reducing the huge losses associated with PQ, increasing top management awareness, increasing employee skills and awareness, increasing PQ training courses and providing strategic planning in LDNs. As explained in chapter 6, both the CSFs and barriers of PQP framework implementation are correlated and belong to each other to affect PQP implementation and how they significantly influence PQ improvement within LDNs. Moreover, section 7.5 and figure 7.5 illustrated that the qualitative data analysis revealed that there will be extremely significant benefits for LDNs, if PQP is implemented. Therefore, from the field study conducted in this research, the positive benefits of implementing PQP are not accidental, but can be obtained simultaneously after creating trigger changes in the framework implementation requirements. These are to be carried continuously, and help in finding the outstanding barriers, and defining each difficulty separately, whether it belongs to technical or non-technical issues [15].

In addition, the relative importance index (RII) and rank of PQP benefits is identified, in that which one of the 11 PQP benefits is most important for three LDNs after implementing the three phases of PQP respectively. Table 8.5 presented the relative importance index (RII) and ranks of PQP benefit results.

Table 8.5: The relative importance index (RII) and rank of PQP Benefits

PQP Benefits	West Network		East Network		South Network		Overall	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Increasing the end users awareness	0.559	10	0.541	9	0.613	9	0.571	9
Increasing the end users satisfaction	0.547	11	0.529	11	0.575	11	0.551	11
Improving PQ performance	0.573	9	0.531	10	0.579	10	0.561	10
Reducing the end users complaints	0.625	7	0.619	7	0.654	8	0.632	8
Monitor & Measuring PQ disturbances	0.664	6	0.701	2	0.708	6	0.691	6
providing PQ diagnosis system and database	0.742	1	0.723	1	0.742	2	0.735	1

Reducing the huge losses of PQ cost	0.703	2	0.693	4	0.718	4	0.704	4
Increasing the top management awareness	0.623	8	0.606	8	0.676	7	0.635	7
Increasing the employee skills and awareness	0.689	4	0.681	6	0.745	1	0.705	3
Increasing PQ training courses	0.694	3	0.697	3	0.728	3	0.706	2
Providing strategic planning	0.686	5	0.691	5	0.711	5	0.696	5

As indicated in table 8.5, providing a PQ diagnosis system and database has been ranked the first benefit by west network respondents RII = 0.742 and by east network respondents RII = 0.723. However, this factor has been ranked as second by south distribution network respondents RII = 0.742. According to the three distribution network respondents, the overall rank for this factor RII = 0.735, which indicated agreement on how it is very significant for LDNs to prepare and build a PQ database and diagnostic systems. This is due to lack of measurement and monitoring archives to compare past measurements with current ones, in order to identify the problems roots and the factors beyond them. Moreover, the three distribution network respondents have ranked increasing PQ training courses as the second important factor among all PQP benefits with relative index (RII) = 0.706. However, this factor was ranked third by each network, but the overall ranking was the second. This is mainly because if LDNs staff have enough training courses, then PQP implementation can performed and conducted to monitor PQDs with accurate outcome.

Increasing the employee skills and awareness has been ranked the third important factor of PQP benefit RII =0.705. It has been ranked by west network respondents RII = 0.689, by east network respondents RII = 0.681 and by south network respondents RII = 0.745. PQDs were not solved due lack of staff awareness, which affect PQP implementation and rise the end user complaint's. Therefore, increasing the employee skills and awareness considered one of the most important benefits that LDNs will gain after implementing the PQP framework successfully.

The three first factors can be considered as the most important benefits for three distribution networks, which are: providing PQ diagnosis system and database, increasing PQ training courses and increasing the employee skills and awareness. These factors may have a direct change on LDNs staff and end user after implementing PQP. It can be seen from table 8.5, the relative importance index (RII) and rank of PQP benefits show the top important factors from 1 to 11, which are categorised based on the three LDNs respondents, as they decided, which benefit is most important for each distribution network, after implementing PQP successfully.

8.5 Summary

Part one in this chapter has presented the main findings of the study, which clearly show poor implementation of PQP based on the CSFs chosen to assess PQP implementation in LDNs. Approximately 51.9% to 56.6% of the respondents, who were surveyed, were not aware if there was PQP implemented across the three networks. Lack of PQ awareness was found among the top management and staff, who deal with improvements regarding PQDs. This lack of top management awareness has led to setting unclear long term strategy. A strategy is needed to accommodate the economic growth, and for designing the distribution networks based on each consumer type and load. It was also due to lack of employees participation of both skills and knowledge to be aware and understood PQ issues, in order to satisfy consumers by preventing them from connecting illegally, which causes both PQDs and technical and commercial losses. It shows that there are no statistically significant differences in employees' work position, educational level, experience, and responsibility on the combined dependent variables along with all participants from all three networks and the levels of PQ awareness regarding the CSFs derived from the literature to implement PQP in LDNs. Moreover, these factors explained a total of 54.58% of the overall variance of PQP implementation. In addition, the relative importance index method (RII) was employed to identify the importance of each CSF on PQP implementation. It revealed that PQ awareness was the most important factor, which delayed the implementation of PQP, as it was ranked the first amongst all CSFs with relative index (RII) = 6.603.

The second part of this chapter introduced the proposed PQP framework developed by the researcher. The proposed framework consisted of three essential phases. This framework is designed as a guideline to implement PQP in the LDNs environment. The proposed PQP framework had specific process stages;

The purpose of phase one is to encourage LDNs top management and staff to become aware and understand the significance of PQP implementation by increasing both their skills and knowledge by conducting more intensive PQP awareness courses, before starting to implement PQP across its networks.

Phase two involved the preparation of the PQP, and comprised seven crucial requirements, as follows: PQP strategy, conduct studies regarding PQ issues, accommodating the economic growth and network design, enough resources, equipment standards, PQ standards, and conducting training courses. Phase two emphasized top management, to prepare and plan well the implementation requirements needed to achieve the high level of PQ before starting to implement PQP. Phase two shows that top management responsibility is very crucial to making their employees motivated and involved, to assure that the process of implementation makes expectable change in implementing PQP.

Phase three, or the implementation stage, was designed to prevent the outstanding problems in phases 1 and 2 from recurring, by determining both the weaknesses and obstacles, with the aim of reaching a high level of PQ. It was designed to focus on consumer satisfaction by considering their complaints and needs in everyday process. PQP improvements should be conducted by proper teams to measure and analyse PQDs by building a PQ database at all three networks in order to increase the awareness level.

The overall outcomes of implementing the PQP is presented in figure 8.2 and table 8.4, which would have a positive impact on LDNs after implementing the PQP framework, are not accidental, but can be obtained simultaneously after creating trigger changes in the framework implementation requirements. In addition, the relative importance index (RII) and rank of PQP benefits used in this thesis, identified which of the 11 PQP benefits is most important for three LDNs after implementing the three phases of PQP respectively, as explained in table 8.5.

Therefore, the proposed PQP framework was developed to ensure the following points;

- The validation of the proposed PQP framework was done based on multiple level data collection, and an extensive literature review, as well as empirical tests performed before collecting the primary data. This helped the researcher in identifying the areas of weakness, which were not clearly understandable and needed to be improved.

- The findings also indicated that the process stages of the developed PQP framework need more assessment to consider the smooth changes after each phase. As a result, the researcher noted that the research results were found to have made substantial contributions for LDNs staff, in understanding the importance of implementing a PQP, derived from the comprehensive questions included in both the survey and interviews. This showed how far away they are from reaching a high level of PQ and satisfying their end users.

The following chapter (9) presents the conclusion for the whole thesis and creates recommendations, limitations and future work of PQP improvements and implementation.

Chapter Nine: Conclusion, Recommendation, and Future work

9.1 Introduction

The aim of this research is to study the PQP implementation framework, and the obstacles and barriers faced by LDNs utilities in implementing a PQP. Firstly, to identify the most critical success factors that would have a major impact on PQP implementation in LDNs. This framework encourages and guides the implementation teams to have an obvious and clear vision of how to prevent existing obstacles from reappearing in different forms, leading to long-term PQP improvements.

The researcher has developed a PQP framework for the purpose of this study to suit the LDNs case. The proposed PQP framework model was validated based on the identified CSFs, barriers, benefits of PQP, which were analysed using different analysis techniques based on both SPSS and NVivo software. In order to implement the PQP framework successfully, there are some fundamental requirements that must be considered as explained in section 4.7 and section 8.4.2, which will positively impact on implementing PQP successfully.

9.2 Significance of the Study

- The implementation of PQP will enable LDNs to step forward, to tackle any PQ problems by setting up a clear and long term strategy, with the most crucial objectives, by involving all the departments and staff, who have direct relation and are responsible for improving PQDs.
- The proposed framework findings, gained from this study, are compared to international PQ practices. If the proposed framework is adopted and adapted to suit the General Electricity Company of Libya (GECOL) circumstances of PQ problems, it will help them to make a smooth transformation from poor PQ in the network to efficiency and effectiveness that satisfy their customers.

9.3 General Conclusions

Other conclusions that have emerged from this study are as follows:

- A comprehensive literature review was conducted to draw the requirements along with the description and exploration of the critically significant factors, and to understand the barriers and benefits of implementing a PQP, which has been defined for the purpose of this thesis as explained in chapters two, three and four respectively. The main purpose of the developed PQP framework is to guide LDNs, which have not previously implemented PQP, to improve PQDs.

- A PQ survey questionnaire was sent to 397 respondents, comprising head managers, middle managers, engineers, technicians and employees, conducted during April-June 2010 giving a response rate of 81%. The quantitative data were analysed by using Statistical Package for Social Science (SPSS) software, version 18.

- Face to face semi-structured interviews were conducted with 44 Libyan Distribution Systems staff to investigate, why there were barriers to PQP implementation. The interviewees consisted of head managers, middle managers, engineers, technicians and employees from four departments, mainly those dealing directly with PQ issues. These were planning, training, distribution, and customer departments in LDNs. The qualitative data were analysed using NVivo software, version 9.

- PQP framework implementation was investigated empirically based on the combined methodology quantitative and qualitative approaches. The need for PQP framework implementation in one of the developing countries is significantly important for GECOL, especially in three west, east and south Libyan distribution networks. PQP implementation plays a significant role in improving PQDs. The purpose of implementing PQP is associated with completing and developing systems to achieve the strategy's objectives set by all departments.

- The outcome of this study showed that GECOL top management do not give enough attention to their departments and staff, to set up long term strategy to improve PQDs facing the end users and distribution networks on regular basis. This was due to some difficulties, which still exist and made the process of implementing PQP complicated and slow as result of lack of knowledge, as explained in section 7.4.

- The PQP implementation requires significant attention from top management to help the distribution networks achieve their goals, by converting studies and recommendations into practice, and apply PQP practically. The first action, which LDNs should take, is to identify what they have experienced, about the difficulties of PQP implementation in the past, and what were the most crucial factors that needed to be improved to draw a clear strategy based on these requirements and start addressing their objectives. One of the essential PQP framework requirements is to spend more time and resources on education and awareness programmes. This will assist the electrical distribution network to address PQDs.

- PQP could be implemented faster and has positive feedback, if the concept of PQ is known and understood by staff and end users. This will be depended on how electrical distribution utilities apply PQP implementation. As a result, the level of awareness should increase in order to decrease the level of PQDs. However, GECOL must have a clear strategy, in such a case to avoid any disruption from its side, which could result in PQDs for both the networks and customers.

- The implementation difficulties should be regularly assessed to identify the hidden reasons associated with, and causing poor implementation. Thus, without adequate knowledge, awareness, planning, designing, preparation, training, PQ standards, clear strategy, and most important the support of top management for this programme, PQDs will never end and their severity will affect all consumers.
- The absence of national distribution competition from private companies is another aspect for GECOL to not be enthusiastic about implementing PQP. As a result,

difficulties face implementation, in the increased demand on electricity and the sharp rise in economic growth. This requires the company to have a strict strategy based on the current situation to accommodate these two increases, in order to solve PQ problems. Hence, the distribution networks department should be concerned about these increases and should also consider the lack of both end user and staff awareness regarding PQDs to tackle these difficulties.

- The distribution networks are not designed to be compatible with the increase in demand, as well as economic growth. Therefore, it will be possible, if the government also intervened to stop projects being implemented randomly, which result in bad PQ being delivered to the customer. Moreover, more generation plants are needed in the south network to avoid any negative impacts, which could result in GMMRP well fields pumping and cause huge disturbances to the SDN customers. The GMMRP pumping plants were driven far away from the generation systems by large induction motors. In this respect, providing power using alternative generations such renewable energy, wind turbine or solar energy to accommodate sustainable development in the current situation and future. This would have significant and positive improvement regarding PQ especially in southern distribution network and the other distribution networks. As a result, If LDNs management have obvious strategic planning, the southern distribution network can improve the PQDs by applying these alternative generation resources. However, these types of power generation systems have negative impact on PQ disturbances, which on-going studies focus on how to minimise the severity of causing PQDs especially in urban, rural and remote areas, which located far away from the generation plants.

- There is lack of PQ awareness regarding the infrastructure based on electricity between the Libyan government and the GECOL. Thus, it was not at the level where the network could absorb the increases of demand to be met with the residential increases and requirements. The random distribution networks infrastructure made it difficult for LDNs to accommodate these citizens, connect them to the network, and meet their requirements, as they are located in different areas. Moreover, when the end users were not connected by the company, the power was stolen due to illegal connection. This led to losses in the network as a result of a bad service by the supplier. The mentality of LDNs end user was just on how to have electricity connected to their houses without considering whether it was of good quality or not. However, when the number of electronic equipment rapidly increased cross the country after 1999, then they suffered from the poor PQ, which affected their equipment.

- Pressure on demand could be eliminated, if the distribution networks are designed properly. The illegal network connections, such as scattered private agriculture projects, were implemented randomly without any considerations for the high temperature especially in the summer. It is also due to a number of users operating huge numbers of air conditioning units. As a result, the quality of the supply becomes low. Thus, those who ignored proper procedure in implementing these projects made it difficult for GECOL to improve PQDs.

- The LDNs and especially the SDN need to improve their engineers' and technicians' skills and experience by conducting more training courses to deal with PQ events and find the appropriate solutions for their customers. It is seen that neither LDNs nor their customers are aware of the definition of PQ. This was drawn by many issues regards PQDs.

- Training courses aim to train and develop the human resources to increase the awareness and the knowledge to improve the knowledge level of the company employees regarding PQP. Moreover, they increase the employee's skills in order to cover the requirements of new projects by training experts in various disciplines regarding PQP. The Libyan distribution system must establish laboratories with modern training, and should be connected between the specialized training centres across distribution networks to increase the efficiency of staff. Therefore, LDNs must achieve the goals by implementing many training programmes in and out of the company, which will raise the efficiency of technical staff in order to improve PQDs.

- PQP cannot achieve success if PQDs are treated as purely internal utility matters. For that reason, Libyan distribution system should combine improvements in utility processes and infrastructure, with government leadership in enforcement, and collaboration with customers. As result, raising public awareness regarding PQ problems and highlighting its negative impact on the company reputation by making it a "shared problem" between GECOL and its customers, will increase the performance of PQP. Furthermore, LDNs must design and implement infrastructure investment programmes for distribution networks, which should emphasize rapid and visible improvements in customer service in terms of satisfaction levels.

- One of PQP implementation requirements should be based on hard and detailed data, employing analysis, and prioritising measurements, which are revised and compared to PQ standards. Moreover, establishing a main information centre to collect information on the distribution networks regarding PQDs which should be connected through computer networks and the Internet. As a result, PQDs data will be linked and available at all the distribution centres, in order to facilitate the dissemination of information, which should be contributed by all departments to provide enough information related to PQ. Therefore, these centres will help the departments involved in implementing PQP to develop their strategy. In response to these steps, the requirements should be prepared in order to implement PQP in LDNs, as explained in sections 4.7 and 8.4.2.

- The most important CSFs, which significantly affected the PQP implementation according to each west, east and south distribution network current level are; 1 PQ awareness, 2 PQ disturbances, 3 PQ management commitment, 4 PQ employees participation and training and 5 PQ customers satisfaction. According to LDNs, it seems that PQ awareness was the most important factor, which delays the PQP implementation as it was ranked the first amongst all CSFs. This factor has significant effect on all PQ disturbances, PQ management commitment, PQ employees' participation and training and PQ customers' satisfaction, which negatively impacted on the PQP implementation in LDNs, as shown in figure 6.17.

- The developed PQP framework is designed to improve PQDs in LDNs and to satisfy the end users and meet their expectation, who always complain regarding poor PQ. In this respect, when the end user becomes aware regarding PQ issues and understanding its significant impact on both their sensitive equipments and the distribution networks, then they can be effectively contribute as one of the parameters in PQP framework implementation, which will be considered to improve PQDs. This can contribute by stopping the illegal connections from their sides and report that to customer department to take immediate actions. They can stop buying the electronic equipments, which do not have high PQ standards and not compatible with power supply standards. It is also by recording PQDs on-line throughout the PQ database, where the significant area that most PQDs occur can be identified easily. This will increase their knowledge gradually and to be in the same line with LDNs staff for long PQ improvements.

- This study also revealed that the main PQP barriers were found in the large distribution networks WDN1, SDN2 and EDN3, which faced some particular barriers. WDN1 faces three factors; F1, lack of PQP awareness, F2, lack of PQP top management attention, and F4, lack of PQP involvement, whereas EDN3 faces F1, lack of PQP awareness, F2, lack of PQP top management attention, F3, lack of PQP resources and F4, lack of PQP involvement and SDN2 faces F3, lack of PQP resources. These four factors appeared in USA, European, India, Malaysia, Latin America, Brazil, Germany, Pakistan, Austria, France, Italy, Poland, Portugal, Slovenia, Spain and UK. As a result, it can be said that LDNs have so far struggled to implement PQP effectively.

In brief, the essential future challenge for the Libyan distribution systems contains two main reciprocally decisive goals; as economic developments are increasing constantly, there should be a clear strategy, which would support the increased demands and the future requirements in order to improve PQDs. Yet, it appears that the rapid growth of the electrical power distributed through the distribution networks will be highly recommended to be under management control. According to the real current level of LDNs and the problems they faced in terms of PQDs, it is imperative for the Libyan distribution systems to ensure that any added changes would be to improve networks regarding PQDs, and accommodate sustainable development in the future.

9.4 Research Recommendations

Chapter 8 highlighted and gave more details about the research findings gained from the data collected, which were illustrated in-depth in chapters 6 and 7. There should be significant recommendations towards implementing, improving and evaluating PQP for three Libyan west, east and south distribution networks, where this study was conducted, and for other Libyan distribution networks.

9.4.1 Management Commitment

- Highly visible support by top management to educate and admonish staff regarding PQP to participate in any strategic planning tasks to improve PQDs.
- Explain the size of PQ problems and the expected benefits of PQP for LDNs and its customers after implementing PQP.
- Engage relevant departments involved in PQP implementation.
- Show top management commitment and support by involvement in PQP implementation.
- Reinforce sense of responsibility and mutual trust regarding the implementation PQP.
- Present results and key achievements after implementing PQP.

9.4.2 Data Gathering and Analysis

- Get updated and complete information about customer sensitive loads and connections and how they are susceptible to PQ variation.
- Classify distribution networks based on where most PQDs occur.
- Provide PQ monitoring devices to collect and analyse information based on the

severity of each PQ disturbance reported to find the appropriate solutions.

- Providing the infrastructure to exchange this information among all the distribution networks
- PQDs should be recorded electronically by using modern systems, for reference and comparison to other similar problems occurring in future.
- Establishing a PQ database to contribute to the improvement and development of information and problems related to PQDs needed for PQP implementation.

9.4.3 Infrastructure Upgrade

- Replace defective equipment, which is still installed in distribution networks and customer connections, which lead to PQDs due to heavy loads and faulty connections.
- Gradually eliminating the waiting list for new connections to avoid associated electricity theft by faulty connection to the distribution networks, which lead to PQ issues.
- Allow easier identification of PQ problem location and targeting specific corrective monitoring and measurement equipment.

9.4.4 Training Courses

Improving the engineers and technician's PQ skills and experience is very significant by conducting more PQP training courses. This would help to deal with PQDs and find the appropriate solutions for customers;

- Apply moral persuasion to increase employees PQ awareness.
- Develop culture among employees to respond to customer PQ complaints.
- Train personnel in new enforcement approaches and develop their knowledge and skills regarding PQDs.
- Prepare and equip employees to implement the new PQP requirements and solutions.
- Consider providing rigorous training on PQDs with appropriate materials and facilities.

9.4.5 Customer Cooperation

- Alert customers about the benefits of PQP.

- Identify illegal connections by the consumers in the network as they cause direct consequences with PQDs.
- Establish PQ standards for customer rights and customer service of new and existing connections to be included in the PQ contract.
- Put customer PQ measurements data and records on-line to be evaluated on regular basis and compare them to PQ standards.
- Increase the number of PQ customer service locations to ensure faster response and follow-up of PQ complaints.

Therefore, employing these recommendations among western, eastern and southern distribution networks in implementing PQP will facilitate tackling PQDs. PQDs among LDNs are thought to be caused by the earlier factors as well as troubles due to poor maintenance arising from random infrastructure resulting from the lack of PQ awareness. However, LDNs are not maintained as intended due to absolute shortage of resources and manpower. Therefore, LDNs seem to be in much need of physical and human resources for maintenance due to huge number of consumer connections spread over a wide area. For this reason, once sufficient resources and manpower become available and the level of PQ awareness increases, both can lead to implementing PQP successfully.

On the other hand, with regards to planning and operation departments, LDNs are required to provide electricity of high quality without interruption, and ensure economic operation of end users' facilities. Therefore, adequate investment in system maintenance or expansion needs to be made to reduce failure rate of power system elements and to ensure a high level of PQ in supplying energy to customers. Since, if LDNs installed communication infrastructure and integrated IT systems are deployed so that branches of distribution network offices can share PQ data and manage customer's complaints in an integrated manner. As a result, LDNs will be able to perform PQ standards to identify outstanding issues and develop countermeasures far more effectively.

Therefore, infrastructure was not at the level where the network could absorb the increases in demand due to population increases and requirements. Hence, it is one of the real reasons causing PQDs in LDNs, which has not met and adapted to the growing demand and the increase in economic growth. This is due to cities, villages and remote areas with small populations located far away from each other.

Customer categorization can be of assistance in resolving PQDs if the LDNs management adopt it, not only in urban areas, but also in rural areas, where many villages and remote areas with small populations suffer bad PQ service. In addition, distribution utilities should accommodate varied levels of consumers. As a result, each level of users can be determined separately and easily to diagnose and resolve any issues, which lead to PQDs.

9.5 Future of PQP Implementation in the LDNs

In this context, the Libyan distribution system is similar to other systems, yet has its own characteristics. It is designed to deliver secure and good quality power to customers through different levels of substations. Therefore, the system's design characteristic may be considered in reducing the impacts of PQ problems. The basic concept is to separate the technical problems, leading to poor PQ, from the non-technical ones. The non-technical issues include both the CSFs and barriers of PQP implementation. Therefore, LDNs are among those systems facing poor PQ, as in most under-developed countries. Unfortunately, the analysis of the quantitative and qualitative data in Chapters 6 and 7 showed that in the last two decades, LDNs have not implemented PQPs. This is mainly because no PQ department has so far been established, to influence the measurement of PQDs. This absence of a PQ department is due to lack of awareness on the part of top management regarding the importance of PQ as shown in table 8.2. As a result, LDNs have faced very significant difficulties in implementing PQP. In addition, lack of PQ awareness has led LDNs to face twelve significant difficulties through not implementing PQP.

Despite to all low level of CSFs of PQP and PQP barriers that face the PQP implementation successfully, some utilities in less developed countries have stated that their priority is to diagnose PQ problems based on long term strategy of PQP implementation taking into account both CSFs and PQP barriers for appropriate solutions in order to satisfy consumers. Yet, lack of PQ awareness is still the major obstacle, which prevented these utilities from implementing a PQP effectively. However, if the electrical distribution utilities in under-developed countries have good PQP awareness, Top Management Leadership in PQPs, PQP planning team, PQP Training Courses, PQP Database and Infrastructure and PQP Consultants and Implementation Team, which could lead to overcoming the barriers to PQP implementation. Moreover, the obstacles leading to poor PQP implementation in LDNs need to be addressed, before the preparation and implementation phases of the PQP framework.

Moreover, the sudden increase in the number of concerns over PQDs is a result of the huge increase in the use of non-linear loads. The growth of non-linear equipment had a significant impact on both end user and the distribution networks themselves, which delayed PQP implementation. Therefore, by increasing the awareness level of PQ both staff and end users will be enthusiastic and eager to cooperate in implementing PQP successfully, as the feedback will benefit all of them.

PQP can help LDNs in reducing the huge number of complaints from end users, and the costs represented in the damage to their equipment. It can also have a positive impact on improving their service and saving some of the significant resources spent. On the other hand, PQP implementation is essential for the future of PQ, especially in urban, rural and remote areas in developing countries. PQPs allow Libyan distribution utilities to improve the power supply by conducting such programmes regularly to reduce end users' complaints, and satisfy them in a way appropriate to their expectations. Implementing a PQP can overcome barriers, including the lack of: a clear strategy, end user awareness, accommodation for economic growth, equipment standards, distribution network design, planning and infrastructure, resources, staff awareness, skills and experience, top management responsibility and commitment, training courses and support, and financial resources, as well as PQ measurement, consultants, standards, monitoring and databases. In addition, PQPs can increase the knowledge and skills of distribution utilities' staff by overcoming the complicated PQDs that most frequently occur by offering them education and training courses to raise PQ awareness.

This study indicates that PQP framework implementation will grow rapidly and will become one of the key approaches for most distribution companies in solving PQDs. Nonetheless, it will take more time for some utilities in under-developed countries, such as GECOL, to employ it and gain the significant and expected improvements.

9.6 Research Limitations

One of the main research limitations that can be encountered in this study is when the interviews were conducted. Some interviewees did not permit the researcher to record their interviews. Therefore, in order to carry out further research this factor needs to be considered; first, with more explanation about the research objective and aims to avoid data error, which leads to misunderstanding the research purpose. Moreover, no PQP implementations were conducted in LDNs, but there were few studies regarding PQ measurements, but with no available data that can be accessed to assess the current level of PQDs. Thus, these issues arise from cultural and awareness factors, where some respondents were not familiar with such a procedure, or because they thought that their information would be passed to their managers or unwilling to answer. This lack limited the number of interviewees, who were highly experienced regarding PQ issues in the past.

In addition, the selection of participates in interviews were strict to be within the departments that have direct relation in PQP improvements. Therefore, more interviews are needed in the future to cover all the departments, such as Repair & Maintenance, Operation, Design and control departments, which have responsibilities in PQP implementation but are not included in this study due to time limitations.

In terms of the samples in this study, employees, who work in Libyan distribution departments, and are involved in PQP implementation, hold a high diploma and almost technician level expertise. Even though, the concept of PQ is considered to be new in GECOL. Therefore, expecting major outcomes regarding the CSFs and barriers of PQP implementation is subject to increasing the awareness level among them. Furthermore, further studies need to focus on the end user as one of the major research samples, who should participate in such studies in order to conclude the full picture of PQP framework aspects and the factors relative to its implementation.

9.7 Future Work

The concept of PQP is considered as a new phenomenon due to inadequate previous studies.

This requires more attention and studies to be undertaken to raise some questions and directions of its importance. Moreover, this thesis attempts to highlight the lack of PQP implementation factors internationally and employed LDNs as case studies. Therefore, the findings would be useful to scholars, researchers and students, who are interested in knowing the factors associated with PQP implementation failure for both practical and academic applications.

This study was conducted in three LDNs only, which are west, east and south. However, this study can be broadly generalized, if all Libyan distribution networks included and studied, which can lead to focusing on the overall level of PQP framework evaluation in GECOL, in terms of guidelines not implementation, in order to draw more contributions, recommendations, descriptions and conclusions.

This study focused on LDNs only. Future research work can be carried out to cover both the generation and transmission sectors by considering both the CSFs and barriers to PQP, and how they made substantial change on PQDs improvements from the power generation plant through transmission line end, to be distributed to end users without any interruption. This can lead to a comparative analysis and studies between these factors in terms of CSFs and barriers of PQP among generation, transmission and distribution sectors by taking into account the employee categories in terms of work experience, responsibilities, position and education level.

This study was conducted before the war in Libya in 2011, between April 2010 and January 2011. Therefore, the level of PQDs would be even worse after many transmission and distribution lines have been affected. Moreover, future research needs to evaluate these damages and assess the current distribution network level. Along with the findings of this study, it can give a real estimation of which parts of the distribution network are more severely affected due to the number of obstacles, as stated.

From the qualitative analysis in section 7.4 and the finding in section 8.3, it is clear that LDNs are still face poor PQP implementation. This will lead to delay for some time, if top management did not take both CSFs and barriers of PQP implementation into account. Lack of PQ awareness and understanding the importance of PQP implementation along with research conclusions and limitations can lead to further prospects as a starting point for future research work.

Future work should be undertaken to focus on the top management promises regarding their duties in PQP implementation. This can lead to providing in depth information in how to establish clear objectives for PQP implementation, and involving all employees in any strategies across all GECOL departments, which is part of top management responsibilities and attention, for successful PQP implementation and PQDs improvements.

Future research is needed to reveal the significant impact of the end user made participating in PQP implementation and how PQDs can be solved during the full framework implementation phases. This can provide a widespread image of understanding and to discover relationships when PQDs shared with end users in terms of CSFs of PQP and cooperation.

More future research work can be undertaken on how the Libyan Ministry of Housing and Utilities can play significant roles and influence on short time changes in end users' awareness of their significant impact on PQDs, by preventing the implementation of the random constructions, and how their cooperation is important to reduce these issues positively, and their effect on PQP implementation.

The PQP implementation framework was developed and validated for the LDNs context. Future work needs to be undertaken to apply this framework practically on real performance in LDNs, and to assess its efficacy along with requirements. Future work can also be undertaken in other developed and under-developed countries, which have similar circumstances, in order to provide a different comparison, in terms of CSFs and barriers of PQP and their implications from the perspective of culture and awareness impacts on PQDs improvements, and to examine its validity.

9.8 Summary

This chapter summarises the research conducted on Critical Factors Facing Implementation of Total Power Quality Programme Framework in Developing Countries: Case Study-Libyan Electrical Distribution Networks. It starts with the conclusion of the findings from data collected from LDNs staff by employing a mixed methodology, namely quantitative and qualitative methods. This research highlights and examines empirically the CSFs, barriers and benefits of PQP along with developed PQP framework to be implemented in LDNs. Moreover, recommendations and requirements of PQP implementation and PQDs improvements, research limitation, future of PQP in LDNs and research future work were suggested to support the roadmap of PQP implementation in the LDNs context.

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APPENDIXES

APPENDIX A: Power Quality Survey Questionnaire

Dear Respondent

This Power Quality Survey Questionnaire form part of my PhD's research on "Critical Factors Facing Implementation of Power Quality Programme Framework: Case Study-Libyan Electrical Distribution Networks". The aim is to develop an appropriate framework for PQP implementation in Libyan Electrical Distribution Networks. Towards that end, this survey will try to investigate how the critical success factors of PQP barriers have been tackled in your Network.

Please note that your participation is important to the survey results and the information obtained will be useful in identifying PQP difficulties and reaching high level of power quality that will benefit Libyan distribution systems. All responses given will be treated with the utmost confidence and the results will be used for research purposes only. The access to data is restricted to me and to my supervisor.

After completing the attached survey, seal it in the envelope provided and return it to the distribution department, within three week from the date which the survey been handed to you. The time estimated to fill in the questionnaire should not take more than 20 minutes of your time to complete. This work has been approved by the Engineering & Design Research Ethics Committee.

The Questionnaire Instructions

- Please select answers based upon your own opinion and experiences.
- Please read each statement and base your response on how things actually in your network.
- When you finish the questionnaire, please put in the provided envelope and get it back to distribution department in your organization.

For any enquires about the survey you can contact me on the following No:

Eng. Saad Sultan
School of Engineering and Design
Electrical Engineering & Electronics Research
309A Howell Building, Brunel University, Uxbridge, Middlesex, UB8 3PH, U.K
Tel: +44(0)1895-267535 Mob: +44(0)7900387676
email: Saad.Sultan@Brunel.ac.uk

Thanks for your participation and your time in completing this questionnaire is very much appreciated.

Please see next pages to proceed filling the questionnaire

Part One Personal Background

The following Questions 1 to 6 are related to your background knowledge.

1-	Work Position?	☐ 1. Head manager ☐ 2. Department manager ☐ 3. Engineer ☐ 4. Technician ☐ 5. employee
2-	Education Level?	☐ 1. High Diploma ☐ 2. High school Diploma ☐ 3. Undergraduate Degree ☐ 4. Postgraduate Degree
3-	Work experience?	☐ 1. 0-5 years ☐ 2. 6-15 years ☐ 3. 16-25 years ☐ 4. 26-35 years ☐ 5. 36 or more years
4-	Work Responsibility?	☐ 1. Repair & Maintenance ☐ 2. Operation ☐ 3. Control ☐ 4. Production ☐ 5. Sales, marketing ☐ 6. Design
5-	No. Of employees?	☐ 1. < 300 employees ☐ 2. 301-750 employees ☐ 3. 751-1100 employees ☐ 4. >1100 employees

Part Two Elements of Power Quality Improvements

In part two you are consider to a number of statements in relation with power quality improvements include Definitions, Customers Satisfaction, Management Commitment According to your experience and knowledge.
Where 1 = **Strongly Disagree** and 5 = **Strongly Agree**.

Definitions

The following statements 7 to 11 are related to power quality definitions, please indicate to what extent you agree or disagree.

1= Strongly Disagree	2= Disagree	3= Neutral	4=Agree	5= Strongly Agree

The aim of improving the Power Quality is:

6-	To ensure the reliability and availability of the service.	1☐ 2☐ 3☐ 4☐ 5☐
7-	To satisfy customer's needs.	1☐ 2☐ 3☐ 4☐ 5☐
8-	To reduce the losses in the network.	1☐ 2☐ 3☐ 4☐ 5☐
9-	To make customers aware of PQ	1☐ 2☐ 3☐ 4☐ 5☐
10-	To increase the network's efficiency	1☐ 2☐ 3☐ 4☐ 5☐

Customers Satisfaction

The following statements 12 to 16 are related to customers satisfaction, please indicate to what extent you agree or disagree.

1= Strongly Disagree	2= Disagree	3= Neutral	4=Agree	5= Strongly Agree

11- Customer complaints are considered when identifying patterns and preventing same power quality problems from recurring in the future.	1☐ 2☐ 3☐ 4☐ ☐5
12- Customer satisfactions can help in keeping the high quality of the generated power.	1☐ 2☐ 3☐ 4☐ 5☐
13- The company adapts measures to encourage their employees to satisfy the customers' needs.	1☐ 2☐ 3☐ 4☐ 5☐
14- The company accommodates the growing demand of the electricity in order to improve the power quality for its customers.	1☐ 2☐ 3☐ 4☐ 5☐
15- Customers' awareness can reduce power quality problems.	1☐ 2☐ 3☐ 4☐ 5☐

Management Commitment

The following statements 17 to 23 are related to Management Commitment, please indicate to what extent you agree or disagree.

1= Strongly Disagree	2= Disagree	3= Neutral	4=Agree	5= Strongly Agree

16- When the network faces any power quality problems, it identifies the root causes of the problems then finds and implements the optimal solution.	1☐ 2☐ 3☐ 4☐ 5☐
17- Inaccurate managerial decision would effect of decreasing the power quality efficiency.	1☐ 2☐ 3☐ 4☐ 5☐
18- Planning a good strategy to increase the capability of the network is essential factor to meet the increasing demand for the customers.	1☐ 2☐ 3☐ 4☐ 5☐
19- Following the recommendations and studies of researches are very important to the company in order to improve the power quality for its customers.	1☐ 2☐ 3☐ 4☐ 5☐
20- The power service which distributed has good reliability and availability all the time.	1☐ 2☐ 3☐ 4☐ 5☐
21- The company is responsible to ensure the security and the quality of the electricity before it is delivered to its customers.	1☐ 2☐ 3☐ 4☐ 5☐
22- Using an international or a national benchmarks and standards are vital for the company's policy to identify the improvement of power quality.	1☐ 2☐ 3☐ 4☐ 5☐

Part Three Elements of Power Quality Requirements

In part three you are consider to a number of statements in relation with power quality requirements include, Employees Participation and Training and awareness According to your experience and knowledge.
Where 1 = **Strongly Disagree** and 5 = **Strongly**

Employees Participation and Training

The following statements 24 to 29 are related to Employees Participation and Training, please indicate to what extent you agree or disagree.

1= Strongly Disagree	2= Disagree	3= Neutral	4=Agree	5= Strongly Agree

23- Solving power quality problems requires the involvement of the employees at all levels engineer, technician and top managers.	1☐ 2 ☐ 3 ☐ 4☐ ☐5
24- Sufficient training for employees can improve the company performance in avoiding any troubles with regard to power quality in the future.	1☐ 2 ☐ 3 ☐ 4☐ ☐5
25- The appropriate qualifications and experience of the employees is an important factor in improving the network.	1☐ 2 ☐ 3 ☐ 4☐ ☐5
26- Conducting a survey or other feedback techniques is important to identify the need of the employees for any specific training with regard to power quality problems.	1☐ 2 ☐ 3 ☐ 4☐ ☐5
27- The company takes seriously any suggestions made by its employees related to power quality problems.	1☐ 2 ☐ 3 ☐ 4☐ ☐5
28- The employees are involved by the company in any strategies which make customers aware for the impacts of power quality problems.	1☐ 2 ☐ 3 ☐ 4☐ ☐5

Customers and Company Awareness

The following statements 30 to 37 are related to Customers and Company Awareness, please indicate to what extent you agree or disagree.

1= Strongly Disagree	2= Disagree	3= Neutral	4=Agree	5= Strongly Agree

Events are due to less awareness of:

29- The concept of power quality.	1☐ 2☐ 3 ☐ 4☐ ☐ 5
30- Taking electrical supply in an illegal way.	1☐ 2☐ 3 ☐ 4☐ ☐ 5
31- Excessive use of electronics devices	1☐ 2☐ 3 ☐ 4☐ ☐5
32- A faulty connection.	1☐ 2☐ 3 ☐ 4☐ ☐ 5
33- Natural cause's out of utility control.	1☐ 2☐ 3 ☐ 4☐ ☐ 5
34- Proper design mixed welding plant, heavy duty motors in residential areas.	1☐ 2☐ 3 ☐ 4☐ ☐ 5
35- Utility faults due to none regular maintenance or repair.	1☐ 2☐ 3 ☐ 4☐ ☐ 5
36- Bad design, long high voltage lines with heavy or light loads.	1☐ 2☐ 3 ☐ 4☐ ☐ 5

Part Four Power Quality Programme Implementation

PQP Barriers

In section one you are consider to a number of statements from BA1 to BA16 in relation with PQP Barriers according to your experience and knowledge,
Please indicate to what extent you believe they are exist.

Where 1= **Not applicable** and 5= **High Extent**

1= Not applicable	2= Very low extent	3= Low extent	4= Moderate	5= High Extent

BA1	lack of staff awareness, skills and experience	1☐ 2☐ 3☐ 4☐ 5☐
BA2	lack of end users awareness	1☐ 2☐ 3☐ 4☐ 5☐
BA3	lack of customer cooperation	1☐ 2☐ 3☐ 4☐ 5☐
BA4	lack of long-term strategy and planning	1☐ 2☐ 3☐ 4☐ 5☐
BA5	lack of top management commitment	1☐ 2☐ 3☐ 4☐ 5☐
BA6	lack of network designing	1☐ 2☐ 3☐ 4☐ 5☐
BA7	lack of distribution networks infrastructure	1☐ 2☐ 3☐ 4☐ 5☐
BA8	lack of conducting research and studies	1☐ 2☐ 3☐ 4☐ 5☐
BA9	lack of top management responsibility	1☐ 2☐ 3☐ 4☐ 5☐
BA10	lack of training courses, and support	1☐ 2☐ 3☐ 4☐ 5☐
BA11	lack of financial resources	1☐ 2☐ 3☐ 4☐ 5☐
BA12	lack of enough incentives	1☐ 2☐ 3☐ 4☐ 5☐
BA13	lack of PQ measurement	1☐ 2☐ 3☐ 4☐ 5☐
BA14	lack of PQ consultants	1☐ 2☐ 3☐ 4☐ 5☐
BA15	lack of PQ standards	1☐ 2☐ 3☐ 4☐ 5☐
BA16	lack of PQ database	1☐ 2☐ 3☐ 4☐ 5☐

PQP Benefits

In section two you are consider to a number of statements from BN1 to BN11 in relation with PQP Benefits according to your experience and knowledge,
Please indicate to what extent you believe they are positive.
1= **Not Sure** and 5= **Very Positive**

1= Not Sure	2= Negative	3= Moderate	4= Positive	5= Very Positive

BN1	Increasing the end users awareness	1☐ 2☐ 3☐ 4☐ 5☐
BN2	Increasing the end users satisfaction	1☐ 2☐ 3☐ 4☐ 5☐
BN3	Improving PQ performance	1☐ 2☐ 3☐ 4☐ 5☐
BN4	Reducing the end users complaints	1☐ 2☐ 3☐ 4☐ 5☐
BN5	Monitor & Measuring PQ disturbances	1☐ 2☐ 3☐ 4☐ 5☐
BN6	providing PQ diagnosis system and database	1☐ 2☐ 3☐ 4☐ 5☐
BN7	Reducing the huge losses of PQ cost	1☐ 2☐ 3☐ 4☐ 5☐
BN8	Increasing the top management awareness	1☐ 2☐ 3☐ 4☐ 5☐

BN9	Increasing the employee skills and awareness	1☐	2☐	3☐	4☐	5☐
BN10	Increasing PQ training courses	1☐	2☐	3☐	4☐	5☐
BN11	Providing strategic planning	1☐	2☐	3☐	4☐	5☐

Part Five Disturbances and Network History

In part five you are asked to answer a number of questions and statements related to Network Details, Measurement History, Disturbances and Solutions according to your experience in the company. Please read each question carefully.

Network Details

The following Questions 38 to 43 are related to Network Details.

37- Which network do you work at?
☐ 1. Western Network ☐ 2. Eastern Network ☐ 3. Southern Network

38- Who are the most customers utilizing of the electricity connected to the network?
☐ 1. Residential users ☐ 2. Industrial and commercial users
☐ 3. Agriculture users

39- During Which time of the year does your network often experience most power quality disturbances?

1.☐ Winter season 2.☐ Summer season 3.☐ Spring season 4.☐ Autumn season
5 ☐ Don't know

40- What is the level of power quality problems face the network?

☐ 1. Severe ☐ 2. Moderate ☐ 3. Mild ☐ 4. None

41- What level of **energy losses** does the network record due to Technical and Non-Technical problems?

☐ 1. 1-10 % 2.☐ 11-25 % 3.☐ 26-41 % 4.☐ 42-65 %
☐ 5. 66-85 % 6. ☐ Don't know

42- How often do you experience power supply failure in the network?
1.☐ < 30 minutes once a year 2.☐ >30 minutes once a year 3.☐ 1 hour twice a year
☐ 4. More than an hour a year ☐ 5. Do not know

Measurement History

The following Questions 44 to 48 are related to Measurement History.

43- Does the network use statistical tools to monitor and measure the power quality through its systems?

1. ☐ None ☐ 2. When needed ☐ 3. Regularly ☐ 4. Continuously ☐ 5. Don't know

44- When did the network install its measurement equipment?

☐1. In the last 3 months ☐ 2. In the last year ☐3. Two years ago
☐4. Over two years ago ☐ 5. Do not know

45- How did you resolve the power quality problems at the network in the past?

☐ 1. Through local employee 2 ☐ Through contractors 3☐Solved temporarily
☐ 4. Unable to resolve 5.☐ Not resolved

46- Which pieces of equipment are mainly affected by power quality disturbances in the network?

☐ 1. Electric motors ☐ 2. Air conditioning
☐ 3. Lighting equipment, Computers ☐ 4. IT Network &telecommunication equipment
☐ 5. Electrnonic Equipments ☐ 6. Welding Machine

47- Which power quality parameters did the network specify in the past measurement history?

☐1. Losses, Reliability ☐2. Harmonics Flicker ☐3. Voltage unbalances
☐4. Voltage profile ☐5. Reactive power, Power factor

Disturbances Affecting Networks

The following Questions 49.1 to 49.10 are related to Disturbances Affecting Networks.

48- Which one of the following disturbances is affecting the network?

1= Very Little	2= Little	3= Neutral	4=Much	5= Very Much

1	Presence of harmonics, flicker.	1☐	2☐	3☐	4☐	5☐
2	Power interruptions- short < 1 min.	1☐	2☐	3☐	4☐	5☐
3	Power interruptions- long > 1 min.	1☐	2☐	3☐	4☐	5☐
4	Voltage sags and swells.	1☐	2☐	3☐	4☐	5☐
5	Under voltage.	1☐	2☐	3☐	4☐	5☐
6	Over voltage.	1☐	2☐	3☐	4☐	5☐
7	Outage.	1☐	2☐	3☐	4☐	5☐
8	Transient, surge and unbalance.	1☐	2☐	3☐	4☐	5☐
9	Voltage collapse and voltage stability	1☐	2☐	3☐	4☐	5☐
10	Low Power factor	1☐	2☐	3☐	4☐	5☐

Disturbances Malfunction Users Tools

The following Questions 50.1 to 50.8 are related to Disturbances Malfunction Users Tools.

49- How frequent does each of the following disturbances cause malfunction in the network's equipment?

1= Not at all	2= Once a year	3=Twice year	4=More than twice a year	5= Do not know

1	Short interruption < 1 min	1☐	2☐	3☐	4☐	5☐
2	Long interruption > 1 min	1☐	2☐	3☐	4☐	5☐
3	Voltage sags and swells	1☐	2☐	3☐	4☐	5☐
4	Transients and surge	1☐	2☐	3☐	4☐	5☐
5	outage	1☐	2☐	3☐	4☐	5☐
6	Harmonics	1☐	2☐	3☐	4☐	5☐
7	Under and Over Voltage	1☐	2☐	3☐	4☐	5☐
8	Unbalance load and missing of one phase	1☐	2☐	3☐	4☐	5☐

Solutions History

50- What solutions are most effective and most commonly used to eliminate/reduce the effects of poor power quality?

☐ 1. Back-up generators
☐ 2. Voltage stabilisers
☐ 3. UPS uninterruptible power supplies
☐ 4. Surge protectors
☐ 5. Harmonic filter passive
☐ 6. Static VAr compensator
☐ 7. Reactor or capacitor

51- Please specify any comments, related to power quality, that was not included in this questionnaire and you wish bring it up?

……
……
………………………………………………………………………………………………..

Please fill in the section below in case if there is any further clarification. The information below will not be passed or revealed to any third party and they are optional:

Your name (optional) ……………………………………………………………
Your telephone number………………………………………………………….
Your fax……………………………………………………………………………
Your Email…………………………………………………………………………
Name of Department……………………………………………………….
Position/Title………………………………………………………………

The end of the questionnaire

Thank you very much for completed this questionnaire as I appreciated your valuable time

إستبيان بحث جودة الطاقة الكهربائية

هذه الدراسة تشكل جزءا من بحثي فى رسالة الدكتوراه والمتعلق بمشاكل جودة الطاقة الكهربائية لمناقشة "العوامل الحاسمة التي تواجه تنفيذ برنامج جودة الطاقة الكهربائية دراسة خاصة: شبكات التوزيع الكهرباء الليبية" وآثارها على كفاءة الشبكة. ألهدف الأساسي من هذا الإستبيان هو وضع إطار مناسب للتنفيذ برنامج جودة الطاقة الكهربائية في شبكات التوزيع الكهرباء الليبية. وتحقيقا لهذه الغاية، سوف تحاول هذه الدراسة معرفة كيف تم تناول عوامل النجاح الحاسمة و الحواجز الخاصة بتنفيذ هذا البرنامج في الشركة.
يرجى الملاحظة بأن مشاركتكم في الحصول على نتائج المسح والمعلومات مهمة والتي ستكون مفيدة في تحديد الصعوبات الخاصة بتنفيذ هذا البرنامج والوصول ألى مستوى عال من جودة الطاقة الكهربائية التي ستفيد أنظمة توزيع الكهرباء الليبية .جميع الردود من هذا الاستبيان سوف نتعامل معها باقصى قدر من السرية والنتائج سوف تستخدم لأغراض البحث فقط. الوصول إلى البيانات تقتصرفقط على الدراسة الأكاديمية. بعد الأنتهاء من تعبئة الأستبيانات المرفقة، الرجاء ختم الأظرف المرفقة وإعادتها إلى قسم التوزيع في غضون ثلاثة أسابيع من تاريخ الأستلام. أن الوقت المقدر لملء الاستبيان لا يستغرق أكثر من 20 دقائق من وقتك لإستكماله.

تمت الموافقة على هذا العمل من قبل لجنة آداب المهنة والخاصة بالبحوث في كلية الهندسة والتصميم جامعة برونيل.

أرشادات لملء الاستبيان:
اولاً، يرجى اختيار الأجابة على أساس الخبرة و الرأي الخاصة بك.

ثانياً، يرجى قراءة كل جملة بدقة وأختار الاجابة المناسبة على كيفية سير الامور في الشركة.

ثالثاً،عند الانتهاء من الاستبيان، يرجى وضعها في الظرف المرفق و إعادته إلى القسم الخاص بك.

للأستفسار عن الأستبيان يمكنك الاتصال بي على رقم التالي:

Eng. Saad Sultan
School of Engineering and Design
Electrical Engineering & Electronics Research
309A Howell Building, Brunel University, Uxbridge
Middlesex, UB8 3PH, U.K
Tel: +44(0)1895-267535 Mob: +44(0)7900387676
email: Saad.Sultan@Brunel.ac.uk

وقتك فى تكملة هذا الأستبيان هو موضع تقدير كبير جداً

يرجى الاطلاع على الصفحات التالية للشروع بملء الاستبيان

1

الجزء الأول البيانات الشخصية:

الأسئلة من رقم 1 الى 6 متعلقة بمعلوماتك الشخصية فى مجال عملك.

1	مركزك الوظيفي	1. ☐ مدير إدارة 2. ☐ مدير قسم 3. ☐ مهندس 4. ☐ فنى 5. ☐ موظف
2	مؤهلك العلمي	1. ☐ دبلوم عالي 2. ☐ دبلوم ثانوية عامة 3. ☐ شهادة جامعية بكالوريس 4. ☐ شهادة جامعية عليا
3	الخبرة	1. ☐ 0 – 5 سنوات 2. ☐ 6 – 15 سنة 3. ☐ 16 – 25سنة 4. ☐ 26 – 35 سنة 5. ☐ 36 سنة فاكثر
4	مسئولياتك	1. ☐ الصيانة 2. ☐ التشغيل 3. ☐ التحكم 4. ☐ الإنتاج 5. ☐ مبيعات، تسويق 6. ☐ التخطيط
5	عدد الافراد العاملين	1. ☐ أقل من 300 2. ☐ 301 – 750 3. ☐ 751 – 1100 4. ☐ اكثر من 1100
6	ساعات العمل	1. ☐ 8 ساعات يومياً، 5 أيام فى الأسبوع 2. ☐ 8 ساعات يومياً، 6 أيام فى الأسبوع 3. ☐ 8 ساعات يومياً، 7 أيام فى الأسبوع 4. ☐ 12 ساعة يومياً، 7 أيام فى الأسبوع

الجزء الثانى عوامل تحسين جودة الطاقة الكهربائية

في هذا القسم يوجد عدد من الأسئلة التى لها علاقة كبيرة بتحسين جودة الطاقة الكهربائية تتضمن تعريف جودة الطاقة الكهربائية، رضاء الزبائن ،التزام الإدارة وفقا لما تتمتعون به من خبرة ومعرفة. حيث 1 = لااوافق بشدة و5 = أوافق بشدة

تعريف جودة الطاقة الكهربائية

الأسئلة من رقم7 الى 11 متعلقة بتعريف جودة الطاقة الكهربائية، يرجى الإشارة إلى أي مدى توافق أو لا توافق.

1= لا اوافق بشدة	2= لا اوافق	3= لا خيار	4= اوافق	5= اوافق بشدة

الهدف من تحسين جودة الطاقة الكهربائية هو:

7	لضمان توافر و ثقة الخدمة من غير اى مشاكل	☐1 ☐2 ☐3 ☐4 ☐5
8	لتلبية وارضاء احتياجات الزبائن	☐1 ☐2 ☐3 ☐4 ☐5
9	لتقليل الخسائر فى الشبكة	☐1 ☐2 ☐3 ☐4 ☐5
10	لجعل الزبائن تدرك أهميتها	☐1 ☐2 ☐3 ☐4 ☐5
11	لأجل زيادة فعالية الشبكة	☐1 ☐2 ☐3 ☐4 ☐5

رضاء الزبائن

الأسئلة من رقم12 الى 16 متعلقة بجودة الطاقة الكهربائية والزبائن، يرجى الإشارة إلى أي مدى توافق أو لا توافق.

1= لا اوافق بشدة	2= لا اوافق	3= لا خيار	4= اوافق	5= اوافق بشدة

12	شكاوى الزبائن توخذ بعين الإعتبار للتعرف على مشاكل جودة الكهرباء ومنعها من التكرار مستقبلاً.	☐1 ☐2 ☐3 ☐4 ☐5
13	رضا الزبائن يمكن ان يساعد فى الحفاظ على جودة الطاقة المولدة بدرجة عالية.	☐1 ☐2 ☐3 ☐4 ☐5
14	الشركة تتكيف بأتخاذ تدابير لتشجيع موظفيها لإرضاء الزبائن على أساس جودة الطاقة الكهربائية.	☐1 ☐2 ☐3 ☐4 ☐5
15	الشركة تقوم بمتابعة ومواكبة زيادة الطلب (الإستهلاك) من اجل تحسين جودة الكهرباء.	☐1 ☐2 ☐3 ☐4 ☐5
16	وفقاً لخبرتكم الزبائن من جميع القطاعات يفترض ان يكونو مدركين بمشاكل جودة الطاقة الكهربائية.	☐1 ☐2 ☐3 ☐4 ☐5

التزام الأدارة

الأسئلة من رقم17 الي 23 متعلقة بجودة الطاقة الكهربائية والأدارة، يرجي الإشارة إلي أي مدى توافق أو لا توافق.

1= لا اوافق بشدة	2= لا اوافق	3= لا خيار	4= اوافق	5= اوافق بشدة

17	عندما تواجه الشركة اى مشكلة متعلقة بجودة الطاقة الكهربائية تحدد المشكلة من جذورها و اسبابها، ثم تضع وتطبّق الحل الأمثل.	☐1	☐2	☐3	☐4	☐5
18	القرارات الإدارية قد تؤثر في كفاءة جودة الطاقة.	☐1	☐2	☐3	☐4	☐5
19	تخطيط استراتيجية جيدة لزيادة قدرة الشبكة هو عامل أساسي لتلبية الطلب المتزايد من قبل زبائنها.	☐1	☐2	☐3	☐4	☐5
20	تتبع التوصيات والدراسات من خلال البحوث التى تجرى مهمة جداً للشركة من اجل تحسين جودة الكهرباء لزبائنها.	☐1	☐2	☐3	☐4	☐5
21	خدمة الكهرباء التى يتم توزيعها من قبل الشركة لها جودة عالية من ناحية توافرها والاعتماد عليها في كل وقت.	☐1	☐2	☐3	☐4	☐5
22	الشركة هي المسؤولة لضمان وتأمين جودة الكهرباء قبل توزيعها للزبائن.	☐1	☐2	☐3	☐4	☐5
23	استخدام مقاييس ومعايير دولية أووطنية مهمة جداً لسياسة الشركة لتحديد وتحسين جودة الطاقة الكهربائية.	☐1	☐2	☐3	☐4	☐5

الجزءالثالث عوامل متطلبات جودة الطاقة الكهربائية

في هذا القسم يوجد عدد من الأسئلة التى لها علاقة كبيرة بتحسين جودة الطاقة الكهربائية تتضمن مشاركة الموظفين ،التدريب ونسبة وعي الخاص بجودة الطاقة الكهربائية وفقا لما تتمتعون به من خبرة ومعرفة. حيث 1 = لااوافق بشدة و5 = أوافق بشدة

مشاركة الموظفين والتدريب

الأسئلة من رقم 24 الي 29 متعلقة بمشاركة الموظفين والتدريب ، يرجي الإشارة إلي أي مدى توافق أو لا توافق.

1= لا اوافق بشدة	2= لا اوافق	3= لا خيار	4= اوافق	5= اوافق بشدة

24	حل اى مشكلة خاصة بجودة الكهرباء يتطلب مشاركة موظفين من جميع المستويات	☐1	☐2	☐3	☐4	☐5
25	التدريب الكافى لرفع مهارات العاملين يمكن ان يزيد من تحسين أداء الشركة لتجنب أي مشكلات في المستقبل فيما يتعلق بجودة الطاقة الكهربائية.	☐1	☐2	☐3	☐4	☐5
26	المؤهلات والخبرات المناسبة للموظفين عاملاً مهماً لتحسين الشبكة.	☐1	☐2	☐3	☐4	☐5
27	الإستبيانات اللازمة مع أستخدم وسائل اخرى مهمة لتحديد حاجة الموظفين الى اى تدريبات محددة.	☐1	☐2	☐3	☐4	☐5
28	الشركة تأخذ بمحمل الجد الأقتراحات المقدمة من موظفيها والمتعلقة بجودة الطاقة الكهربائية.	☐1	☐2	☐3	☐4	☐5
29	الموظيفين معنيين باى أستراتيجية بواسطة الشركة لغرض أدراك الزبائن بالأثار المترتبة من مشاكل فى جودة الطاقة الكهربائية.	☐1	☐2	☐3	☐4	☐5

أسباب جودة الطاقة الكهربائية

الأسئلة من رقم30 الي 37 متعلقة بأسباب جودة الطاقة الكهربائية وكيفية حدوثها، يرجي الإشارة إلي أي مدى توافق أو لا توافق.

1= لا اوافق بشدة	2= لا اوافق	3= لا خيار	4= اوافق	5= اوافق بشدة

مشاكل جودة الطاقة الكهربائية تحدث بسبب:

30	قلة وعى المستخدمين بمفهوم أوتعريف جودة الطاقة الكهربائية	☐1	☐2	☐3	☐4	☐5
31	السرقة، أخذ الكهرباء بغير طريقة شرعية	☐1	☐2	☐3	☐4	☐5
32	الإستخدام المفرط للطاقة بدون حاجة	☐1	☐2	☐3	☐4	☐5
33	اخطاء فى التوصيلات	☐1	☐2	☐3	☐4	☐5
34	اسباب طبيعية : ظروف خارجة عن سيطرة الشركة ، مثلاً الطقس.	☐1	☐2	☐3	☐4	☐5
35	الجيران مثلاً: معدات اللحام، المحركات الكهربائية الثقيلة فى المناطق الصناعية.	☐1	☐2	☐3	☐4	☐5
36	الشركة ،لايوجد برنامج دورى او مستمر للصيانة	☐1	☐2	☐3	☐4	☐5
37	سوء التصميم، خطوط ضغط عالى طويلة مع احمال ثقيلة او خفيفة	☐1	☐2	☐3	☐4	☐5

3

الجزء الرابع تنفيذ برنامج جودة الطاقة الكهربائية

عوائق تنفيذ برنامج جودة الطاقة الكهربائية

في هذا القسم يوجد عدد من الأسئلة التي لها علاقة كبيرة بعوائق تنفيذ برنامج جودة الطاقة الكهربائية ، وفقا لما تتمتعون به من خبرة ومعرفة يرجى الإشارة إلى أي مدى هذه العوائق موجودة في الشركة. حيث 1 = لا توجد و5 = مرتفعة جداً

1= لا توجد	2= منخفضة جداً جداً	3= منخفضة	4= معتدل	5= مرتفعة جداً

1	عدم وجود وعي الموظفين والمهارات والخبرات	☐1	☐2	☐3	☐4	☐5
2	عدم وجود الوعي للمستخدمين النهائيين	☐1	☐2	☐3	☐4	☐5
3	عدم تعاون العملاء	☐1	☐2	☐3	☐4	☐5
4	عدم وجود استراتيجية طويلة الأجل والتخطيط	☐1	☐2	☐3	☐4	☐5
5	عدم التزام الإدارة العليا	☐1	☐2	☐3	☐4	☐5
6	عدم وجود تصميم جيد لشبكات التوزيع	☐1	☐2	☐3	☐4	☐5
7	نقص البنية التحتية لشبكات التوزيع	☐1	☐2	☐3	☐4	☐5
8	عدم وجود إجراء البحوث والدراسات بشكل منتظم	☐1	☐2	☐3	☐4	☐5
9	انعدام المسؤولية الإدارة العليا	☐1	☐2	☐3	☐4	☐5
10	عدم وجود دورات تدريبية، ودعم	☐1	☐2	☐3	☐4	☐5
11	نقص الموارد المالية	☐1	☐2	☐3	☐4	☐5
12	عدم وجود حوافز كافية للمهندسيين والفنيين	☐1	☐2	☐3	☐4	☐5
13	عدم وجود قياسات لإضطرابات جودة الطاقة الكهربائية	☐1	☐2	☐3	☐4	☐5
14	عدم وجود استشاريين لإضطرابات جودة الطاقة الكهربائية	☐1	☐2	☐3	☐4	☐5
15	عدم وجود معايير لإضطرابات جودة الطاقة الكهربائية	☐1	☐2	☐3	☐4	☐5
16	عدم وجود قاعدة بيانات لإضطرابات جودة الطاقة الكهربائية	☐1	☐2	☐3	☐4	☐5

فوائد تنفيذ برنامج جودة الطاقة الكهربائية

في هذا القسم يوجد عدد من الأسئلة التي لها علاقة كبيرة بفوائد تنفيذ برنامج جودة الطاقة الكهربائية ، وفقا لما تتمتعون به من خبرة ومعرفة يرجى الإشارة إلى أي مدى تعتقد أنها ايجابية جداً على الشركة . حيث 1 = غير متأكد و5 = أيجابي جداً

1= غير متأكد	2= سلبي	3= منخفضة	4= أيجابي	5= أيجابي جداً

1	زيادة وعي المستخدمين النهائيين	☐1	☐2	☐3	☐4	☐5
2	زيادة رضا المستخدمين النهائيين	☐1	☐2	☐3	☐4	☐5
3	تحسين الأداء لجودة الطاقة الكهربائية	☐1	☐2	☐3	☐4	☐5
4	الحد من شكاوى المستخدمين النهائيين	☐1	☐2	☐3	☐4	☐5
5	مراقبة و قياس إضطرابات جودة الطاقة الكهربائية	☐1	☐2	☐3	☐4	☐5
6	توفير نظام وقاعدة بيانات لتشخيص إضطرابات جودة الطاقة الكهربائية	☐1	☐2	☐3	☐4	☐5
7	الحد من خسائر كبيرة الناتجة من إضطرابات جودة الطاقة الكهربائية من حيث التكلفة	☐1	☐2	☐3	☐4	☐5
8	زيادة وعي الإدارة العليا	☐1	☐2	☐3	☐4	☐5
9	زيادة مهارات الموظفيين والتوعية	☐1	☐2	☐3	☐4	☐5
10	زيادة دورات التدريب المقررة لإضطرابات جودة الطاقة الكهربائية	☐1	☐2	☐3	☐4	☐5
11	توفير التخطيط الاستراتيجي	☐1	☐2	☐3	☐4	☐5

[redacted]

فى هذا الجزء ووفقاً لخبرتكم مطلوب منكم الأجابة على عدد من الأسئلة والخاصة بمشاكل جودة الطاقة الكهربائية التى حدثت والحلول التى عملت والقياسات التى اخدث فى الماضى من اجل تحسين جودة الطاقة الكهربائية التى تقدمها الشركة , من فضلك أقراء كل سؤال بعناية.

4

بيانات عن الشبكات

الأسئلة من رقم38 الى 46 متعلقة ببيانات عن الموقع.

38. في اى جزء من الشبكة أنت تعمل؟

1. ☐ شبكة توزيع الغربية 2. ☐ شبكة توزيع الشرقية 3. ☐ شبكة توزيع الجنوبية

39. من هم أكثر المستخدمين المستفدين من الكهرباء والمتصلين بالشبكة؟

1. ☐ المستخدمين في قطاع والمنزلية 2. ☐ المستخدمين في قطاع الصناعي والتجاري
3. ☐ المستخدمين في قطاع الزراعي

40. في اى وقت من السنة تعاني الشركة من مشاكل وإضطرابات بسبب جودة الطاقة الكهربائية؟

1. ☐ موسم الشتاء 2. ☐ موسم الصيف 3. ☐ موسم الربيع 4. ☐ موسم الخريف 5. ☐ لا ادرى

41. الى اى مستوى تعاني الشركة من مشاكل بسبب جودة الكهرباء؟

1. ☐ حاد 2. ☐ معتدل 3. ☐ غير حاد 4. ☐ لا يوجد

42 . ما هو مستوى خسائر الكهرباء التي تسجلها الشركة سنوياً بسبب مشكلات فنية وغير فنية؟

1. ☐ 1 - 10% 2. ☐ 11 - 25% 3. ☐ 26 - 41% 4. ☐ 42 - 65% 5. ☐ 66 - 85% 6. ☐ لا ادرى

43 . ما هو معدل فقدان الإمداد الكهربائي في الشبكة؟

1. ☐ اقل من نصف ساعة، مرة واحدة سنوياً 2. ☐ اكثر من نصف ساعة، مرة واحدة سنوياً
3. ☐ ساعة واحدة مرتين في السنة 4. ☐ اكثر من ساعة في السنة 5. ☐ لا اعلم

قياسات جودة الطاقة الكهربائية

الأسئلة من رقم44 إلى 48 متعلقة بقياسات جودة الطاقة الكهربائية.

44. هل تستخدم الشركة اى ادوات إحصائية لمتابعة وقياس الطاقة التي تمر بانظمتها لإحراز مستوى مناسب من الجودة لرفع الكفاءة و تحسين الأداء؟

1. ☐ لا 2. ☐ عند الحاجة 3. ☐ بصورة دورية 4. ☐ بصورة مستمرة 5. ☐ لا ادرى

45. متى تم تثبيت اجهزة القياس؟

1. ☐ في الأشهر الثلاثة الاخيرة 2. ☐ خلال السنة الماضية 3. ☐ منذ سنتان 4. ☐ منذ اكثر من سنتان
5. ☐ لا ادري

46. كيف تمكنتم من حل مشاكل جودة الطاقة في الشركة في الماضي؟

1. ☐ من خلال الموظفين المحليين 2. ☐ من خلال متعهدين 3. ☐ حلت مؤقتاً 4. ☐ لم نستطع حلها 5. ☐ بقيت بغير حل

47. ما هي الأجهزة التي تتأثر بشكل رئيسي بفعل إضطرابات الكهرباء من خلال شكاوى الزبائن للشركة؟
أرجو تحديد اكبر عدد ممكن

1. ☐ المحركات الكهربائية 2. ☐ اجهزة التكييف
3. ☐ معدات الإضاءة ،الحواسيب 4. ☐ اجهزة شبكة تقنية المعلومات والإتصالات
5. ☐ معدات الكترونية 6. ☐ آلة لحام

5

48. اى من مشاكل جودة الطاقة الكهربائية قامت الشركة بالعمل عليها سابقاً؟
أرجو تحديد اكبر عدد ممكن

1. ☐ الخسائر والموثوقية   2. ☐ التذبذب و الرمش   3. ☐ إختلالات الجهد   4. ☐ مشاكل الجهد
5. ☐ الطاقة الإرتدادية و معامل الطاقة

تأثير إضطرابات جودة الطاقة الكهربائية

49. اى من هذه الإضطرابات أكثر تأثيراً على الشركة؟

1= قليل جدا	2= قليل	3=وسط	4= كثير	5=كثير جدا

1	وجود تذبذب(توفقيات)، الرمش	☐1	☐2	☐3	☐4	☐5
2	إنقطاع الكهرباء – أقصر من دقيقة	☐1	☐2	☐3	☐4	☐5
3	إنقطاع الكهرباء – اطول من دقيقة	☐1	☐2	☐3	☐4	☐5
4	إنخفاض أوإرتفاع الجزر التربيعي لقيمة الجهد	☐1	☐2	☐3	☐4	☐5
5	هبوط الجهد دون المستوى المحدد لاكثر من دقيقة	☐1	☐2	☐3	☐4	☐5
6	ارتفاع الجهد اعلى من المستوى المحدد لاكثر من دقيقة	☐1	☐2	☐3	☐4	☐5
7	إنقطاع تام	☐1	☐2	☐3	☐4	☐5
8	تغيرات مفاجئة في التيار مع إختلال التوازن	☐1	☐2	☐3	☐4	☐5
9	انهيار الجهد، واستقرار الجهد	☐1	☐2	☐3	☐4	☐5
10	انخفاض معامل القدرة	☐1	☐2	☐3	☐4	☐5

إضطرابات جودة الطاقة الكهربائية على اجهزة المستخدمين

50. برأيك اى من الأسباب المذكورة تسبب اكبر قدر من اعطال للأجهزة ومشاكل اخرى في الشركة؟
أرجو تحديد اكبر عدد ممكن

1= لا يحدث	2= مرة في السنة	3= مرتان في السنة	4= اكثر من مرتان في السنة	5= لا ادري

1	إنقطاع الكهرباء – أقصر من دقيقة	☐1	☐2	☐3	☐4	☐5
2	إنقطاع الكهرباء – لطول من دقيقة	☐1	☐2	☐3	☐4	☐5
3	إنخفاض أوإرتفاع الجزر التربيعي لقيمة الجهد	☐1	☐2	☐3	☐4	☐5
4	تغيرات مفاجئة في التيار	☐1	☐2	☐3	☐4	☐5
5	الانقطاع التام	☐1	☐2	☐3	☐4	☐5
6	تذبذبات غير مرغوب فيها(توافقيات)	☐1	☐2	☐3	☐4	☐5
7	قيمة الجهد دون او اعلى من المستوى المحدد لاكثر من دقيقة	☐1	☐2	☐3	☐4	☐5
8	إختلال توازن الحمل وفقدان أحد الاوجهه	☐1	☐2	☐3	☐4	☐5

حلول جودة الطاقة الكهربائية

51. ما هي الحلول او الأجهزة الأكثر فاعلية والأكثر شيوعا لإزالة او تقليل المشاكل الناجمة من آثار ردئة جودة الطاقة الكهربائية؟
يرجى تحديد أكبر عدد ممكن

1. ☐ مولدات احتياطية   2. ☐ اجهزة تثبيت الجهد   3. ☐ امدادات الطاقة الغير منقطعة
4. ☐ حماية التغير المفاجئ   5. ☐ منقيات التذبذبالأيجابى   6. ☐ معوض للقوى الفعالة   7. ☐ مكثفات و ملفات

52. اى تعليقات تتعلق بجودة الطاقة او انقطاعها والتي لم تدرج وتريد إدراجه هنا ؟
....
....
....

6

يرجى ملء الفراغ الوراد أدناه في حالة اذا كان هناك أي مزيد من التوضيح. المعلومات الورادة أدناه سوف لن تمرر أو تكشف الى أي طرف ثالث.

الأسم (اختيارى)..
رقم هاتفك..
رقم الفاكس..
عنوان بريدك الالكتروني...

نهاية الأستبيان

شكراً جزيلاً لأستكمال هذا الاستبيان مع تقديرى الكبير لوقتكم الثمين

7

APPENDIX B: PQ Interview Questionnaire Guide

Interview Date: …………………

Name of Department: ……………………………………………........
Name of Participant (optional): ……………………………………
Phone: ………………………………………………..........................
Email (optional): ……………………………………………...........
Position/Title: …………………………………………….............

Introduction:

Good Morning/Afternoon. My name is ………………… ……………..From Brunel University and I am conducting this interview as part of my PhD's thesis: "Critical Factors Facing Implementation of Power Quality Program Framework: Case Study-Libyan Electrical Distribution Networks".

This morning/afternoon I would like to talk to you about your perception of power quality programme implementation in your company.

This interview is completely voluntary and confidential, so if at any time you would rather not to answer any question please say so. The information will be used for a report but I will not include your name. This work has been approved by the Engineering & Design Research Ethics Committee.

The interview should last about 45-60 minutes and with your permission will be taped. With your agreement I will proceed with the interview.

For any enquires you can contact me on the following contact details:

Eng. Saad Sultan
School of Engineering and Design
Electrical Engineering & Electronics Research
309A Howell Building, Brunel University, Uxbridge
Middlesex, UB8 3PH, U.K
Tel: +44(0)1895-267535
Mob: +44(0)7900387676
email: Saad.Sultan@Brunel.ac.uk

School of Engineering and Design, Electronic and Computing Engineering

Participant Information Sheet

Title of Study: "Critical Factors Facing Implementation of Power Quality Program Framework: Case Study-Libyan Electrical Distribution Networks"

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information. Ask me if there is anything that is not clear or if you would like more information.

Thank you for reading this.

What is the purpose of the study?

I am interested in finding out the Critical Factors Facing Implementation of Power Quality Program Framework in LDNs. The knowledge gained from the questionnaire and the interview will be fed into my research, which will investigate PQP difficulties facing Libyan distribution networks.

Do I have to take part?

Participation is completely voluntary, and you can change your mind about taking part at any time.

What will happen to the results of the research study?

The results of the study will form a part of my thesis document, and will be published in national and international journals and at conferences. The raw data will be stored securely until destroyed.

School of Engineering and Design, Electronic and Computing Engineering

Consent Form

Title of Project: "Critical Factors Facing Implementation of Power Quality Program Framework: Case Study-Libyan Electrical Distribution Networks"

Name of Researcher: Saad Sultan

1. I confirm that I have read and understand the information sheet for the above study. I am fully aware about the purpose of this research.	☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.	☐
3. I agree to the interview being audio-recorded for purposes of transcription.	☐
4. I agree to take part in the above study.	☐

Comments:____

____

____

____

____

____

____

_________________ _________________ _________________

Name of participant Date Signature

Power Quality Programme

Q1. What does the word "power Quality" means to you?

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....
....

Q2. Has your company installed a formal power quality program?

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....
....

Q3. What are the benefits which your company will gain when they implement power quality program?

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....
....

Q4. What are the difficulties facing your company in implementing power quality programme?

....
....
....

Lack of top management awareness...
Lack of Customer awareness..
Lack of infrastructure to meet the economic growth.............................
Lack of resources...
Lack of motivation by end users...
Lack of employees training and awareness...
Lack of power quality standards...

Q5. Which power quality standards has your company used to improve its service?

IEEE……………………………………………………….
IEC…………………………………………………………
National Power Quality standard……………………………..
Other (specify) ……………………………………………….

Q6. How Power quality disturbances are revised by using power quality standards?

....
....
....

Q7. How important are power quality standards to customers and are they within the contractual terms between the company and the customer?

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....
....

Factor 1: Management Commitment Regarding Power Quality

Q8. Does your company have specific and clear strategy regarding power quality improvement?

....
....
....

What is the purpose of this strategy?

....
....
....

Q9. Does the management consider all department employees' suggestions or opinion in consideration when developing their power quality strategy? Yes No How?

....
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....

Q10. To what extent does the top management committed to bear the responsibility to improve power quality issues?

....
....
....

Q11. When the company faces any power quality problems, do you think they are able to identify the root which causes these problems? How?

....
....
....

Q12. In your opinion, who is responsible for solving power quality issues in your company?

Senior management…………………………….........
Control department……………...............................
Distribution systems Department…………….............
Planning department………………………………....
Customers…………………………......................
Staff……………………………………….............
Other………………………………………............

Q13. Does the company design and upgrade the distribution networks based on the increase demand on electricity by consumers and economic growth with consideration of each customer type? How?

....
....
....

Factor 2: Customer Satisfaction

Q14. Who is responsible of causing power quality problems in your company? Why?

....
....
....

Q15. How does your company deal with customer complaints regarding power quality issues?

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....
....

Q16. What are the 3 most important outstanding problems with your customers regarding power quality?

....
....
....

Q17. To what extent do you believe that customers who are taking electrical supply in an illegal way be a part of causing power quality issues?

....
....
....

Q18. How do you ensure the quality of the electricity before delivered to customers?

....
....
....

Q19. How do you measure customer satisfaction regarding power quality?

....
....
....

Q20. Do you think Customer satisfaction is one of some solutions would help in improving power quality issues? How?

....
....
....

Q21. How do you educate or aware your customers to help you in resolving power quality issues?

....
....
....

Factor 3: Power Quality Disturbances

Q22. When was power quality disturbances first occurred as serious problem in your company?

....
....
....
....

1- Does your company use statistical tools to monitor and measure the power quality disturbances in distribution systems?

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....
....

2- When did the company install its measurement equipments?

....
....

....
....

3- Which power quality parameters did the network specify in the past measurement?

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....
....
....

4- What are other power quality problems you have faced in your company?

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....
....

5- Do you think that there is a relation between unsatisfactory customer's reaction and power quality disturbance? And to what extend does your company consider this relation?

....
....
....

Factor 4: Employee's Participation and Training

Q23. Do you train your employees regarding power quality issues as part of the solutions? If yes does their training positively help in PQ issues?

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....
....

Q24. What percentage of staff has received awareness training regarding power quality programme?

....
....
....

Q25. Are there enough resources available for employees training regarding power quality issues?

....
....

....

Q26. Are there any team properly trained to analyse and solve power quality disturbances?

....
....
....

Overall picture

Factor 5: Continuous Improvement

Q27. Do you think that power quality has changed positively after implementing power quality programme?

....
....
....

Q28. How would you rate the overall success of the power quality programme up to now?

....
....
....

Q29. Are there any topics you feel that they were not covered?

....
....
....

Q30. Is there any person you think I should talk to about these issues?

....
....
....

Confirm Confidentiality!!

Thank You

Interview Date: …………………

القسم..
أسم المشارك:...
الهاتف:...
الأيميل (اختياري) ....
الصفة\ المهنة:...

مقدمة :

صباح الخير / بعد الظهر. اسمي...................................... من جامعة برونيل وأنا إجراء هذه المقابلة كجزء من بحثي فى رسالة الدكتوراه في مجال جودة الطاقة الكهربائية.عنوان الأطروحة هو: "دراسة لتحليل مشاكل جودة الطاقة الكهربائية وتنفيذ برنامج جودة الطاقة الكهربائية لشبكات التوزيع الليبية".

هذا الصباح / بعد ظهر أود أن أتحدث إليكم عن التصور الخاص لتنفيذ برنامج جودة الطاقة الكهربائية فى الشركة.

هذه المقابلة هي طوعية وسرية تماما ، وذلك في أي وقت إذا كنت لا ترغب في الإجابة على أي سؤال الرجاء أن تقول ذلك. سوف نتعامل مع هذه المعلومات باقصى قدر من السرية والنتائج سوف تستخدم لأغراض البحث فقط. والوصول إلى البيانات تقتصرفقط على الدراسة الأكاديمية. المعلومات سوف يتم أستخدامها فى تقريري ألنهائي ولكن بدون إشارة إلى اسمك.

تمت الموافقة على هذا العمل من قبل لجنة آداب المهنة والخاصة بالبحوث في كلية الهندسة والتصميم جامعة برونيل.

المقابلة سوف تستغرق من 45-60 دقيقة مع العلم سأقوم بتسجيلها اذا إذنت بذلك. مع الاتفاق الخاص سأشرع مع المقابلة.

للأستفسار عن لأي معلومة يمكنك الاتصال بي على رقم التالي:

Eng. Saad Sultan
School of Engineering and Design
Electrical Engineering & Electronics Research
309A Howell Building, Brunel University, Uxbridge
Middlesex, UB8 3PH, U.K
Tel: +44(0)1895-267535 Mob: +44(0)7900387676
email: Saad.Sultan@Brunel.ac.uk

وقتك فى تكملة هذه المقابلة هو موضع تقدير كبير جدآ

Brunel UNIVERSITY LONDON

School of Engineering and Design, Electronic and Computing Engineering

نموذج معلومات المشارك بالبحث

عنوان الدراسة: "دراسة لتحليل مشاكل جودة الطاقة الكهربائية وتنفيذ برنامج جودة الطاقة الكهربائية لشبكات التوزيع الكهرباء الليبية".

أنت مدعو للمشاركة في دراسة بحثية عن تنفيذ برنامج جودة الطاقة الكهربائية. قبل أن تقرر، من المهم أن تفهم ما الهدف والغاية من هذا البحث. الرجاء ان تستغرق وقتا طويلا لقراءة المعلومات التالية واذا لديك أي استفسار أو إذا كان هناك أي شيء غير واضح أو إذا كنت ترغب في مزيد من المعلومات الرجاء ان تسألني.

ما هو الغرض من الدراسة؟

أرغب في معرفة العوامل الحاسمة التي تواجه تنفيذ برنامج جودة الطاقة الكهربائية في أنظمة توزيع الكهرباء الليبية. المعرفة والمعلومات المكتسبة من المقابلة سوف تستخدم لأغراض البحث فقط ، والتي سوف تحقق الصعوبات التي تواجه تنفيذ برنامج جودة الطاقة الكهربائية في شبكات التوزيع الليبية.

المشاركة طوعية تماما، ويمكنك تغيير رأيك حول المشاركة في أي وقت.

ماذا سيحدث لنتائج الدراسة البحثية؟

نتائج هذه المقابلة ستكون جزء من بحثي فى رسالة الدكتوراه ، وسوف تنشر في بعض الاوراق العلمية من خلال المجلات المتخصصة العلمية وفي المؤتمرات الدولية. سيتم تخزين البيانات بشكل آمن حتى اتلافها.

نموذج الموافقة

عنوان الدراسة: "دراسة لتحليل مشاكل جودة الطاقة الكهربائية وتنفيذ برنامج جودة الطاقة الكهربائية لشبكات التوزيع الكهرباء الليبية".

اسم الباحث: سعد سلطان

1. أؤكد أن قراءت وفهم ورقة المعلومات الخاصة بالدراسة أعلاه. وأنا أدرك تماما الغرض من هذا البحث.	
2. أنا أفهم أن مشاركتي طوعية وأنني حر في الانسحاب في أي وقت، دون إبداء أي سبب.	
3. أنا أوافق على تسجيل المقابلة صوتياً لأغراض التحليل.	
4. أنا أوافق على المشاركة في الدراسة المشار إليها أعلاه.	

ملاحظة: ____

أسم المشارك:...

التوقيع:..

التاريخ:..

برنامج جودة الطاقة الكهربائية

1- ماذا يعني مصطلح " جودة الطاقة الكهربائية" لك؟

....
....
....
....

2- هل قامت الشركة بتنفيد أى برنامج خاص بجودة الطاقة الكهربائية؟

....
....
....
....

3- ما هي الفوائد التي ستحصل الشركة عليها عند تنفيذ برنامج خاص لتحسين مشاكل جودة الطاقة الكهربائية؟

....
....
....
....

4- ما هي الصعوبات التي تواجه الشركة فى تنفيذ برنامج لتحسين جودة الطاقة الكهربائية؟

....
....
....
....

عدم وجود وعي الإدارة العليا
عدم وجود وعي العملاء
عدم وجود البنية التحتية لتلبية النمو الاقتصادي
نقص الموارد
انعدام الحافز من قبل المستخدمين النهائيين
عدم وجود تدريب الموظفين والتوعية
عدم وجود معايير جودة الطاقة الكهربائية

5- ما هى معايير جودة الطاقة الكهربائية المستخدمة فى الشركة لغرض تحسين نوعية الكهرباء؟

IEEE...
IEC...
معايير و مواصفات وطنية موحدة بجودة الطاقة الكهربائية...
معايير أخرى حدد...

6- كيف تتم مراجعة مشاكل جودة الطاقة الكهربائية بأستخدام معايير جودة الطاقة الكهربائية فى الشركة ؟

....
....
....
....

7- ما هي أهمية معايير جودة الطاقة الكهربائية للزبائن وهل هى من ضمن الشروط التعاقدية بين الشركة و الزبون ؟

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....

الجزء الأول: التزام الإدارة بشأن جودة الطاقة

8- هل ألشركة لديها استراتيجية واضحة و محددة بشأن تحسين جودة الطاقة الكهربائية ؟ ما هو الغرض من هذه الاستراتيجية؟

....
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....
....

9- هل الإدارة تأخذ اقتراحات الموظفين من كل الأقسام بعين الأعتبار عند تطوير استراتيجية خاصة بجودة الطاقة الكهربائية؟ نعم لا؟كيف؟

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....

10- إلى أي مدى تلتزم إدارة الشركة لتحمل المسؤولية على تحسين مشاكل جودة الطاقة الكهربائية ؟

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11- عندما تواجه الشركة أي مشاكل جودة الطاقة الكهربائية ، هل تعتقد أنها قادرة على التعرف على الأسباب الجذرية التي ادت إلى هذه المشاكل؟ How? كيف؟

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....
....

12- من هو المسؤول عن حل مشاكل جودة الطاقة الكهربائية في الشركة؟

الإدارة العليا..
إدارة التحكم..
إدارة التوزيع..
إدارة التخطيط...
الزبائن...
الموظفين..
أخرى..

13- هل الشركة تصمم وتطور شبكات التوزيع على أساس كل من زيادة الطلب على الكهرباء من قبل المستهلكين وعلى زيادة النمو الاقتصادي فى البلاد مع الأخذ فى الأعتبار أنواع المستهلكين فى كل شبكة ؟ كيف؟

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....

الجزء الثاني : رضاء المستهلكين

14- برأيك من هو المسؤول في تسبب مشاكل جودة الطاقة الكهربائية في الشركة؟؟ لماذا؟

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15- كيف تتعامل الشركة مع شكاوى المواطنين فيما يتعلق بمشاكل جودة الطاقة الكهربائية ؟

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16- ما هي أهم 3 مشاكل مع الزبائن و المتعلقة بجودة الطاقة الكهربائية ؟

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17- إلى أي مدى تعتقد أن المواطنين الذين يقومون بتوصيل التيار الكهربائي بطريقة غير مشروعة يكون جزءا فى تسبب مشاكل جودة الطاقة الكهربائية ؟

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18- كيف يمكنك التأكد من جودة الكهرباء قبل توزيعها للمستهلكين؟

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....

19- كيف يمكنكم قياس رضا المستهلكين بشأن جودة الطاقة الكهربائية ؟

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20- هل تعتقد أن رضا المستهلكين هو أحد الحلول من شأنه أن يساعد في تحسين نوعية جودة الطاقة الكهربائية ؟ كيف؟

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....

21- كيف تتم عملية توعية الزبائن لمساعدتكم في حل المشاكل المتعلقة بجودة الطاقة الكهربائية ؟

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....

الجزء الثالث : مشاكل جودة الطاقة الكهربائية

22- متى كان أول ظهورلمشاكل جودة الطاقة الكهربائية كمشاكل خطيرة في الشركة؟ (السنة)

....
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....
....

1. هل الشركة تستخدام أدوات إحصائية لرصد وقياس مشاكل جودة الطاقة الكهربائية في نظم التوزيع؟

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....

2. متى قامت الشركة بتركيب اجهزة قياس لرصد مشاكل جودة الطاقة الكهربائية ؟

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....
....
....

3. أى نوع من انواع مشاكل جودة الطاقة الكهربائية تم تحديده فى القياسات الماضية؟

....
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....
....

4. ما هي الأنواع الأخرى من مشاكل جودة الطاقة الكهربائية التي تواجهها الشركة؟

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....

5. هل تعتقد أن هناك علاقة بين رد فعل المستهلكين الغير راضين على جودة الكهرباء و مشاكل جودة الطاقة الكهربائية ؟ وإلى أي مدى تنظر الشركة في هذه العلاقة؟

....
....
....
....

الجزء الرابع: تدريب و مشاركة الموظفين فيما يتعلق بجودة الكهرباء

23- هل يتم تدريب الموظفين تدريب خاص فيما يتعلق بمشاكل جودة الطاقة الكهربائية كجزء من الحلول؟ إذا كانت الإجابة بنعم هل تدريبهم ساعد بشكل إيجابي في حل مشاكل جودة الطاقة الكهربائية ؟

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....

24- ما نسبة الموظفين اللذين تلقو تدريب توعوي فيما يتعلق بمشاكل جودة الطاقة الكهربائية؟

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....

25- هل هناك موارد متوفرة ما يكفي لتدريب الموظفين فيما يتعلق بمشاكل جودة الطاقة الكهربائية ؟

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....

26- هل هناك أي فريق تم تدريبه جيداً لغرض تحليل وحل مشاكل جودة الطاقة الكهربائية ؟

....
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....

الجزء الخامس: التطوير المستمر

27- هل تعتقد أن جودة الطاقة الكهربائية قد تغيرت بشكل إيجابي بعد تنفيذ برنامج جودة الطاقة الكهربائية ؟

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28- كيف تقيم النجاح الكلى لبرنامج جودة الطاقة الكهربائية حتى الآن؟

....
....
....
....

29- هل هناك أي موضوعات أنت تشعر لم يتم تغطيتها؟

....
....
....
....

30- هل هناك أي شخص يجب أن نتحدث إليه بخصوص هذا القضايا؟

....
....
....
....

تأكيد السرية !!!!

نـهاية المقابلة

شكراً جزيلاً لاأستكمال هذا المقابلة مع تقديرى الكبير لوقتكم الثمين

APPENDIX C: Ethical Approval Letter

School of Engineering and Design
Head of School: Professor Savvas Tassou
BSc, PhD, MBA, CEng, MIMechE, MASHRAE, MIIR, MInstR

Brunel
UNIVERSITY
WEST LONDON

Brunel University, Uxbridge,
Middlesex, UB8 3PH, UK
Telephone +44 (0)1895 266865
Fax +44 (0)1895 269803
E-mail savvas.tassou@brunel.ac.uk
Web www.brunel.ac.uk

01 May 2012

Mr Saad Sultan
School of Engineering and Design
Brunel University

Dear Mr Sultan

EC/252 Power Quality Framework Programme in Libya

Your application for ethics approval has now been considered by the School Research Ethics Committee and I can confirm that approval has been given for the project to go forward.

If there are any changes in protocol then the Ethics Committee needs to be informed and may require further documentation to continue approving this project.

Yours sincerely,

Paul Worthington, School Manager
Secretary to SED Research Ethics Committee

APPENDIX D: Questionnaire and Interview Cover Letters

Head of School
Professor S. A. Tassou
BSc, PhD, MBA, CEng, MIMechE, MASHRAE
School of Engineering & Design

Head of Electronic & Computer Engineering
Professor A. H. Sadka
BEng, MSc, PhD, MIET, SMIEEE, CEng

Date: 22 March 2010

Brunel UNIVERSITY WEST LONDON
Uxbridge
Middlesex UB8 3PH

Dr M K Darwish
BSc, PhD, FIET, MIEEE
Senior Lecturer in Power Electronics
Telephone (01895) 266755
Fax (01895) 258728
Email mohamed.darwish@brunel.ac.uk

TO WHOM IT MAY CONCERN

Ref: Mr Saad Sultan

Mr Saad Sultan is carrying out a research work (PhD) in the field of Electric Power Quality. Part of his research work is to do a comparison study of the Electric Power Quality issues in both Libya and the UK, with the aim to produce a better understanding, analysis and recommendation of suitable solutions for Power Quality problems particularly in non-linear loads.

Mr Sultan has prepared his questionnaire and is ready to conduct his field study which could take up to 8 weeks in Libya starting from 1st April 2010. Your support and collaboration will be very much appreciated in his research as he will be conducting his questionnaire at three different end-users (industrial, commercial and domestic).

So far, Mr Sultan is doing very well in his research work and the effort he has put so far in preparing his field study is exceptional and hopefully it will be matched by equally good implementation.

Kind regards.

M. Darwish

Dr. M. K. Darwish

ELECTRONIC & COMPUTER ENGINEERING
SCHOOL OF ENGINEERING & DESIGN
Brunel University
Uxbridge
UB8 3PH
UK

Head of School
Professor S. A. Tassou
BSc, PhD, MBA, CEng, MIMechE, MASHRAE
School of Engineering & Design

Head of Electronic & Computer Engineering
Professor A. H. Sadka
BEng, MSc, PhD, MIET, SMIEEE, CEng

Brunel
UNIVERSITY
WEST LONDON

Uxbridge
Middlesex UB8 3PH

Dr M K Darwish
BSc, PhD, FIET, MIEEE
Senior Lecturer in Power Electronics
Telephone (01895) 266755
Fax (01895) 258728
Email mohamed.darwish@brunel.ac.uk

Date: 9 December 2010

Electrical General Company of Libya
Tripoli, Libya

Ref: Mr Saad Sultan

Mr Saad Sultan is carrying out a research work (PhD) in the field of Electric Power Quality. Part of his research work is to do a comparison study of the Electric Power Quality issues in both Libya and the UK, with the aim to produce a better understanding, analysis and recommendation of suitable solutions for Power Quality problems particularly in non-linear loads.

Mr Sultan has prepared his an interview questionnaire and is ready to conduct the interview which could take up to 3 weeks in Libya starting from 20th December 2010. Your support and collaboration will be very much appreciated during his interview conducting period.

So far, Mr Sultan is doing very well in his research work and the effort he has put so far in preparing his interview is exceptional and hopefully it will be matched by equally good implementation.

Kind regards.

M. Darwish

Dr. M. K. Darwish

BRUNEL UNIVERSITY
SCHOOL OF ENGINEERING
AND DESIGN
- 9 DEC 2010
UXBRIDGE
MIDDLESEX
UB8 3PH

APPENDIX E: Multivariate Tests for PQP Factors by Employees Characteristics

Multivariate Tests Work Position[c]

Which network do you work at?	Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
West Network	Intercept	Pillai's Trace	.957	673.694[a]	5.000	150.000	.000	.957
		Wilks' Lambda[d]	.043	673.694[a]	5.000	150.000	.000	.957
		Hotelling's Trace	22.456	673.694[a]	5.000	150.000	.000	.957
		Roy's Largest Root	22.456	673.694[a]	5.000	150.000	.000	.957
	WP	Pillai's Trace	.139	1.103	20.000	612.000	.341	.035
		Wilks' Lambda[d]	.866	1.101	20.000	498.444	.344	.035
		Hotelling's Trace	.148	1.098	20.000	594.000	.346	.036
		Roy's Largest Root	.089	2.737[b]	5.000	153.000	.021	.082
East Network	Intercept	Pillai's Trace	.974	899.609[a]	5.000	122.000	.000	.974
		Wilks' Lambda[d]	.026	899.609[a]	5.000	122.000	.000	.974
		Hotelling's Trace	36.869	899.609[a]	5.000	122.000	.000	.974
		Roy's Largest Root	36.869	899.609[a]	5.000	122.000	.000	.974
	WP	Pillai's Trace	.172	1.126	20.000	500.000	.318	.043
		Wilks' Lambda[d]	.837	1.119	20.000	405.578	.327	.044
		Hotelling's Trace	.184	1.109	20.000	482.000	.336	.044
		Roy's Largest Root	.087	2.165[b]	5.000	125.000	.062	.080
South Network	Intercept	Pillai's Trace	.982	1093.825[a]	5.000	98.000	.000	.982
		Wilks' Lambda[d]	.018	1093.825[a]	5.000	98.000	.000	.982
		Hotelling's Trace	55.807	1093.825[a]	5.000	98.000	.000	.982
		Roy's Largest Root	55.807	1093.825[a]	5.000	98.000	.000	.982
	WP	Pillai's Trace	.244	1.310	20.000	404.000	.168	.061
		Wilks' Lambda[d]	.772	1.322	20.000	325.979	.162	.063
		Hotelling's Trace	.275	1.328	20.000	386.000	.157	.064
		Roy's Largest Root	.173	3.502[b]	5.000	101.000	.006	.148

Computed using alpha = .05

a. Exact statistic

b. The statistic is an upper bound on F that yields a lower bound on the significance level.

c. Design: Intercept+WP

Multivariate Tests Education Level[c]

Which network do you work at?	Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
West Network	Intercept	Pillai's Trace	.951	586.946[a]	5.000	151.000	.000	.951
		Wilks' Lambda	.049	586.946[a]	5.000	151.000	.000	.951
		Hotelling's Trace	19.435	586.946[a]	5.000	151.000	.000	.951
		Roy's Largest Root	19.435	586.946[a]	5.000	151.000	.000	.951
	EL	Pillai's Trace	.098	1.036	15.000	459.000	.417	.033
		Wilks' Lambda	.904	1.033	15.000	417.246	.419	.033
		Hotelling's Trace	.103	1.030	15.000	449.000	.422	.033
		Roy's Largest Root	.069	2.106[b]	5.000	153.000	.068	.064
East Network	Intercept	Pillai's Trace	.926	309.820[a]	5.000	123.000	.000	.926
		Wilks' Lambda	.074	309.820[a]	5.000	123.000	.000	.926
		Hotelling's Trace	12.594	309.820[a]	5.000	123.000	.000	.926
		Roy's Largest Root	12.594	309.820[a]	5.000	123.000	.000	.926
	EL	Pillai's Trace	.178	1.580	15.000	375.000	.077	.059
		Wilks' Lambda	.829	1.589	15.000	339.950	.075	.060
		Hotelling's Trace	.197	1.595	15.000	365.000	.073	.062
		Roy's Largest Root	.137	3.430[b]	5.000	125.000	.006	.121
South Network	Intercept	Pillai's Trace	.942	318.834[a]	5.000	99.000	.000	.942
		Wilks' Lambda	.058	318.834[a]	5.000	99.000	.000	.942
		Hotelling's Trace	16.103	318.834[a]	5.000	99.000	.000	.942
		Roy's Largest Root	16.103	318.834[a]	5.000	99.000	.000	.942
	EL	Pillai's Trace	.150	1.065	15.000	303.000	.389	.050
		Wilks' Lambda	.852	1.091	15.000	273.697	.365	.052
		Hotelling's Trace	.171	1.116	15.000	293.000	.341	.054
		Roy's Largest Root	.156	3.144[b]	5.000	101.000	.011	.135

Computed using alpha = .05

a. Exact statistic

b. The statistic is an upper bound on F that yields a lower bound on the significance level.

c. Design: Intercept+EL

Multivariate Tests Work Responsibility[c]

Which network do you work at?	Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
West Network	Intercept	Pillai's Trace	.960	723.556[a]	5.000	150.000	.000	.960
		Wilks' Lambda	.040	723.556[a]	5.000	150.000	.000	.960
		Hotelling's Trace	24.119	723.556[a]	5.000	150.000	.000	.960
		Roy's Largest Root	24.119	723.556[a]	5.000	150.000	.000	.960
	WR	Pillai's Trace	.143	1.139	20.000	612.000	.305	.036
		Wilks' Lambda	.862	1.138	20.000	498.444	.306	.036
		Hotelling's Trace	.153	1.135	20.000	594.000	.308	.037
		Roy's Largest Root	.079	2.432[b]	5.000	153.000	.037	.074
East Network	Intercept	Pillai's Trace	.968	745.467[a]	5.000	122.000	.000	.968
		Wilks' Lambda	.032	745.467[a]	5.000	122.000	.000	.968
		Hotelling's Trace	30.552	745.467[a]	5.000	122.000	.000	.968
		Roy's Largest Root	30.552	745.467[a]	5.000	122.000	.000	.968
	WR	Pillai's Trace	.186	1.217	20.000	500.000	.234	.046
		Wilks' Lambda	.826	1.207	20.000	405.578	.244	.047
		Hotelling's Trace	.198	1.193	20.000	482.000	.254	.047
		Roy's Largest Root	.096	2.400[b]	5.000	125.000	.041	.088
South Network	Intercept	Pillai's Trace	.963	501.336[a]	5.000	97.000	.000	.963
		Wilks' Lambda	.037	501.336[a]	5.000	97.000	.000	.963
		Hotelling's Trace	25.842	501.336[a]	5.000	97.000	.000	.963
		Roy's Largest Root	25.842	501.336[a]	5.000	97.000	.000	.963
	WR	Pillai's Trace	.204	.860	25.000	505.000	.663	.041
		Wilks' Lambda	.807	.861	25.000	361.841	.661	.042
		Hotelling's Trace	.226	.862	25.000	477.000	.660	.043
		Roy's Largest Root	.130	2.620[b]	5.000	101.000	.029	.115

Computed using alpha = .05

a. Exact statistic

b. The statistic is an upper bound on F that yields a lower bound on the significance level.

c. Design: Intercept+WR

APPENDIX F: Normality values of skewness and kurtosis

Variables	N	Skewness		Kurtosis	
	Statistic	Statistic	Std. Error	Statistic	Std. Error
Work Position	397	.903	.122	.631	.244
Education Level	397	.328	.122	-1.681	.244
Work Experience	397	.558	.122	-.266	.244
Work Responsibility	397	.768	.122	-1.122	.244
Q7	397	-1.016	.122	.986	.244
Q8	397	-1.339	.122	1.050	.244
Q9	397	-1.393	.122	1.330	.244
Q10	397	-.498	.122	-.665	.244
Q11	397	-1.440	.122	1.396	.244
Q12	397	.341	.122	-1.534	.244
Q13	397	.849	.122	-.405	.244
Q14	397	.306	.122	-1.498	.244
Q15	397	.635	.122	-.961	.244
Q16	397	1.125	.122	.290	.244
Q17	397	.025	.122	-1.440	.244
Q18	397	-.892	.122	.400	.244
Q19	397	.332	.122	-1.514	.244
Q20	397	-.179	.122	-1.464	.244
Q21	397	-.252	.122	-.804	.244
Q22	397	.028	.122	-1.680	.244
Q23	397	.173	.122	-1.651	.244
Q24	397	.166	.122	-1.547	.244
Q25	397	.596	.122	-1.149	.244
Q26	397	.571	.122	-1.077	.244
Q27	397	.746	.122	-.765	.244
Q28	397	.966	.122	-.188	.244
Q29	397	.864	.122	-.559	.244
Q30	397	-1.586	.122	.367	.244
Q31	397	-1.419	.122	.909	.244
Q32	397	-1.564	.122	.846	.244
Q33	397	-1.838	.122	.958	.244
Q34	397	-1.646	.122	.952	.244
Q35	397	-.877	.122	1.356	.244
Q36	397	-.411	.122	-.561	.244
Q37	397	-.574	.122	.069	.244
Q49.1	397	.076	.122	-.821	.244

Q49.2	397	.478	.122	-.760	.244
Q49.3	397	-.313	.122	-.640	.244
Q49.4	397	-.147	.122	-.693	.244
Q49.5	397	-.175	.122	-.765	.244
Q49.6	397	.078	.122	-1.131	.244
Q49.7	397	-.045	.122	-1.316	.244
Q49.8	397	.061	.122	-1.094	.244
Q49.9	397	.156	.122	-1.074	.244
Q49.10	397	.099	.122	-1.169	.244
Q50.1	397	-.301	.122	-1.421	.244
Q50.2	397	-.640	.122	-.780	.244
Q50.3	397	-.650	.122	-.846	.244
Q50.4	397	-.516	.122	-.956	.244
Q50.5	397	-.332	.122	-1.235	.244
Q50.6	397	-.512	.122	-1.084	.244
Q50.7	397	-.502	.122	-.998	.244
Q50.8	397	-.510	.122	-.958	.244
Valid N (listwise)	397				

APPENDIX G: Summary of Descriptive Analysis
(Range Minimum, Maximum, Mean, Standard Deviation and Variance)

Variables	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Work Position	397	4	1	5	2.50	.855	.730
Education Level	397	3	1	4	1.88	.969	.940
Work Experience	397	4	1	5	1.97	.876	.767
Work Responsibility	397	5	1	6	2.76	1.965	3.861
Q7	397	4	1	5	4.20	.922	.850
Q8	397	4	1	5	4.10	.922	.849
Q9	397	4	1	5	4.17	1.053	1.109
Q10	397	4	1	5	3.46	1.151	1.325
Q11	397	4	1	5	4.26	.846	.715
Q12	397	3	1	4	2.69	1.039	1.079
Q13	397	3	1	4	2.31	.963	.926
Q14	397	3	1	4	2.66	1.063	1.129
Q15	397	3	1	4	2.44	1.015	1.030
Q16	397	3	1	4	2.28	.871	.759
Q17	397	3	1	4	2.23	1.060	1.123
Q18	397	4	1	5	3.94	1.039	1.079
Q19	397	3	1	4	2.03	1.102	1.214
Q20	397	3	1	4	2.35	1.087	1.182
Q21	397	3	1	4	2.70	.937	.878
Q22	397	3	1	4	2.12	1.052	1.108
Q23	397	3	1	4	2.06	1.076	1.158
Q24	397	3	1	4	2.62	1.147	1.316
Q25	397	3	1	4	2.21	1.173	1.376
Q26	397	3	1	4	2.29	1.120	1.254
Q27	397	3	1	4	2.15	1.097	1.204
Q28	397	3	1	4	2.01	1.035	1.071
Q29	397	3	1	4	2.05	1.092	1.192
Q30	397	4	1	5	3.06	1.95	.705
Q31	397	4	1	5	3.09	1.97	.577
Q32	397	4	1	5	3.09	1.00	.360
Q33	397	4	1	5	3.01	1.86	.548
Q34	397	4	1	5	2.92	1.96	.539
Q35	397	4	1	5	3.34	1.73	.585
Q36	397	4	1	5	3.81	1.93	1.092
Q37	397	4	1	5	3.39	.930	.865
Q49.1	397	4	1	5	2.74	1.156	1.336
Q49.2	397	4	1	5	2.43	1.222	1.493
Q49.3	397	4	1	5	3.22	1.163	1.352
Q49.4	397	4	1	5	2.77	1.090	1.187
Q49.5	397	4	1	5	3.08	1.180	1.393
Q49.6	397	4	1	5	2.78	1.297	1.682

Q49.7	397	4	1	5	3.00	1.447	2.093
Q49.8	397	4	1	5	2.84	1.300	1.689
Q49.9	397	4	1	5	2.75	1.298	1.684
Q49.10	397	4	1	5	2.81	1.295	1.677
Q50.1	397	4	1	5	3.16	1.520	2.309
Q50.2	397	4	1	5	3.44	1.335	1.782
Q50.3	397	4	1	5	3.68	1.349	1.819
Q50.4	397	4	1	5	3.52	1.321	1.745
Q50.5	397	4	1	5	3.16	1.407	1.979
Q50.6	397	4	1	5	3.51	1.410	1.988
Q50.7	397	4	1	5	3.52	1.332	1.775
Q50.8	397	4	1	5	3.47	1.332	1.775
Valid N (listwise)	397						

APPENDIX H: Frequency and Percentage of Distributions of Respondents Measuring PQP Implementation Items

Question	Strongly Disagree		Disagree		Neither Agree Nor Disagree		Agree		Strongly Agree		Total	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Q7	16	0.4	8	0.2	16	0.4	196	49.4	161	40.6	397	100
Q8	10	2.5	19	4.8	34	8.6	194	48.9	140	35.3	397	100
Q9	13	3.3	29	7.3	27	6.8	138	34.8	190	47.9	397	100
Q10	24	0.6	70	17.6	73	18.4	159	40.1	71	17.9	397	100
Q11	4	0.1	20	0.5	19	4.8	178	44.8	176	44.3	397	100
Q12	23	5.8	226	56.9	0	0	148	37.3	0	0	397	100
Q13	53	13.4	256	64.5	0	0	88	22.2	0	0	397	100
Q14	32	8.1	218	54.9	0	0	147	37	0	0	397	100
Q15	45	11.3	242	61	0	0	110	27.7	0	0	397	100
Q16	36	9.1	287	72.3	0	0	74	18.6	0	0	397	100
Q17	148	37.3	48	12.1	162	40.8	39	9.8	0	0	397	100
Q18	14	3.5	19	4.8	86	21.7	137	34.5	141	35.5	397	100
Q19	201	50.6	18	4.5	144	36.3	34	8.6	0	0	397	100
Q20	143	36	19	4.8	189	47.6	46	11.6	0	0	397	100
Q21	48	12.1	108	27.2	157	39.5	84	21.2	0	0	397	100
Q22	179	45.1	13	3.3	185	46.6	20	0.5	0	0	397	100
Q23	194	48.9	9	2.3	170	42.8	24	0.6	0	0	397	100
Q24	60	15.1	183	46.1	0	0	154	38.8	0	0	397	100
Q25	131	33	158	39.8	0	0	108	27.2	0	0	397	100
Q26	99	24.9	190	47.9	0	0	108	27.2	0	0	397	100
Q27	122	30.7	184	46.3	0	0	91	22.9	0	0	397	100
Q28	140	35.3	186	46.9	0	0	71	17.9	0	0	397	100
Q29	145	36.5	170	42.8	0	0	82	20.7	0	0	397	100
Q30	7	1.8	13	3.3	20	0.5	185	46.6	172	43.3	397	100
Q31	3	0.8	9	2.3	24	0.6	170	42.8	191	48.1	397	100
Q32	1	0.3	2	0.5	11	2.8	133	33.5	250	63	397	100
Q33	2	0.5	10	2.5	17	4.3	120	30.2	248	62.5	397	100
Q34	3	0.8	8	0.2	16	0.4	158	39.8	212	53.4	397	100
Q35	2	0.5	14	3.5	48	12.1	221	55.7	112	28.2	397	100
Q36	18	4.5	74	18.6	98	24.7	164	41.3	43	10.8	397	100
Q37	15	3.8	49	12.3	128	32.2	175	44.1	30	4.6	397	100
Question	**Very Little**		**Little**		**Neutral**		**Much**		**Very Much**		**Total**	
Q 49.1	71	17.9	93	23.4	128	32.2	80	20.2	25	6.3	397	100
Q 49.2	113	28.5	110	27.7	92	23.2	56	14.1	26	6.5	397	100
Q 49.3	41	10.3	58	14.6	125	31.5	120	30.2	53	13.4	397	100
Q 49.4	68	17.1	71	17.9	158	39.8	84	21.2	16	0.4	397	100
Q 49.5	49	12.3	69	17.4	128	32.2	108	26.4	46	11.6	397	100

Q 49.6	88	22.2	82	20.7	96	24.2	91	22.9	40	10.1	397	100
Q 49.7	91	22.9	58	14.6	90	22.7	75	18.9	83	20.9	397	100
Q 49.8	81	20.4	81	20.4	102	25.7	86	21.7	47	11.8	397	100
Q 49.9	89	22.4	86	21.7	101	25.4	78	19.6	43	10.8	397	100
Q 49.10	79	19.9	100	25.2	78	19.6	99	24.9	41	10.3	397	100
Question	**Not at All**		**Once a Year**		**Twice a Year**		**More Twice a Year**		**Don't Know**		**Total**	
Q 50.1	99	24.9	43	10.8	43	10.8	121	30.5	91	22.9	397	100
Q 50.2	58	14.6	40	10.1	58	14.6	151	38	90	22.7	397	100
Q 50.3	37	9.3	53	13.4	63	15.9	91	22.9	153	38.5	397	100
Q 50.4	38	9.6	67	16.9	57	14.4	120	30.2	115	29	397	100
Q 50.5	80	20.2	53	13.4	59	14.9	133	33.5	72	18.1	397	100
Q 50.6	51	12.8	59	14.9	56	14.1	99	24.9	132	33.2	397	100
Q 50.7	38	9.6	69	17.4	56	14.1	115	29	119	30	397	100
Q 50.8	44	11.1	63	15.9	58	14.6	125	31.5	107	27	397	100

APPENDIX I: Communalities of Factor Analysis

Variables	Initial	Extraction
Q7	1.000	.575
Q8	1.000	.565
Q9	1.000	.682
Q10	1.000	.591
Q11	1.000	.574
Q12	1.000	.665
Q13	1.000	.589
Q14	1.000	.569
Q15	1.000	.655
Q16	1.000	.634
Q17	1.000	.565
Q18	1.000	.503
Q19	1.000	.700
Q20	1.000	.567
Q21	1.000	.624
Q22	1.000	.547
Q23	1.000	.645
Q24	1.000	.591
Q25	1.000	.641
Q26	1.000	.498
Q27	1.000	.671
Q28	1.000	.582
Q29	1.000	.556
Q30	1.000	.543
Q31	1.000	.531
Q32	1.000	.594
Q33	1.000	.625
Q34	1.000	.535
Q35	1.000	.563
Q36	1.000	.772
Q37	1.000	.555
Q49.1	1.000	.522
Q49.2	1.000	.516
Q49.3	1.000	.594
Q49.4	1.000	.516
Q49.5	1.000	.524
Q49.6	1.000	.619
Q49.7	1.000	.580
Q49.8	1.000	.711
Q49.9	1.000	.663
Q49.10	1.000	.650
Q 50.1	1.000	.691
Q 50.2	1.000	.683
Q 50.3	1.000	.558
Q 50.4	1.000	.594
Q 50.5	1.000	.518
Q 50.6	1.000	.692
Q 50.7	1.000	.625
Q 50.8	1.000	.562

Extraction Method: Principal Component Analysis.

APPENDIX J: Respondents Coding

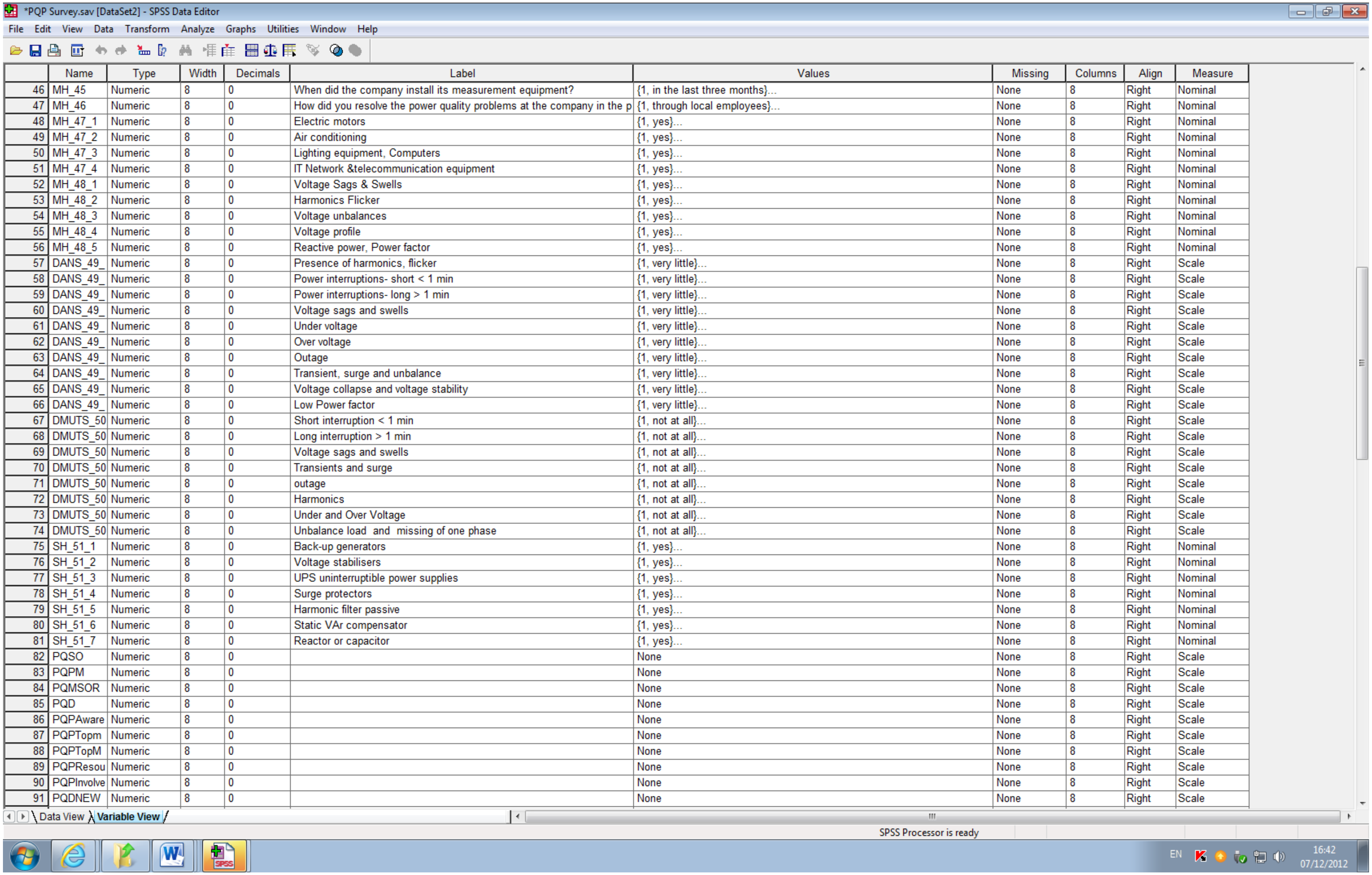
Quantitative Data Respondents Coding

*PQP Survey.sav [DataSet2] - SPSS Data Editor

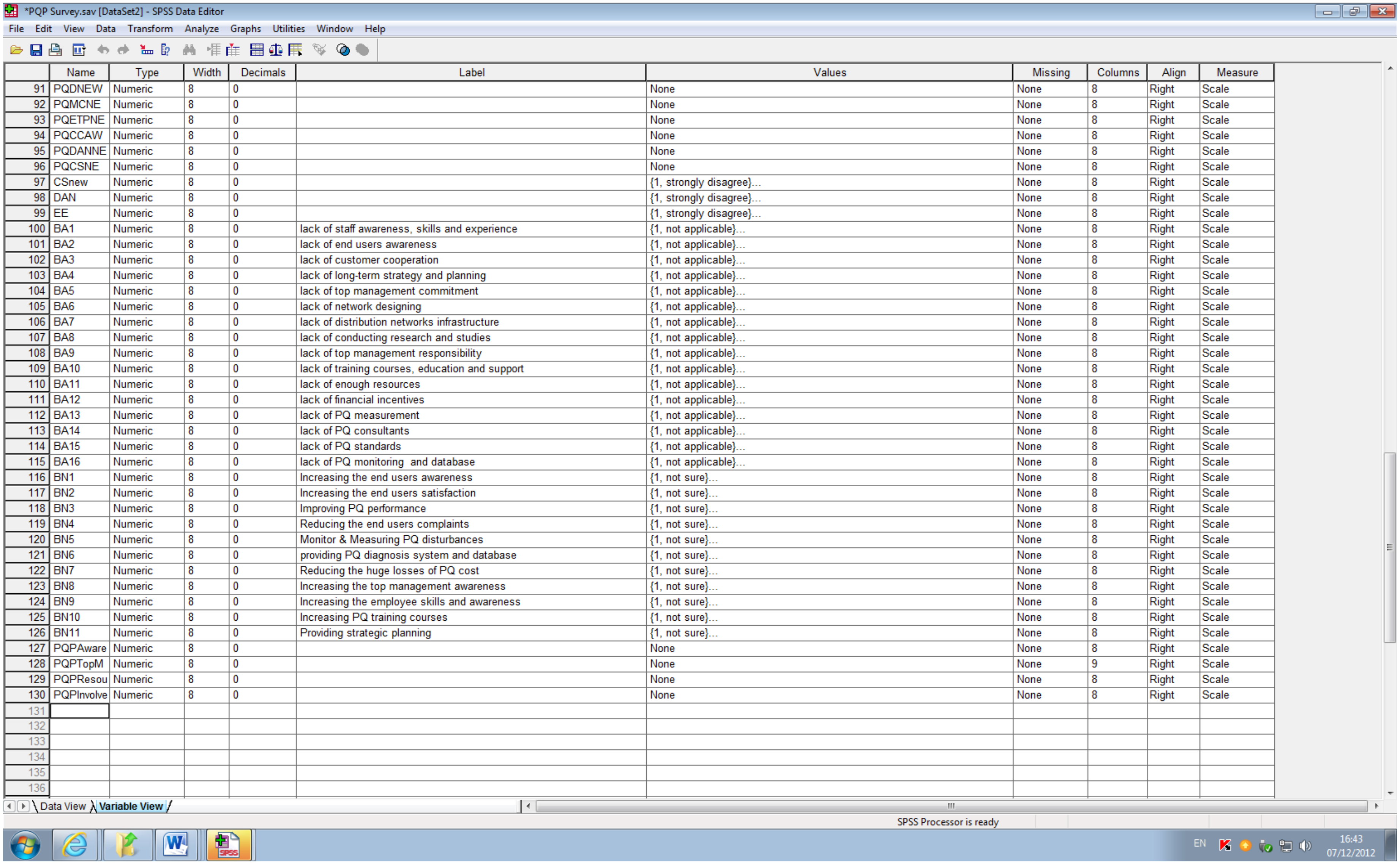
	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure
1	ID	Numeric	8	0	ID	None	None	8	Right	Nominal
2	WP	Numeric	8	0	Work Position	{1, head manager}...	None	8	Right	Nominal
3	EL	Numeric	8	0	Eduction Level	{1, High diploma}...	None	8	Right	Nominal
4	WE	Numeric	8	0	Work Experience	{1, 0-5 years}...	None	8	Right	Nominal
5	WR	Numeric	8	0	Work Responsibility	{1, repair and maintanance}...	None	8	Right	Nominal
6	EM	Numeric	8	0	Number of Employees	{1, <300}...	None	8	Right	Nominal
7	WT	Numeric	8	0	Working Time	{1, 5 days a week,8 hours a day}...	None	8	Right	Nominal
8	D_7	Numeric	8	0	To ensure the reliability and availability of the service	{1, strongly disagree}...	None	8	Right	Scale
9	D_8	Numeric	8	0	To satisfy customer's needs	{1, strongly disagree}...	None	8	Right	Scale
10	D_9	Numeric	8	0	To reduce the losses in the network	{1, strongly disagree}...	None	8	Right	Scale
11	D_10	Numeric	8	0	To make customers aware of the importance of it	{1, strongly disagree}...	None	8	Right	Scale
12	D_11	Numeric	8	0	To increase the network's efficiency	{1, strongly disagree}...	None	8	Right	Scale
13	CS_12	Numeric	8	0	Customer complaints are considered when identifying patterns and prev	{1, strongly disagree}...	None	8	Right	Scale
14	CS_13	Numeric	8	0	Customer satisfactions can help in keeping the high quality of the gener	{1, strongly disagree}...	None	8	Right	Scale
15	CS_14	Numeric	8	0	The company adapts measures to encourage their employees to satisfy	{1, strongly disagree}...	None	8	Right	Scale
16	CS_15	Numeric	8	0	The company accommodates the growing demand of the electricity in or	{1, strongly disagree}...	None	8	Right	Scale
17	CS_16	Numeric	8	0	Customers awareness can reduce power quality problems	{1, strongly disagree}...	None	8	Right	Scale
18	MC_17	Numeric	8	0	When the company faces any power quality problems, it identifies the r	{1, strongly disagree}...	None	8	Right	Scale
19	MC_18	Numeric	8	0	Inaccurate managerial decision would affect of decreasing the efficiency	{1, strongly disagree}...	None	8	Right	Scale
20	MC_19	Numeric	8	0	Planning a good strategy to increase the capability of the network is es	{1, strongly disagree}...	None	8	Right	Scale
21	MC_20	Numeric	8	0	Following the recommendations and studies of researches are very imp	{1, strongly disagree}...	None	8	Right	Scale
22	MC_21	Numeric	8	0	The power service which distributed has good reliability and availability a	{1, strongly disagree}...	None	8	Right	Scale
23	MC_22	Numeric	8	0	The company is responsible to ensure the security and the quality of th	{1, strongly disagree}...	None	8	Right	Scale
24	MC_23	Numeric	8	0	Using an international or a national benchmarks and standards are vital f	{1, strongly disagree}...	None	8	Right	Scale
25	EPT_24	Numeric	8	0	Solving power quality problems requires the involvement of the employee	{1, strongly disagree}...	None	8	Right	Scale
26	EPT_25	Numeric	8	0	Sufficient training for employees can improve the company performance	{1, strongly disagree}...	None	8	Right	Scale
27	EPT_26	Numeric	8	0	The appropriate qualifications and experience of the employees is an im	{1, strongly disagree}...	None	8	Right	Scale
28	EPT_27	Numeric	8	0	Conducting a survey or other feedback techniques is important to identif	{1, strongly disagree}...	None	8	Right	Scale
29	EPT_28	Numeric	8	0	The company takes seriously any suggestions made by its employees r	{1, strongly disagree}...	None	8	Right	Scale
30	EPT_29	Numeric	8	0	The employees are involved by the company in any strategies which ma	{1, strongly disagree}...	None	8	Right	Scale
31	CCAW_30	Numeric	8	0	The concept of power quality	{1, strongly disagree}...	None	8	Right	Scale
32	CCAW_31	Numeric	8	0	Taking electrical supply in an illegal way	{1, strongly disagree}...	None	8	Right	Scale
33	CCAW_32	Numeric	8	0	excessive use of electronics devices	{1, strongly disagree}...	None	8	Right	Scale
34	CCAW_33	Numeric	8	0	A faulty connection	{1, strongly disagree}...	None	8	Right	Scale
35	CCAW_34	Numeric	8	0	Natural cause's out of utility control	{1, strongly disagree}...	None	8	Right	Scale
36	CCAW_35	Numeric	8	0	proper design mixed welding plant, heavy duty motors in residential area	{1, strongly disagree}...	None	8	Right	Scale
37	CCAW_36	Numeric	8	0	Utility faults due to none regular maintenance or repair	{1, strongly disagree}...	None	8	Right	Scale
38	CCAW_37	Numeric	8	0	Bad design, long high voltage lines with heavy or light loads	{1, strongly disagree}...	None	8	Right	Scale
39	ND_38	Numeric	8	0	Which network do you work at?	{1, west network}...	None	8	Right	Ordinal
40	ND_39	Numeric	8	0	who are the most customers utilizing of the electricity connected to the	{1, residential users}...	None	8	Right	Nominal
41	ND_40	Numeric	8	0	During Which time of the year does your company often experience mo	{1, winter season}...	None	8	Right	Nominal
42	ND_41	Numeric	8	0	What is the level of power quality problems face the network?	{1, sever}...	None	8	Right	Nominal
43	ND_42	Numeric	8	0	What level of energy losses does the company/site record due to Techn	{1, 1-10%}...	None	8	Right	Nominal
44	ND_43	Numeric	8	0	How often do you experience power supply failure in the network?	{1, <30 minutes once year}...	None	8	Right	Nominal
45	MH_44	Numeric	8	0	Does your company use statistical tools to monitor and measure the po	{1, none}...	None	8	Right	Nominal
46	MH_45	Numeric	8	0	When did the company install its measurement equipment?	{1, in the last three months}...	None	8	Right	Nominal

Data View | Variable View

SPSS Processor is ready

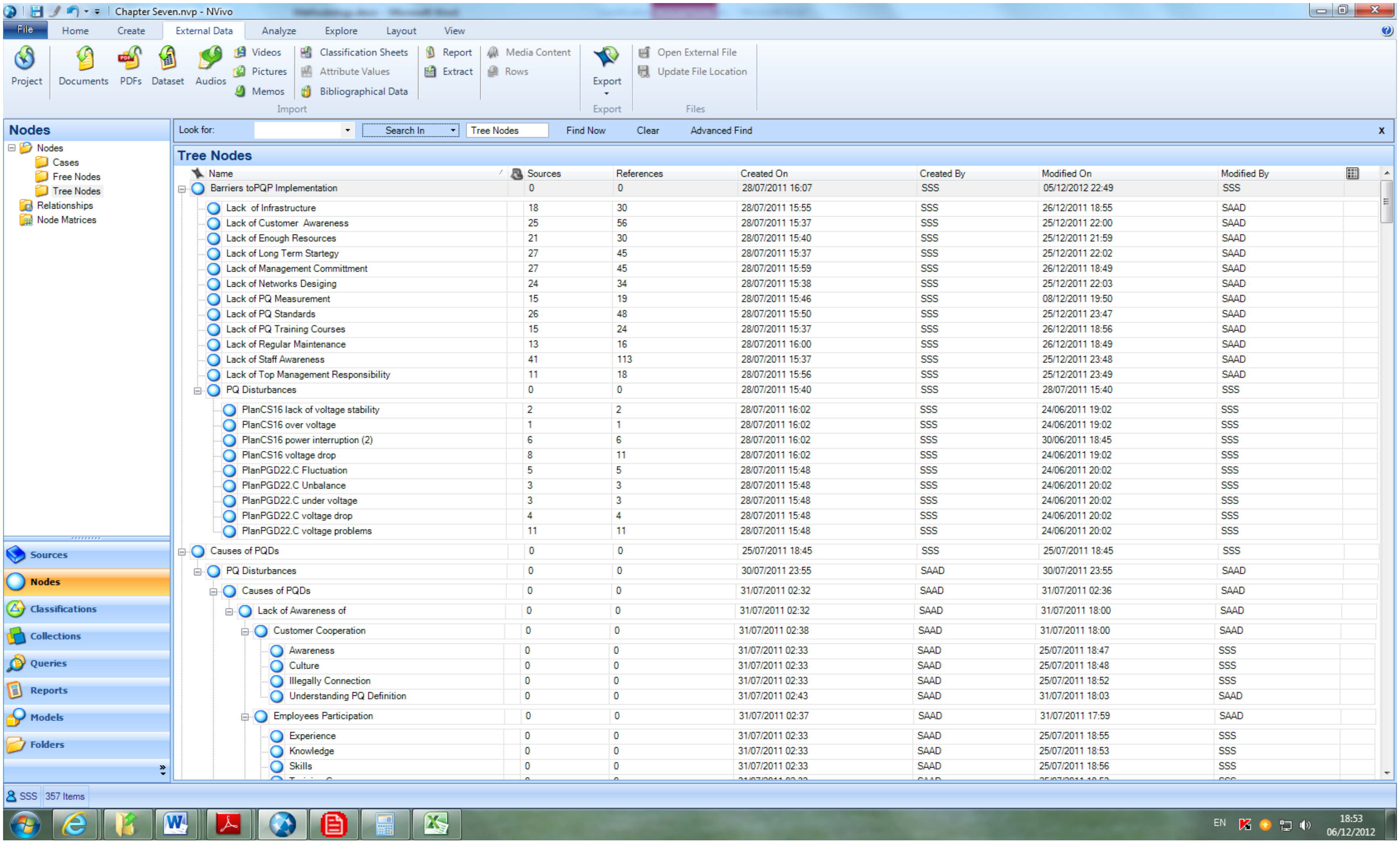


	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure
46	MH_45	Numeric	8	0	When did the company install its measurement equipment?	{1, in the last three months}...	None	8	Right	Nominal
47	MH_46	Numeric	8	0	How did you resolve the power quality problems at the company in the p	{1, through local employees}...	None	8	Right	Nominal
48	MH_47_1	Numeric	8	0	Electric motors	{1, yes}...	None	8	Right	Nominal
49	MH_47_2	Numeric	8	0	Air conditioning	{1, yes}...	None	8	Right	Nominal
50	MH_47_3	Numeric	8	0	Lighting equipment, Computers	{1, yes}...	None	8	Right	Nominal
51	MH_47_4	Numeric	8	0	IT Network &telecommunication equipment	{1, yes}...	None	8	Right	Nominal
52	MH_48_1	Numeric	8	0	Voltage Sags & Swells	{1, yes}...	None	8	Right	Nominal
53	MH_48_2	Numeric	8	0	Harmonics Flicker	{1, yes}...	None	8	Right	Nominal
54	MH_48_3	Numeric	8	0	Voltage unbalances	{1, yes}...	None	8	Right	Nominal
55	MH_48_4	Numeric	8	0	Voltage profile	{1, yes}...	None	8	Right	Nominal
56	MH_48_5	Numeric	8	0	Reactive power, Power factor	{1, yes}...	None	8	Right	Nominal
57	DANS_49_	Numeric	8	0	Presence of harmonics, flicker	{1, very little}...	None	8	Right	Scale
58	DANS_49_	Numeric	8	0	Power interruptions- short < 1 min	{1, very little}...	None	8	Right	Scale
59	DANS_49_	Numeric	8	0	Power interruptions- long > 1 min	{1, very little}...	None	8	Right	Scale
60	DANS_49_	Numeric	8	0	Voltage sags and swells	{1, very little}...	None	8	Right	Scale
61	DANS_49_	Numeric	8	0	Under voltage	{1, very little}...	None	8	Right	Scale
62	DANS_49_	Numeric	8	0	Over voltage	{1, very little}...	None	8	Right	Scale
63	DANS_49_	Numeric	8	0	Outage	{1, very little}...	None	8	Right	Scale
64	DANS_49_	Numeric	8	0	Transient, surge and unbalance	{1, very little}...	None	8	Right	Scale
65	DANS_49_	Numeric	8	0	Voltage collapse and voltage stability	{1, very little}...	None	8	Right	Scale
66	DANS_49_	Numeric	8	0	Low Power factor	{1, very little}...	None	8	Right	Scale
67	DMUTS_50	Numeric	8	0	Short interruption < 1 min	{1, not at all}...	None	8	Right	Scale
68	DMUTS_50	Numeric	8	0	Long interruption > 1 min	{1, not at all}...	None	8	Right	Scale
69	DMUTS_50	Numeric	8	0	Voltage sags and swells	{1, not at all}...	None	8	Right	Scale
70	DMUTS_50	Numeric	8	0	Transients and surge	{1, not at all}...	None	8	Right	Scale
71	DMUTS_50	Numeric	8	0	outage	{1, not at all}...	None	8	Right	Scale
72	DMUTS_50	Numeric	8	0	Harmonics	{1, not at all}...	None	8	Right	Scale
73	DMUTS_50	Numeric	8	0	Under and Over Voltage	{1, not at all}...	None	8	Right	Scale
74	DMUTS_50	Numeric	8	0	Unbalance load and missing of one phase	{1, not at all}...	None	8	Right	Scale
75	SH_51_1	Numeric	8	0	Back-up generators	{1, yes}...	None	8	Right	Nominal
76	SH_51_2	Numeric	8	0	Voltage stabilisers	{1, yes}...	None	8	Right	Nominal
77	SH_51_3	Numeric	8	0	UPS uninterruptible power supplies	{1, yes}...	None	8	Right	Nominal
78	SH_51_4	Numeric	8	0	Surge protectors	{1, yes}...	None	8	Right	Nominal
79	SH_51_5	Numeric	8	0	Harmonic filter passive	{1, yes}...	None	8	Right	Nominal
80	SH_51_6	Numeric	8	0	Static VAr compensator	{1, yes}...	None	8	Right	Nominal
81	SH_51_7	Numeric	8	0	Reactor or capacitor	{1, yes}...	None	8	Right	Nominal
82	PQSO	Numeric	8	0		None	None	8	Right	Scale
83	PQPM	Numeric	8	0		None	None	8	Right	Scale
84	PQMSOR	Numeric	8	0		None	None	8	Right	Scale
85	PQD	Numeric	8	0		None	None	8	Right	Scale
86	PQPAware	Numeric	8	0		None	None	8	Right	Scale
87	PQPTopm	Numeric	8	0		None	None	8	Right	Scale
88	PQPTopM	Numeric	8	0		None	None	8	Right	Scale
89	PQPResou	Numeric	8	0		None	None	8	Right	Scale
90	PQPInvolve	Numeric	8	0		None	None	8	Right	Scale
91	PQDNEW	Numeric	8	0		None	None	8	Right	Scale



	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure
91	PQDNEW	Numeric	8	0		None	None	8	Right	Scale
92	PQMCNE	Numeric	8	0		None	None	8	Right	Scale
93	PQETPNE	Numeric	8	0		None	None	8	Right	Scale
94	PQCCAW	Numeric	8	0		None	None	8	Right	Scale
95	PQDANNE	Numeric	8	0		None	None	8	Right	Scale
96	PQCSNE	Numeric	8	0		None	None	8	Right	Scale
97	CSnew	Numeric	8	0		{1, strongly disagree}...	None	8	Right	Scale
98	DAN	Numeric	8	0		{1, strongly disagree}...	None	8	Right	Scale
99	EE	Numeric	8	0		{1, strongly disagree}...	None	8	Right	Scale
100	BA1	Numeric	8	0	lack of staff awareness, skills and experience	{1, not applicable}...	None	8	Right	Scale
101	BA2	Numeric	8	0	lack of end users awareness	{1, not applicable}...	None	8	Right	Scale
102	BA3	Numeric	8	0	lack of customer cooperation	{1, not applicable}...	None	8	Right	Scale
103	BA4	Numeric	8	0	lack of long-term strategy and planning	{1, not applicable}...	None	8	Right	Scale
104	BA5	Numeric	8	0	lack of top management commitment	{1, not applicable}...	None	8	Right	Scale
105	BA6	Numeric	8	0	lack of network designing	{1, not applicable}...	None	8	Right	Scale
106	BA7	Numeric	8	0	lack of distribution networks infrastructure	{1, not applicable}...	None	8	Right	Scale
107	BA8	Numeric	8	0	lack of conducting research and studies	{1, not applicable}...	None	8	Right	Scale
108	BA9	Numeric	8	0	lack of top management responsibility	{1, not applicable}...	None	8	Right	Scale
109	BA10	Numeric	8	0	lack of training courses, education and support	{1, not applicable}...	None	8	Right	Scale
110	BA11	Numeric	8	0	lack of enough resources	{1, not applicable}...	None	8	Right	Scale
111	BA12	Numeric	8	0	lack of financial incentives	{1, not applicable}...	None	8	Right	Scale
112	BA13	Numeric	8	0	lack of PQ measurement	{1, not applicable}...	None	8	Right	Scale
113	BA14	Numeric	8	0	lack of PQ consultants	{1, not applicable}...	None	8	Right	Scale
114	BA15	Numeric	8	0	lack of PQ standards	{1, not applicable}...	None	8	Right	Scale
115	BA16	Numeric	8	0	lack of PQ monitoring and database	{1, not applicable}...	None	8	Right	Scale
116	BN1	Numeric	8	0	Increasing the end users awareness	{1, not sure}...	None	8	Right	Scale
117	BN2	Numeric	8	0	Increasing the end users satisfaction	{1, not sure}...	None	8	Right	Scale
118	BN3	Numeric	8	0	Improving PQ performance	{1, not sure}...	None	8	Right	Scale
119	BN4	Numeric	8	0	Reducing the end users complaints	{1, not sure}...	None	8	Right	Scale
120	BN5	Numeric	8	0	Monitor & Measuring PQ disturbances	{1, not sure}...	None	8	Right	Scale
121	BN6	Numeric	8	0	providing PQ diagnosis system and database	{1, not sure}...	None	8	Right	Scale
122	BN7	Numeric	8	0	Reducing the huge losses of PQ cost	{1, not sure}...	None	8	Right	Scale
123	BN8	Numeric	8	0	Increasing the top management awareness	{1, not sure}...	None	8	Right	Scale
124	BN9	Numeric	8	0	Increasing the employee skills and awareness	{1, not sure}...	None	8	Right	Scale
125	BN10	Numeric	8	0	Increasing PQ training courses	{1, not sure}...	None	8	Right	Scale
126	BN11	Numeric	8	0	Providing strategic planning	{1, not sure}...	None	8	Right	Scale
127	PQPAware	Numeric	8	0		None	None	8	Right	Scale
128	PQPTopM	Numeric	8	0		None	None	9	Right	Scale
129	PQPResou	Numeric	8	0		None	None	8	Right	Scale
130	PQPInvolve	Numeric	8	0		None	None	8	Right	Scale
131										
132										
133										
134										
135										
136										

Qualitative Data Respondents Coding



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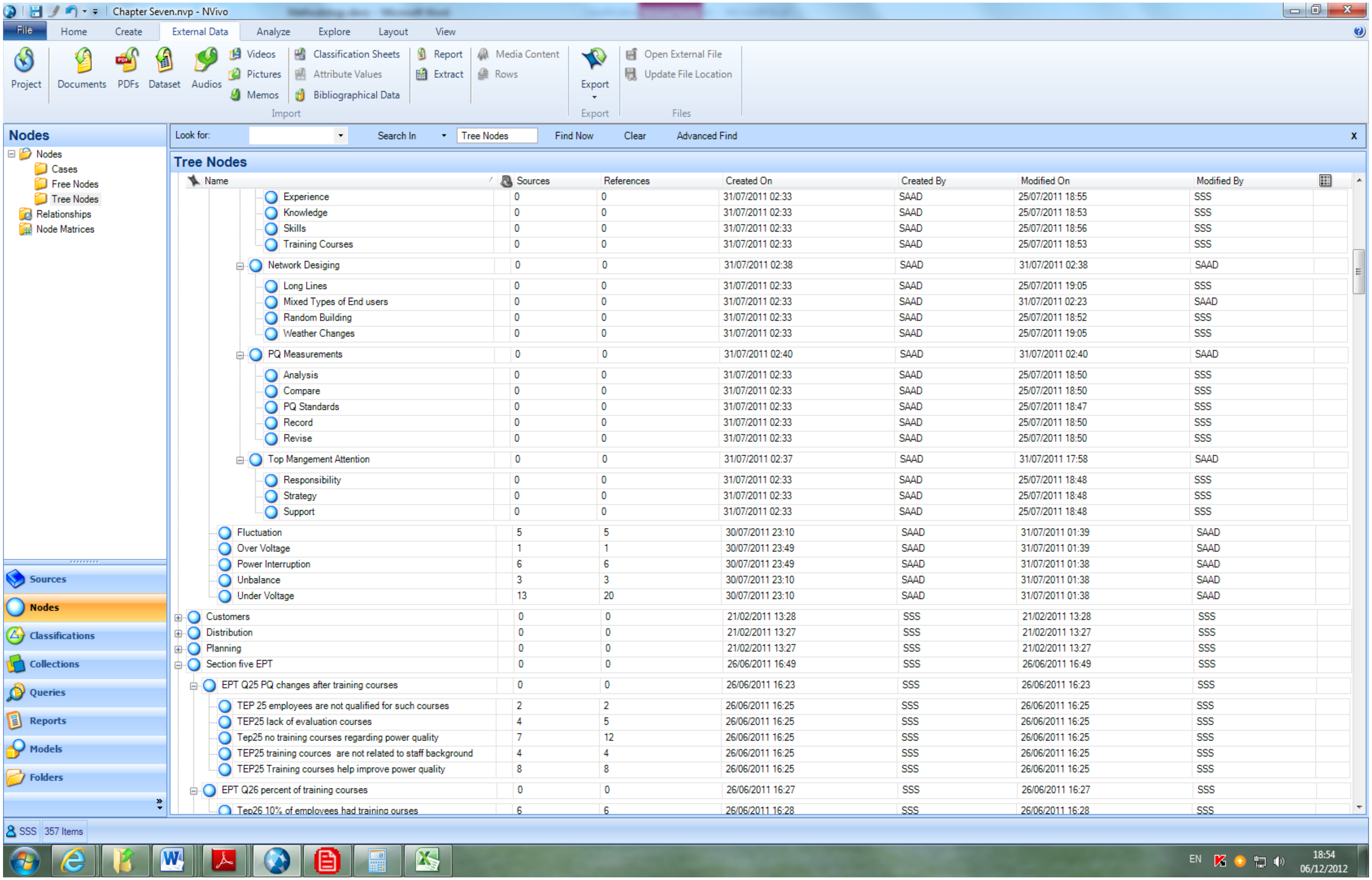
Lack of Customer Awareness	25	56	28/07/2011 15:37	SSS	25/12/2011 22:00	SAAD
Lack of Enough Resources	21	30	28/07/2011 15:40	SSS	25/12/2011 21:59	SAAD
Lack of Long Term Startegy	27	45	28/07/2011 15:37	SSS	25/12/2011 22:02	SAAD
Lack of Management Committment	27	45	28/07/2011 15:59	SSS	26/12/2011 18:49	SAAD
Lack of Networks Desiging	24	34	28/07/2011 15:38	SSS	25/12/2011 22:03	SAAD
Lack of PQ Measurement	15	19	28/07/2011 15:46	SSS	08/12/2011 19:50	SAAD
Lack of PQ Standards	26	48	28/07/2011 15:50	SSS	25/12/2011 23:47	SAAD
Lack of PQ Training Courses	15	24	28/07/2011 15:37	SSS	26/12/2011 18:56	SAAD
Lack of Regular Maintenance	13	16	28/07/2011 16:00	SSS	26/12/2011 18:49	SAAD
Lack of Staff Awareness	41	113	28/07/2011 15:37	SSS	25/12/2011 23:48	SAAD
Lack of Top Management Responsibility	11	18	28/07/2011 15:56	SSS	25/12/2011 23:49	SAAD
PQ Disturbances	0	0	28/07/2011 15:40	SSS	28/07/2011 15:40	SSS
PlanCS16 lack of voltage stability	2	2	28/07/2011 16:02	SSS	24/06/2011 19:02	SSS
PlanCS16 over voltage	1	1	28/07/2011 16:02	SSS	24/06/2011 19:02	SSS
PlanCS16 power interruption (2)	6	6	28/07/2011 16:02	SSS	30/06/2011 18:45	SSS
PlanCS16 voltage drop	8	11	28/07/2011 16:02	SSS	24/06/2011 19:02	SSS
PlanPGD22.C Fluctuation	5	5	28/07/2011 15:48	SSS	24/06/2011 20:02	SSS
PlanPGD22.C Unbalance	3	3	28/07/2011 15:48	SSS	24/06/2011 20:02	SSS
PlanPGD22.C under voltage	3	3	28/07/2011 15:48	SSS	24/06/2011 20:02	SSS
PlanPGD22.C voltage drop	4	4	28/07/2011 15:48	SSS	24/06/2011 20:02	SSS
PlanPGD22.C voltage problems	11	11	28/07/2011 15:48	SSS	24/06/2011 20:02	SSS
Causes of PQDs	0	0	25/07/2011 18:45	SSS	25/07/2011 18:45	SSS
PQ Disturbances	0	0	30/07/2011 23:55	SAAD	30/07/2011 23:55	SAAD
Causes of PQDs	0	0	31/07/2011 02:32	SAAD	31/07/2011 02:36	SAAD
Lack of Awareness of	0	0	31/07/2011 02:32	SAAD	31/07/2011 18:00	SAAD
Customer Cooperation	0	0	31/07/2011 02:38	SAAD	31/07/2011 18:00	SAAD
Awareness	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:47	SSS
Culture	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:48	SSS
Illegally Connection	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:52	SSS
Understanding PQ Definition	0	0	31/07/2011 02:43	SAAD	31/07/2011 18:03	SAAD
Employees Participation	0	0	31/07/2011 02:37	SAAD	31/07/2011 17:59	SAAD
Experience	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:55	SSS
Knowledge	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:53	SSS
Skills	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:56	SSS



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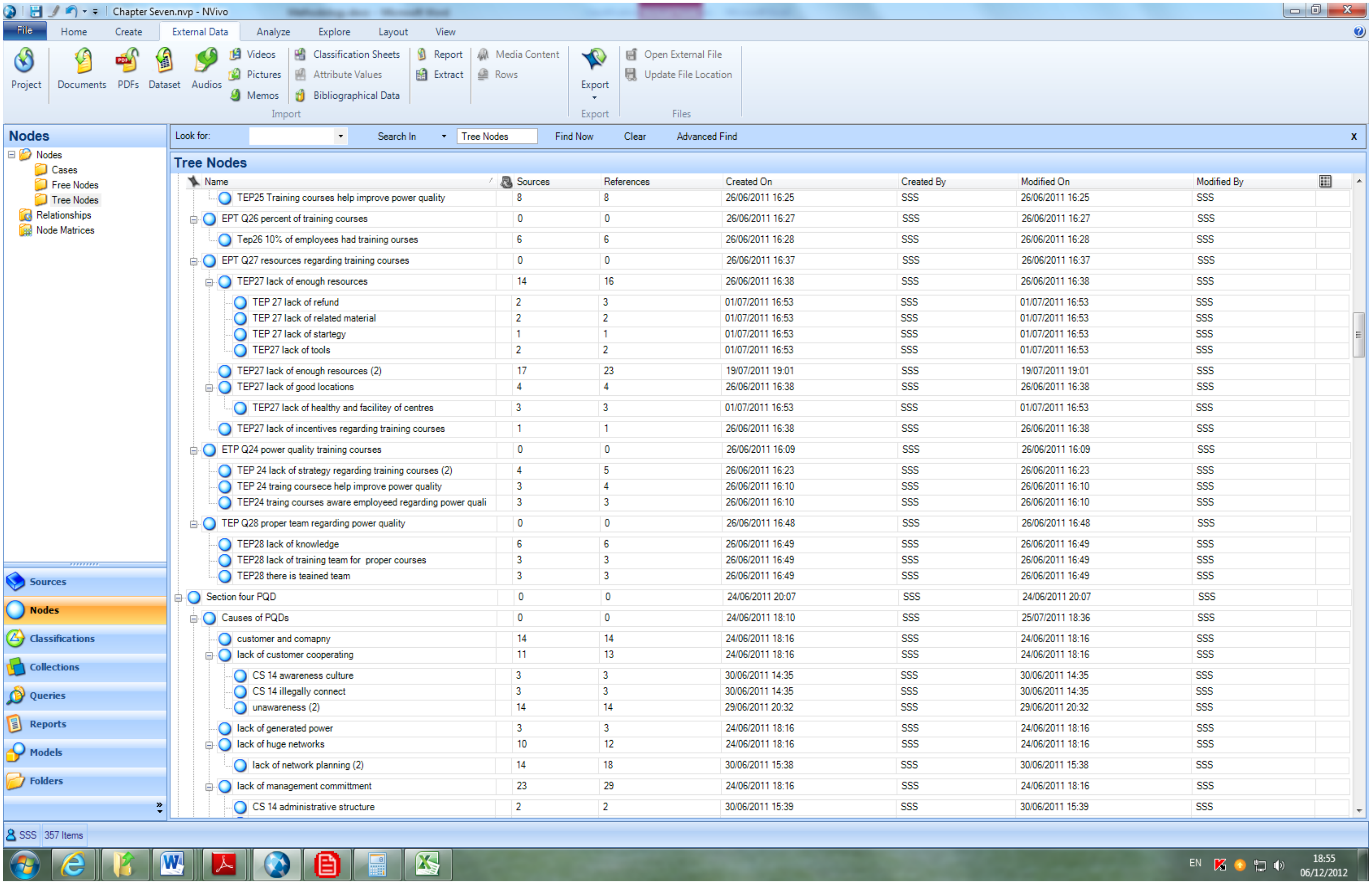
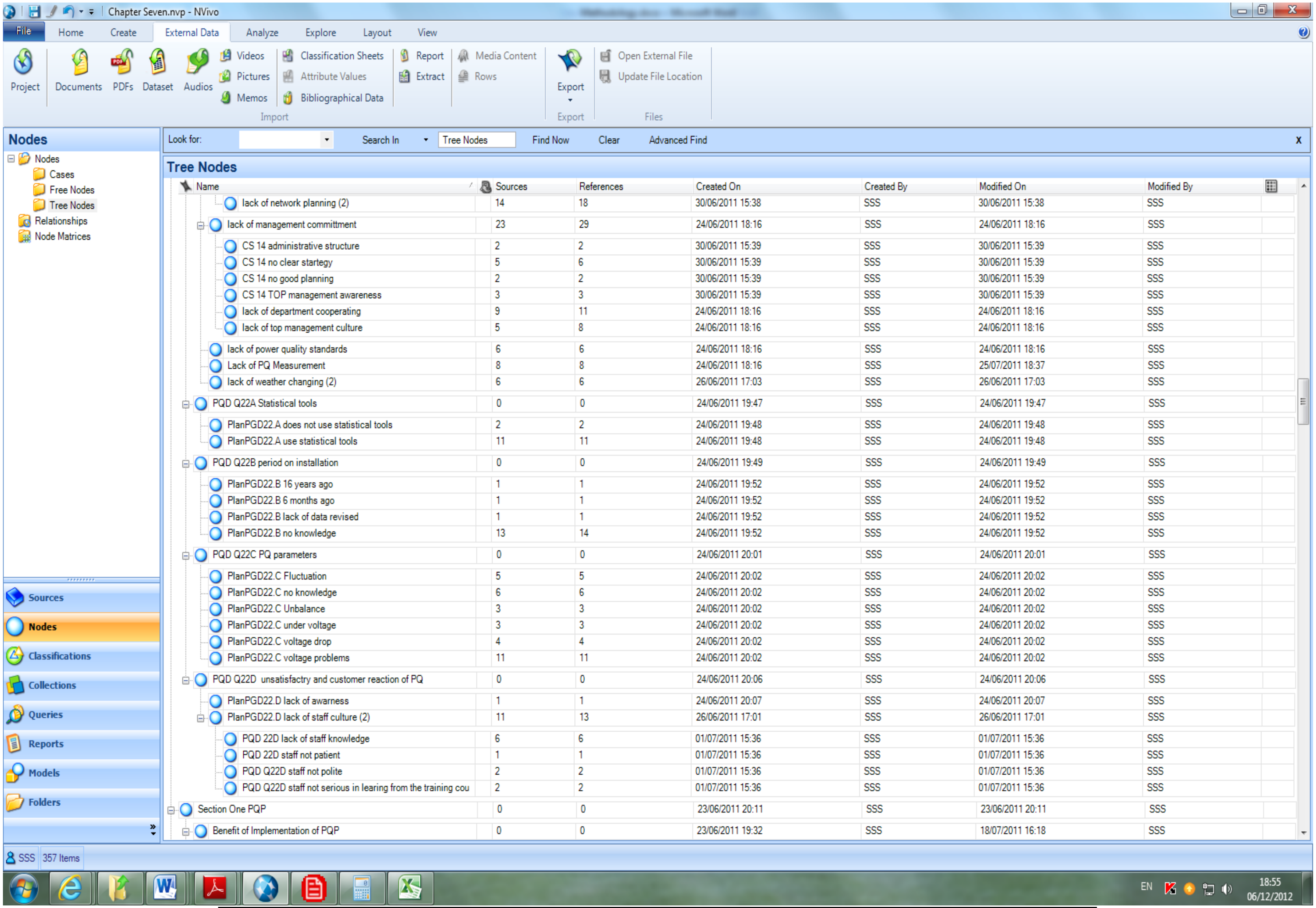
Knowledge	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:53	SSS
Skills	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:56	SSS
Training Courses	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:53	SSS
Network Desiging	0	0	31/07/2011 02:38	SAAD	31/07/2011 02:38	SAAD
Long Lines	0	0	31/07/2011 02:33	SAAD	25/07/2011 19:05	SSS
Mixed Types of End users	0	0	31/07/2011 02:33	SAAD	31/07/2011 02:23	SAAD
Random Building	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:52	SSS
Weather Changes	0	0	31/07/2011 02:33	SAAD	25/07/2011 19:05	SSS
PQ Measurements	0	0	31/07/2011 02:40	SAAD	31/07/2011 02:40	SAAD
Analysis	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:50	SSS
Compare	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:50	SSS
PQ Standards	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:47	SSS
Record	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:50	SSS
Revise	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:50	SSS
Top Mangement Attention	0	0	31/07/2011 02:37	SAAD	31/07/2011 17:58	SAAD
Responsibility	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:48	SSS
Strategy	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:48	SSS
Support	0	0	31/07/2011 02:33	SAAD	25/07/2011 18:48	SSS
Fluctuation	5	5	30/07/2011 23:10	SAAD	31/07/2011 01:39	SAAD
Over Voltage	1	1	30/07/2011 23:49	SAAD	31/07/2011 01:39	SAAD
Power Interruption	6	6	30/07/2011 23:49	SAAD	31/07/2011 01:38	SAAD
Unbalance	3	3	30/07/2011 23:10	SAAD	31/07/2011 01:38	SAAD
Under Voltage	13	20	30/07/2011 23:10	SAAD	31/07/2011 01:38	SAAD
Customers	0	0	21/02/2011 13:28	SSS	21/02/2011 13:28	SSS
Distribution	0	0	21/02/2011 13:27	SSS	21/02/2011 13:27	SSS
Planning	0	0	21/02/2011 13:27	SSS	21/02/2011 13:27	SSS
Section five EPT	0	0	26/06/2011 16:49	SSS	26/06/2011 16:49	SSS
EPT Q25 PQ changes after training courses	0	0	26/06/2011 16:23	SSS	26/06/2011 16:23	SSS
TEP 25 employees are not qualified for such courses	2	2	26/06/2011 16:25	SSS	26/06/2011 16:25	SSS
TEP25 lack of evaluation courses	4	5	26/06/2011 16:25	SSS	26/06/2011 16:25	SSS
Tep25 no training courses regarding power quality	7	12	26/06/2011 16:25	SSS	26/06/2011 16:25	SSS
TEP25 training cources are not related to staff background	4	4	26/06/2011 16:25	SSS	26/06/2011 16:25	SSS
TEP25 Training courses help improve power quality	8	8	26/06/2011 16:25	SSS	26/06/2011 16:25	SSS
EPT Q26 percent of training courses	0	0	26/06/2011 16:27	SSS	26/06/2011 16:27	SSS
Tep26 10% of employees had training ourses	6	6	26/06/2011 16:28	SSS	26/06/2011 16:28	SSS



Name	Sources	References	Created On	Created By	Modified On	Modified By
TEP25 Training courses help improve power quality	8	8	26/06/2011 16:25	SSS	26/06/2011 16:25	SSS
EPT Q26 percent of training courses	0	0	26/06/2011 16:27	SSS	26/06/2011 16:27	SSS
Tep26 10% of employees had training ourses	6	6	26/06/2011 16:28	SSS	26/06/2011 16:28	SSS
EPT Q27 resources regarding training courses	0	0	26/06/2011 16:37	SSS	26/06/2011 16:37	SSS
TEP27 lack of enough resources	14	16	26/06/2011 16:38	SSS	26/06/2011 16:38	SSS
TEP 27 lack of refund	2	3	01/07/2011 16:53	SSS	01/07/2011 16:53	SSS
TEP 27 lack of related material	2	2	01/07/2011 16:53	SSS	01/07/2011 16:53	SSS
TEP 27 lack of startegy	1	1	01/07/2011 16:53	SSS	01/07/2011 16:53	SSS
TEP27 lack of tools	2	2	01/07/2011 16:53	SSS	01/07/2011 16:53	SSS
TEP27 lack of enough resources (2)	17	23	19/07/2011 19:01	SSS	19/07/2011 19:01	SSS
TEP27 lack of good locations	4	4	26/06/2011 16:38	SSS	26/06/2011 16:38	SSS
TEP27 lack of healthy and facilitey of centres	3	3	01/07/2011 16:53	SSS	01/07/2011 16:53	SSS
TEP27 lack of incentives regarding training courses	1	1	26/06/2011 16:38	SSS	26/06/2011 16:38	SSS
ETP Q24 power quality training courses	0	0	26/06/2011 16:09	SSS	26/06/2011 16:09	SSS
TEP 24 lack of strategy regarding training courses (2)	4	5	26/06/2011 16:23	SSS	26/06/2011 16:23	SSS
TEP 24 traing coursece help improve power quality	3	4	26/06/2011 16:10	SSS	26/06/2011 16:10	SSS
TEP24 traing courses aware employeed regarding power quali	3	3	26/06/2011 16:10	SSS	26/06/2011 16:10	SSS
TEP Q28 proper team regarding power quality	0	0	26/06/2011 16:48	SSS	26/06/2011 16:48	SSS
TEP28 lack of knowledge	6	6	26/06/2011 16:49	SSS	26/06/2011 16:49	SSS
TEP28 lack of training team for proper courses	3	3	26/06/2011 16:49	SSS	26/06/2011 16:49	SSS
TEP28 there is teained team	3	3	26/06/2011 16:49	SSS	26/06/2011 16:49	SSS
Section four PQD	0	0	24/06/2011 20:07	SSS	24/06/2011 20:07	SSS
Causes of PQDs	0	0	24/06/2011 18:10	SSS	25/07/2011 18:36	SSS
customer and comapny	14	14	24/06/2011 18:16	SSS	24/06/2011 18:16	SSS
lack of customer cooperating	11	13	24/06/2011 18:16	SSS	24/06/2011 18:16	SSS
CS 14 awareness culture	3	3	30/06/2011 14:35	SSS	30/06/2011 14:35	SSS
CS 14 illegally connect	3	3	30/06/2011 14:35	SSS	30/06/2011 14:35	SSS
unawareness (2)	14	14	29/06/2011 20:32	SSS	29/06/2011 20:32	SSS
lack of generated power	3	3	24/06/2011 18:16	SSS	24/06/2011 18:16	SSS
lack of huge networks	10	12	24/06/2011 18:16	SSS	24/06/2011 18:16	SSS
lack of network planning (2)	14	18	30/06/2011 15:38	SSS	30/06/2011 15:38	SSS
lack of management committment	23	29	24/06/2011 18:16	SSS	24/06/2011 18:16	SSS
CS 14 administrative structure	2	2	30/06/2011 15:39	SSS	30/06/2011 15:39	SSS



Chapter Seven.nvp - NVivo
File Home Create External Data Analyze Explore Layout View
Project Documents PDFs Dataset Audios Videos Pictures Memos Classification Sheets Attribute Values Bibliographical Data Report Extract Media Content Rows Export Open External File Update File Location
Import Export Files
Nodes
Nodes Cases Free Nodes Tree Nodes Relationships Node Matrices
Look for: Search In Tree Nodes Find Now Clear Advanced Find
Tree Nodes
Name Sources References Created On Created By Modified On Modified By
lack of network planning (2) 14 18 30/06/2011 15:38 SSS 30/06/2011 15:38 SSS
lack of management committment 23 29 24/06/2011 18:16 SSS 24/06/2011 18:16 SSS
CS 14 administrative structure 2 2 30/06/2011 15:39 SSS 30/06/2011 15:39 SSS
CS 14 no clear startegy 5 6 30/06/2011 15:39 SSS 30/06/2011 15:39 SSS
CS 14 no good planning 2 2 30/06/2011 15:39 SSS 30/06/2011 15:39 SSS
CS 14 TOP management awareness 3 3 30/06/2011 15:39 SSS 30/06/2011 15:39 SSS
lack of department cooperating 9 11 24/06/2011 18:16 SSS 24/06/2011 18:16 SSS
lack of top management culture 5 8 24/06/2011 18:16 SSS 24/06/2011 18:16 SSS
lack of power quality standards 6 6 24/06/2011 18:16 SSS 24/06/2011 18:16 SSS
Lack of PQ Measurement 8 8 24/06/2011 18:16 SSS 25/07/2011 18:37 SSS
lack of weather changing (2) 6 6 26/06/2011 17:03 SSS 26/06/2011 17:03 SSS
PQD Q22A Statistical tools 0 0 24/06/2011 19:47 SSS 24/06/2011 19:47 SSS
PlanPGD22.A does not use statistical tools 2 2 24/06/2011 19:48 SSS 24/06/2011 19:48 SSS
PlanPGD22.A use statistical tools 11 11 24/06/2011 19:48 SSS 24/06/2011 19:48 SSS
PQD Q22B period on installation 0 0 24/06/2011 19:49 SSS 24/06/2011 19:49 SSS
PlanPGD22.B 16 years ago 1 1 24/06/2011 19:52 SSS 24/06/2011 19:52 SSS
PlanPGD22.B 6 months ago 1 1 24/06/2011 19:52 SSS 24/06/2011 19:52 SSS
PlanPGD22.B lack of data revised 1 1 24/06/2011 19:52 SSS 24/06/2011 19:52 SSS
PlanPGD22.B no knowledge 13 14 24/06/2011 19:52 SSS 24/06/2011 19:52 SSS
PQD Q22C PQ parameters 0 0 24/06/2011 20:01 SSS 24/06/2011 20:01 SSS
PlanPGD22.C Fluctuation 5 5 24/06/2011 20:02 SSS 24/06/2011 20:02 SSS
PlanPGD22.C no knowledge 6 6 24/06/2011 20:02 SSS 24/06/2011 20:02 SSS
PlanPGD22.C Unbalance 3 3 24/06/2011 20:02 SSS 24/06/2011 20:02 SSS
PlanPGD22.C under voltage 3 3 24/06/2011 20:02 SSS 24/06/2011 20:02 SSS
PlanPGD22.C voltage drop 4 4 24/06/2011 20:02 SSS 24/06/2011 20:02 SSS
PlanPGD22.C voltage problems 11 11 24/06/2011 20:02 SSS 24/06/2011 20:02 SSS
PQD Q22D unsatisfactry and customer reaction of PQ 0 0 24/06/2011 20:06 SSS 24/06/2011 20:06 SSS
PlanPGD22.D lack of awarness 1 1 24/06/2011 20:07 SSS 24/06/2011 20:07 SSS
PlanPGD22.D lack of staff culture (2) 11 13 26/06/2011 17:01 SSS 26/06/2011 17:01 SSS
PQD 22D lack of staff knowledge 6 6 01/07/2011 15:36 SSS 01/07/2011 15:36 SSS
PQD 22D staff not patient 1 1 01/07/2011 15:36 SSS 01/07/2011 15:36 SSS
PQD Q22D staff not polite 2 2 01/07/2011 15:36 SSS 01/07/2011 15:36 SSS
PQD Q22D staff not serious in learing from the training cou 2 2 01/07/2011 15:36 SSS 01/07/2011 15:36 SSS
Section One PQP 0 0 23/06/2011 20:11 SSS 23/06/2011 20:11 SSS
Benefit of Implementation of PQP 0 0 23/06/2011 19:32 SSS 18/07/2011 16:18 SSS
Sources
Nodes
Classifications
Collections
Queries
Reports
Models
Folders
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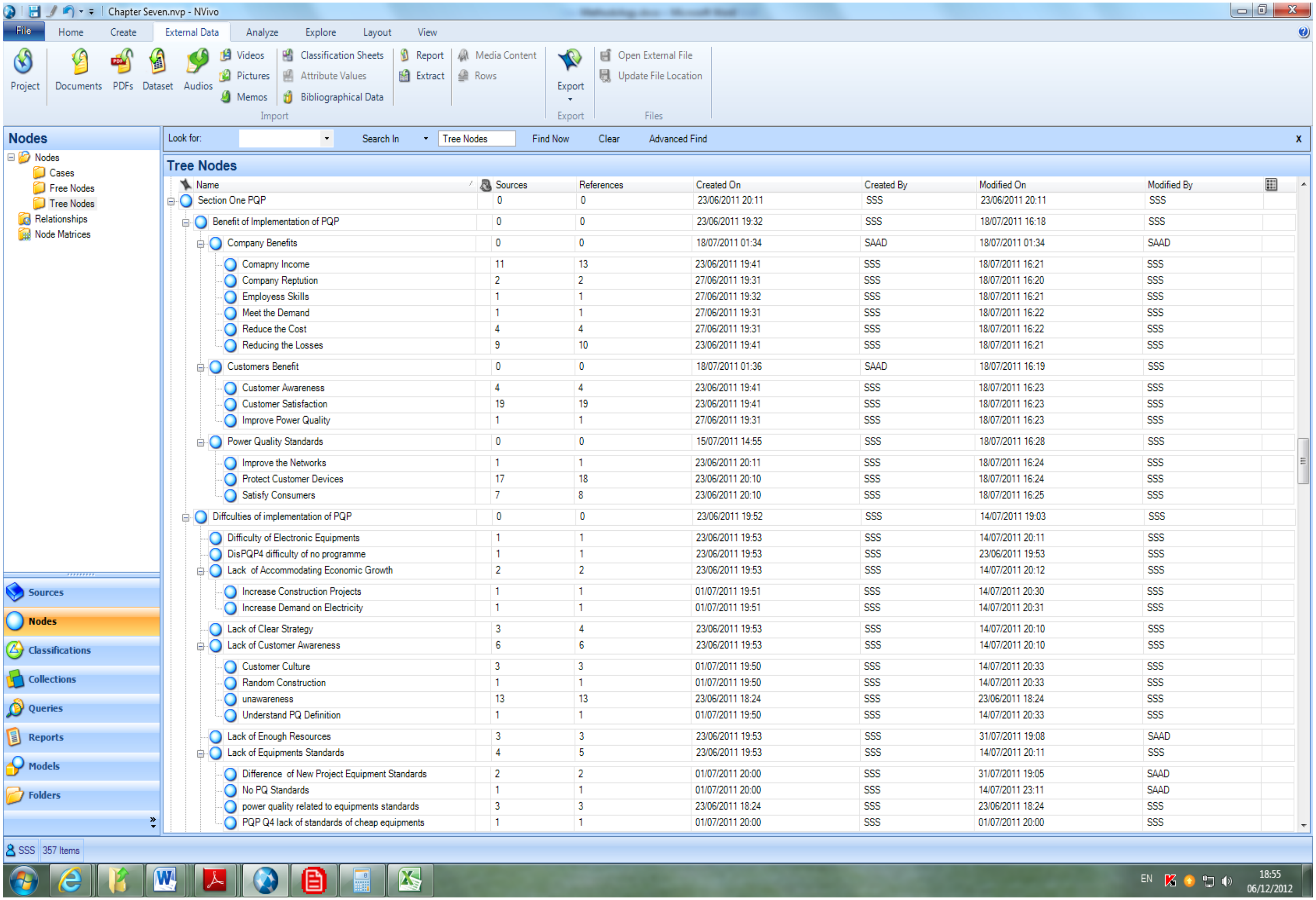
EN 18:55 06/12/2012



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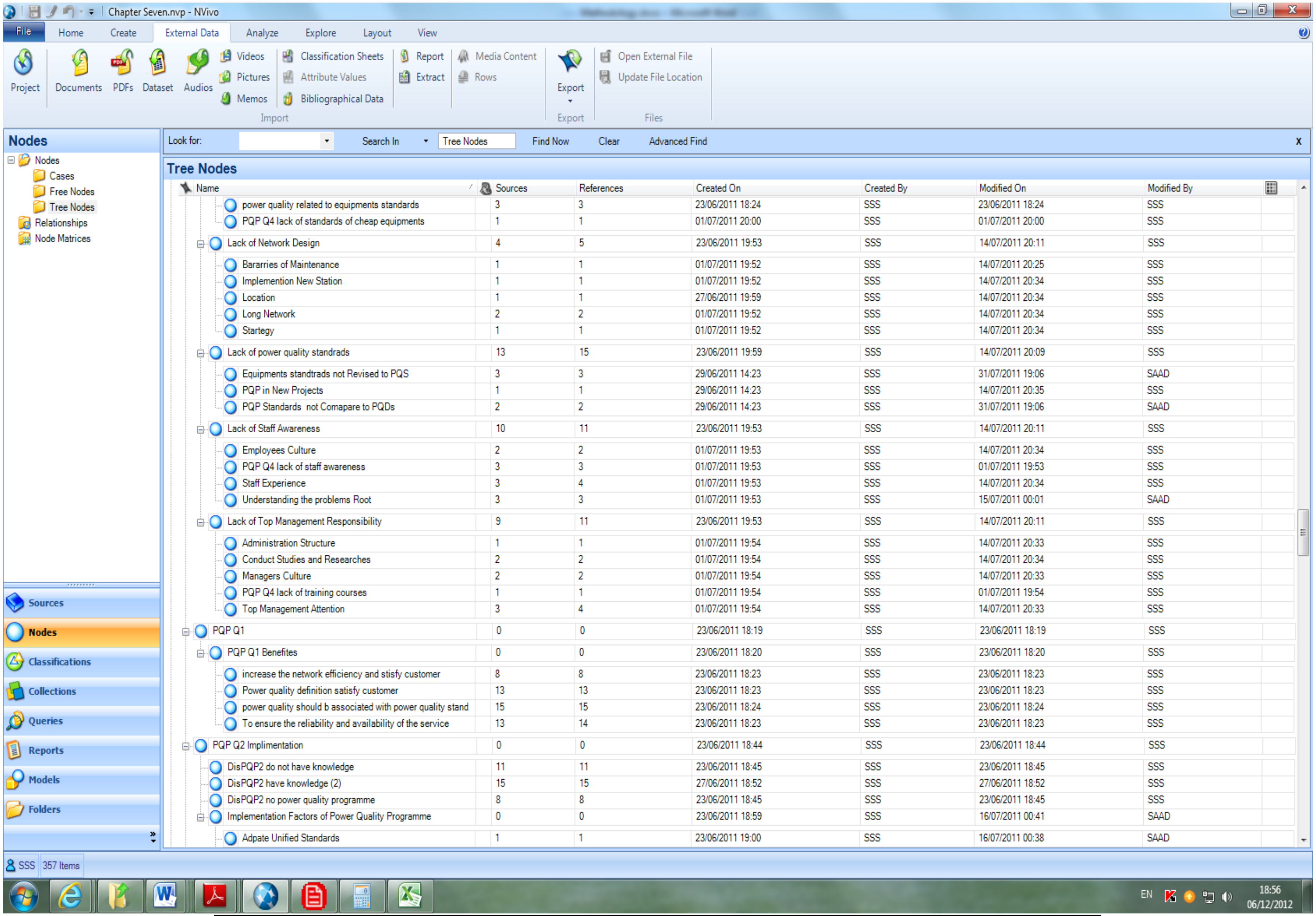
Company Benefits	0	0	18/07/2011 01:34	SAAD	18/07/2011 01:34	SAAD
Comapny Income	11	13	23/06/2011 19:41	SSS	18/07/2011 16:21	SSS
Company Reptution	2	2	27/06/2011 19:31	SSS	18/07/2011 16:20	SSS
Employess Skills	1	1	27/06/2011 19:32	SSS	18/07/2011 16:21	SSS
Meet the Demand	1	1	27/06/2011 19:31	SSS	18/07/2011 16:22	SSS
Reduce the Cost	4	4	27/06/2011 19:31	SSS	18/07/2011 16:22	SSS
Reducing the Losses	9	10	23/06/2011 19:41	SSS	18/07/2011 16:21	SSS
Customers Benefit	0	0	18/07/2011 01:36	SAAD	18/07/2011 16:19	SSS
Customer Awareness	4	4	23/06/2011 19:41	SSS	18/07/2011 16:23	SSS
Customer Satisfaction	19	19	23/06/2011 19:41	SSS	18/07/2011 16:23	SSS
Improve Power Quality	1	1	27/06/2011 19:31	SSS	18/07/2011 16:23	SSS
Power Quality Standards	0	0	15/07/2011 14:55	SSS	18/07/2011 16:28	SSS
Improve the Networks	1	1	23/06/2011 20:11	SSS	18/07/2011 16:24	SSS
Protect Customer Devices	17	18	23/06/2011 20:10	SSS	18/07/2011 16:24	SSS
Satisfy Consumers	7	8	23/06/2011 20:10	SSS	18/07/2011 16:25	SSS
Difficulties of implementation of PQP	0	0	23/06/2011 19:52	SSS	14/07/2011 19:03	SSS
Difficulty of Electronic Equipments	1	1	23/06/2011 19:53	SSS	14/07/2011 20:11	SSS
DisPQP4 difficulty of no programme	1	1	23/06/2011 19:53	SSS	23/06/2011 19:53	SSS
Lack of Accommodating Economic Growth	2	2	23/06/2011 19:53	SSS	14/07/2011 20:12	SSS
Increase Construction Projects	1	1	01/07/2011 19:51	SSS	14/07/2011 20:30	SSS
Increase Demand on Electricity	1	1	01/07/2011 19:51	SSS	14/07/2011 20:31	SSS
Lack of Clear Strategy	3	4	23/06/2011 19:53	SSS	14/07/2011 20:10	SSS
Lack of Customer Awareness	6	6	23/06/2011 19:53	SSS	14/07/2011 20:10	SSS
Customer Culture	3	3	01/07/2011 19:50	SSS	14/07/2011 20:33	SSS
Random Construction	1	1	01/07/2011 19:50	SSS	14/07/2011 20:33	SSS
unawareness	13	13	23/06/2011 18:24	SSS	23/06/2011 18:24	SSS
Understand PQ Definition	1	1	01/07/2011 19:50	SSS	14/07/2011 20:33	SSS
Lack of Enough Resources	3	3	23/06/2011 19:53	SSS	31/07/2011 19:08	SAAD
Lack of Equipments Standards	4	5	23/06/2011 19:53	SSS	14/07/2011 20:11	SSS
Difference of New Project Equipment Standards	2	2	01/07/2011 20:00	SSS	31/07/2011 19:05	SAAD
No PQ Standards	1	1	01/07/2011 20:00	SSS	14/07/2011 23:11	SAAD
power quality related to equipments standards	3	3	23/06/2011 18:24	SSS	23/06/2011 18:24	SSS
PQP Q4 lack of standards of cheap equipments	1	1	01/07/2011 20:00	SSS	01/07/2011 20:00	SSS



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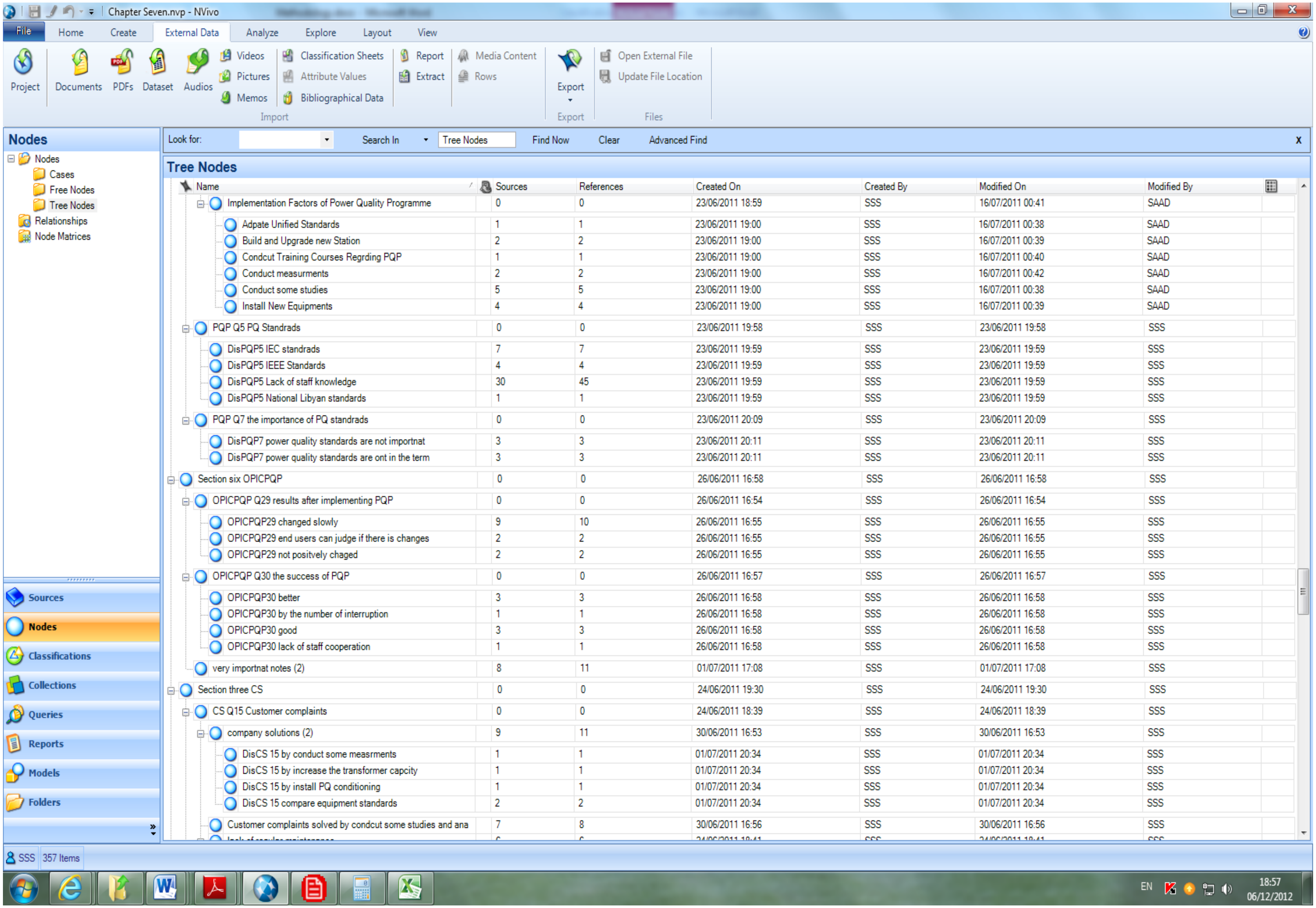
power quality related to equipments standards	3	3	23/06/2011 18:24	SSS	23/06/2011 18:24	SSS
PQP Q4 lack of standards of cheap equipments	1	1	01/07/2011 20:00	SSS	01/07/2011 20:00	SSS
Lack of Network Design	4	5	23/06/2011 19:53	SSS	14/07/2011 20:11	SSS
Bararries of Maintenance	1	1	01/07/2011 19:52	SSS	14/07/2011 20:25	SSS
Implemention New Station	1	1	01/07/2011 19:52	SSS	14/07/2011 20:34	SSS
Location	1	1	27/06/2011 19:59	SSS	14/07/2011 20:34	SSS
Long Network	2	2	01/07/2011 19:52	SSS	14/07/2011 20:34	SSS
Startegy	1	1	01/07/2011 19:52	SSS	14/07/2011 20:34	SSS
Lack of power quality standrads	13	15	23/06/2011 19:59	SSS	14/07/2011 20:09	SSS
Equipments standtrads not Revised to PQS	3	3	29/06/2011 14:23	SSS	31/07/2011 19:06	SAAD
PQP in New Projects	1	1	29/06/2011 14:23	SSS	14/07/2011 20:35	SSS
PQP Standards not Compare to PQDs	2	2	29/06/2011 14:23	SSS	31/07/2011 19:06	SAAD
Lack of Staff Awareness	10	11	23/06/2011 19:53	SSS	14/07/2011 20:11	SSS
Employees Culture	2	2	01/07/2011 19:53	SSS	14/07/2011 20:34	SSS
PQP Q4 lack of staff awareness	3	3	01/07/2011 19:53	SSS	01/07/2011 19:53	SSS
Staff Experience	3	4	01/07/2011 19:53	SSS	14/07/2011 20:34	SSS
Understanding the problems Root	3	3	01/07/2011 19:53	SSS	15/07/2011 00:01	SAAD
Lack of Top Management Responsibility	9	11	23/06/2011 19:53	SSS	14/07/2011 20:11	SSS
Administration Structure	1	1	01/07/2011 19:54	SSS	14/07/2011 20:33	SSS
Conduct Studies and Researches	2	2	01/07/2011 19:54	SSS	14/07/2011 20:34	SSS
Managers Culture	2	2	01/07/2011 19:54	SSS	14/07/2011 20:33	SSS
PQP Q4 lack of training courses	1	1	01/07/2011 19:54	SSS	01/07/2011 19:54	SSS
Top Management Attention	3	4	01/07/2011 19:54	SSS	14/07/2011 20:33	SSS
PQP Q1	0	0	23/06/2011 18:19	SSS	23/06/2011 18:19	SSS
PQP Q1 Benefites	0	0	23/06/2011 18:20	SSS	23/06/2011 18:20	SSS
increase the network efficiency and stisfy customer	8	8	23/06/2011 18:23	SSS	23/06/2011 18:23	SSS
Power quality definition satisfy customer	13	13	23/06/2011 18:23	SSS	23/06/2011 18:23	SSS
power quality should b associated with power quality stand	15	15	23/06/2011 18:24	SSS	23/06/2011 18:24	SSS
To ensure the reliability and availability of the service	13	14	23/06/2011 18:23	SSS	23/06/2011 18:23	SSS
PQP Q2 Implimentation	0	0	23/06/2011 18:44	SSS	23/06/2011 18:44	SSS
DisPQP2 do not have knowledge	11	11	23/06/2011 18:45	SSS	23/06/2011 18:45	SSS
DisPQP2 have knowledge (2)	15	15	27/06/2011 18:52	SSS	27/06/2011 18:52	SSS
DisPQP2 no power quality programme	8	8	23/06/2011 18:45	SSS	23/06/2011 18:45	SSS
Implementation Factors of Power Quality Programme	0	0	23/06/2011 18:59	SSS	16/07/2011 00:41	SAAD
Adpate Unified Standards	1	1	23/06/2011 19:00	SSS	16/07/2011 00:38	SAAD



Name	Sources	References	Created On	Created By	Modified On	Modified By
Implementation Factors of Power Quality Programme	0	0	23/06/2011 18:59	SSS	16/07/2011 00:41	SAAD
Adpate Unified Standards	1	1	23/06/2011 19:00	SSS	16/07/2011 00:38	SAAD
Build and Upgrade new Station	2	2	23/06/2011 19:00	SSS	16/07/2011 00:39	SAAD
Condcut Training Courses Regrding PQP	1	1	23/06/2011 19:00	SSS	16/07/2011 00:40	SAAD
Conduct measurments	2	2	23/06/2011 19:00	SSS	16/07/2011 00:42	SAAD
Conduct some studies	5	5	23/06/2011 19:00	SSS	16/07/2011 00:38	SAAD
Install New Equipments	4	4	23/06/2011 19:00	SSS	16/07/2011 00:39	SAAD
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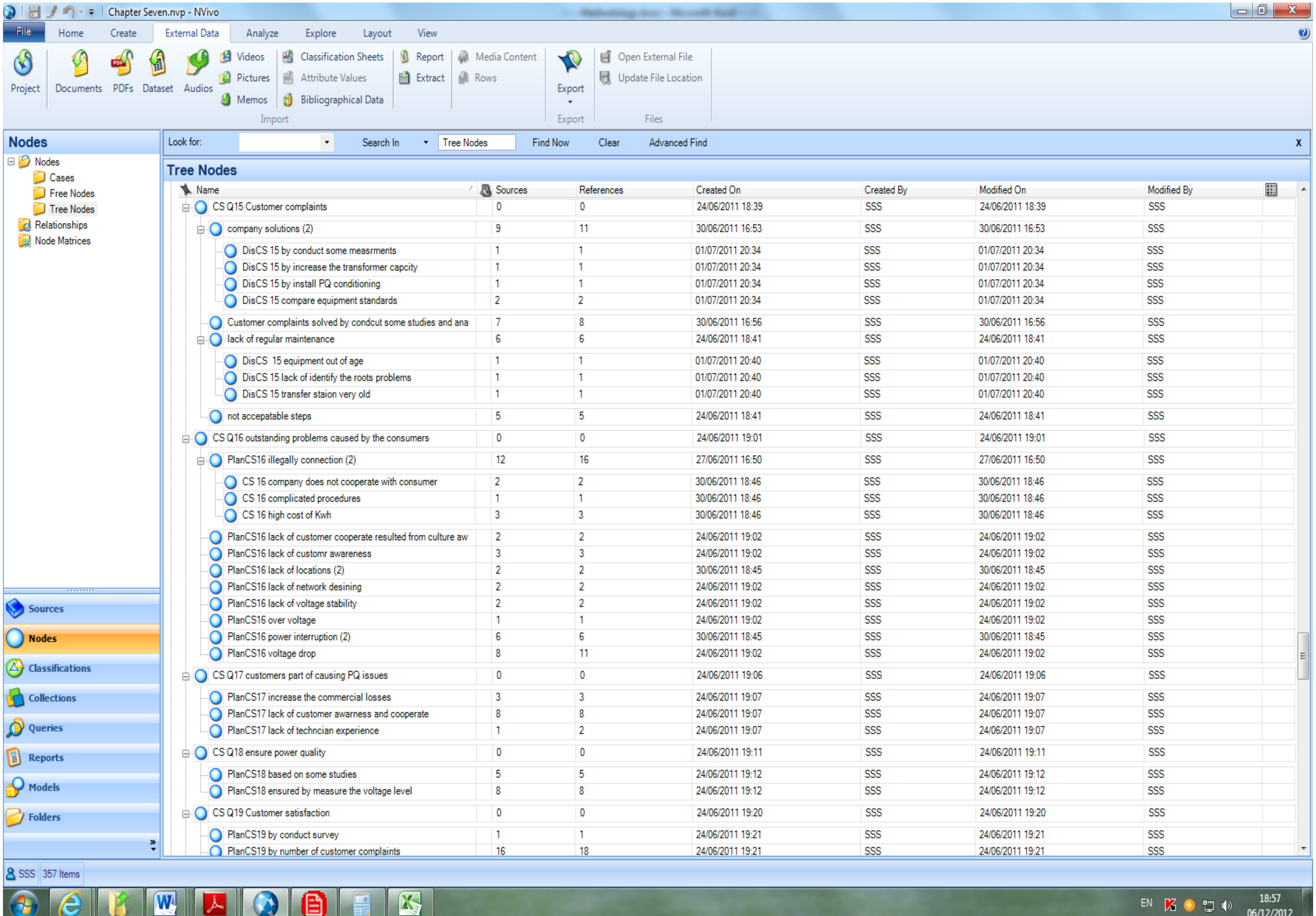
DisPQP5 IEC standrads	7	7	23/06/2011 19:59	SSS	23/06/2011 19:59	SSS
DisPQP5 IEEE Standards	4	4	23/06/2011 19:59	SSS	23/06/2011 19:59	SSS
DisPQP5 Lack of staff knowledge	30	45	23/06/2011 19:59	SSS	23/06/2011 19:59	SSS
DisPQP5 National Libyan standards	1	1	23/06/2011 19:59	SSS	23/06/2011 19:59	SSS
PQP Q7 the importance of PQ standrads	0	0	23/06/2011 20:09	SSS	23/06/2011 20:09	SSS
DisPQP7 power quality standards are not importnat	3	3	23/06/2011 20:11	SSS	23/06/2011 20:11	SSS
DisPQP7 power quality standards are ont in the term	3	3	23/06/2011 20:11	SSS	23/06/2011 20:11	SSS
Section six OPICPQP	0	0	26/06/2011 16:58	SSS	26/06/2011 16:58	SSS
OPICPQP Q29 results after implementing PQP	0	0	26/06/2011 16:54	SSS	26/06/2011 16:54	SSS
OPICPQP29 changed slowly	9	10	26/06/2011 16:55	SSS	26/06/2011 16:55	SSS
OPICPQP29 end users can judge if there is changes	2	2	26/06/2011 16:55	SSS	26/06/2011 16:55	SSS
OPICPQP29 not positvely chaged	2	2	26/06/2011 16:55	SSS	26/06/2011 16:55	SSS
OPICPQP Q30 the success of PQP	0	0	26/06/2011 16:57	SSS	26/06/2011 16:57	SSS
OPICPQP30 better	3	3	26/06/2011 16:58	SSS	26/06/2011 16:58	SSS
OPICPQP30 by the number of interruption	1	1	26/06/2011 16:58	SSS	26/06/2011 16:58	SSS
OPICPQP30 good	3	3	26/06/2011 16:58	SSS	26/06/2011 16:58	SSS
OPICPQP30 lack of staff cooperation	1	1	26/06/2011 16:58	SSS	26/06/2011 16:58	SSS
very importnat notes (2)	8	11	01/07/2011 17:08	SSS	01/07/2011 17:08	SSS
Section three CS	0	0	24/06/2011 19:30	SSS	24/06/2011 19:30	SSS
CS Q15 Customer complaints	0	0	24/06/2011 18:39	SSS	24/06/2011 18:39	SSS
company solutions (2)	9	11	30/06/2011 16:53	SSS	30/06/2011 16:53	SSS
DisCS 15 by conduct some measrments	1	1	01/07/2011 20:34	SSS	01/07/2011 20:34	SSS
DisCS 15 by increase the transformer capcity	1	1	01/07/2011 20:34	SSS	01/07/2011 20:34	SSS
DisCS 15 by install PQ conditioning	1	1	01/07/2011 20:34	SSS	01/07/2011 20:34	SSS
DisCS 15 compare equipment standards	2	2	01/07/2011 20:34	SSS	01/07/2011 20:34	SSS
Customer complaints solved by condcut some studies and ana	7	8	30/06/2011 16:56	SSS	30/06/2011 16:56	SSS


Chapter Seven.nvp - NVivo
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Project Documents PDFs Dataset Audios Videos Pictures Memos Classification Sheets Attribute Values Bibliographical Data Report Extract Media Content Rows Import
Export Export
Open External File Update File Location Files
Nodes
Nodes Cases Free Nodes Tree Nodes Relationships Node Matrices
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Name Sources References Created On Created By Modified On Modified By
CS Q15 Customer complaints 0 0 24/06/2011 18:39 SSS 24/06/2011 18:39 SSS
company solutions (2) 9 11 30/06/2011 16:53 SSS 30/06/2011 16:53 SSS
DisCS 15 by conduct some measrments 1 1 01/07/2011 20:34 SSS 01/07/2011 20:34 SSS
DisCS 15 by increase the transformer capcity 1 1 01/07/2011 20:34 SSS 01/07/2011 20:34 SSS
DisCS 15 by install PQ conditioning 1 1 01/07/2011 20:34 SSS 01/07/2011 20:34 SSS
DisCS 15 compare equipment standards 2 2 01/07/2011 20:34 SSS 01/07/2011 20:34 SSS
Customer complaints solved by condcut some studies and ana 7 8 30/06/2011 16:56 SSS 30/06/2011 16:56 SSS
lack of regular maintenance 6 6 24/06/2011 18:41 SSS 24/06/2011 18:41 SSS
DisCS 15 equipment out of age 1 1 01/07/2011 20:40 SSS 01/07/2011 20:40 SSS
DisCS 15 lack of identify the roots problems 1 1 01/07/2011 20:40 SSS 01/07/2011 20:40 SSS
DisCS 15 transfer staion very old 1 1 01/07/2011 20:40 SSS 01/07/2011 20:40 SSS
not accepatable steps 5 5 24/06/2011 18:41 SSS 24/06/2011 18:41 SSS
CS Q16 outstanding problems caused by the consumers 0 0 24/06/2011 19:01 SSS 24/06/2011 19:01 SSS
PlanCS16 illegally connection (2) 12 16 27/06/2011 16:50 SSS 27/06/2011 16:50 SSS
CS 16 company does not cooperate with consumer 2 2 30/06/2011 18:46 SSS 30/06/2011 18:46 SSS
CS 16 complicated procedures 1 1 30/06/2011 18:46 SSS 30/06/2011 18:46 SSS
CS 16 high cost of Kwh 3 3 30/06/2011 18:46 SSS 30/06/2011 18:46 SSS
PlanCS16 lack of customer cooperate resulted from culture aw 2 2 24/06/2011 19:02 SSS 24/06/2011 19:02 SSS
PlanCS16 lack of customr awareness 3 3 24/06/2011 19:02 SSS 24/06/2011 19:02 SSS
PlanCS16 lack of locations (2) 2 2 30/06/2011 18:45 SSS 30/06/2011 18:45 SSS
PlanCS16 lack of network desining 2 2 24/06/2011 19:02 SSS 24/06/2011 19:02 SSS
PlanCS16 lack of voltage stability 2 2 24/06/2011 19:02 SSS 24/06/2011 19:02 SSS
PlanCS16 over voltage 1 1 24/06/2011 19:02 SSS 24/06/2011 19:02 SSS
PlanCS16 power interruption (2) 6 6 30/06/2011 18:45 SSS 30/06/2011 18:45 SSS
PlanCS16 voltage drop 8 11 24/06/2011 19:02 SSS 24/06/2011 19:02 SSS
CS Q17 customers part of causing PQ issues 0 0 24/06/2011 19:06 SSS 24/06/2011 19:06 SSS
PlanCS17 increase the commercial losses 3 3 24/06/2011 19:07 SSS 24/06/2011 19:07 SSS
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CS Q18 ensure power quality 0 0 24/06/2011 19:11 SSS 24/06/2011 19:11 SSS
PlanCS18 based on some studies 5 5 24/06/2011 19:12 SSS 24/06/2011 19:12 SSS
PlanCS18 ensured by measure the voltage level 8 8 24/06/2011 19:12 SSS 24/06/2011 19:12 SSS
CS Q19 Customer satisfaction 0 0 24/06/2011 19:20 SSS 24/06/2011 19:20 SSS
PlanCS19 by conduct survey 1 1 24/06/2011 19:21 SSS 24/06/2011 19:21 SSS
PlanCS19 by number of customer complaints 16 18 24/06/2011 19:21 SSS 24/06/2011 19:21 SSS
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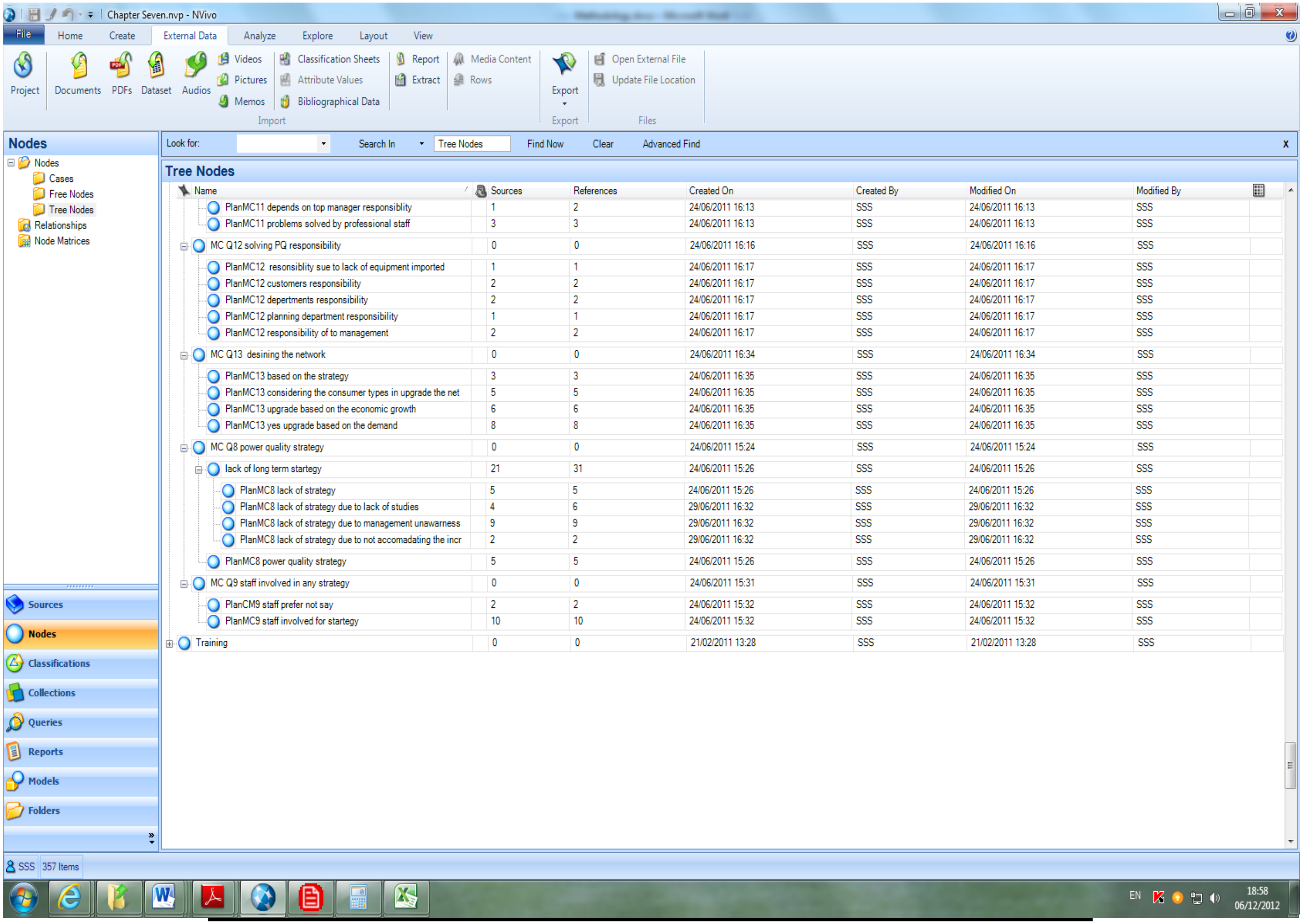
Chapter Seven.nvp - NVivo
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Home
Create
External Data
Analyze
Explore
Layout
View
Project
Documents
PDFs
Dataset
Audios
Videos
Pictures
Memos
Classification Sheets
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Bibliographical Data
Report
Extract
Media Content
Rows
Import
Export
Open External File
Update File Location
Files
Nodes
Cases
Free Nodes
Tree Nodes
Relationships
Node Matrices
Look for:
Search In
Tree Nodes
Find Now
Clear
Advanced Find
Tree Nodes
Name
Sources
References
Created On
Created By
Modified On
Modified By
PlanMC11 depends on top manager responsiblity 1 2 24/06/2011 16:13 SSS 24/06/2011 16:13 SSS
PlanMC11 problems solved by professional staff 3 3 24/06/2011 16:13 SSS 24/06/2011 16:13 SSS
MC Q12 solving PQ responsibility 0 0 24/06/2011 16:16 SSS 24/06/2011 16:16 SSS
PlanMC12 resonsiblity sue to lack of equipment imported 1 1 24/06/2011 16:17 SSS 24/06/2011 16:17 SSS
PlanMC12 customers responsibility 2 2 24/06/2011 16:17 SSS 24/06/2011 16:17 SSS
PlanMC12 depertments responsibility 2 2 24/06/2011 16:17 SSS 24/06/2011 16:17 SSS
PlanMC12 planning department responsibility 1 1 24/06/2011 16:17 SSS 24/06/2011 16:17 SSS
PlanMC12 responsibility of to management 2 2 24/06/2011 16:17 SSS 24/06/2011 16:17 SSS
MC Q13 desining the network 0 0 24/06/2011 16:34 SSS 24/06/2011 16:34 SSS
PlanMC13 based on the strategy 3 3 24/06/2011 16:35 SSS 24/06/2011 16:35 SSS
PlanMC13 considering the consumer types in upgrade the net 5 5 24/06/2011 16:35 SSS 24/06/2011 16:35 SSS
PlanMC13 upgrade based on the economic growth 6 6 24/06/2011 16:35 SSS 24/06/2011 16:35 SSS
PlanMC13 yes upgrade based on the demand 8 8 24/06/2011 16:35 SSS 24/06/2011 16:35 SSS
MC Q8 power quality strategy 0 0 24/06/2011 15:24 SSS 24/06/2011 15:24 SSS
lack of long term startegy 21 31 24/06/2011 15:26 SSS 24/06/2011 15:26 SSS
PlanMC8 lack of strategy 5 5 24/06/2011 15:26 SSS 24/06/2011 15:26 SSS
PlanMC8 lack of strategy due to lack of studies 4 6 29/06/2011 16:32 SSS 29/06/2011 16:32 SSS
PlanMC8 lack of strategy due to management unawarness 9 9 29/06/2011 16:32 SSS 29/06/2011 16:32 SSS
PlanMC8 lack of strategy due to not accomadating the incr 2 2 29/06/2011 16:32 SSS 29/06/2011 16:32 SSS
PlanMC8 power quality strategy 5 5 24/06/2011 15:26 SSS 24/06/2011 15:26 SSS
MC Q9 staff involved in any strategy 0 0 24/06/2011 15:31 SSS 24/06/2011 15:31 SSS
PlanCM9 staff prefer not say 2 2 24/06/2011 15:32 SSS 24/06/2011 15:32 SSS
PlanMC9 staff involved for startegy 10 10 24/06/2011 15:32 SSS 24/06/2011 15:32 SSS
Training 0 0 21/02/2011 13:28 SSS 21/02/2011 13:28 SSS
Sources
Nodes
Classifications
Collections
Queries
Reports
Models
Folders
SSS
357 Items
EN
18:58
06/12/2012

Interviewees and departments Coding			
Case	**Department**	**Position**	**Section**
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Nodes\\Cases\\cust_cons_service_manag80	Customer	Middle Manager	Customer services
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Nodes\\Cases\\Dist_dep_manag67	Distribution	Middle Manager	Not Applicable
Nodes\\Cases\\Dist_empl66	Distribution	Employees	Maintenance Area
Nodes\\Cases\\Dist_mainten_manag76	Distribution	Middle Manager	Maintenance Area
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Nodes\\Cases\\Dist_safty_area_manag69	Distribution	Middle Manager	Protection and Safety
Nodes\\Cases\\Dist_stand_manag_63	Distribution	Middle Manager	Standards
Nodes\\Cases\\Dist_stand_specific_manag74	Distribution	Middle Manager	Standards
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Nodes\\Cases\\planning_empl_MSc_EL_EN59	Planning	Engineer	Studying
Nodes\\Cases\\planning_gen_mang_assist51	Planning	Head Manager	Studying
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Nodes\\Cases\\Training_employee36	Training	Employees	Training Account
Nodes\\Cases\\Training_employee38	Training	Employees	Training Standards
Nodes\\Cases\\Training_employee40	Training	Employees	Training Standards
Nodes\\Cases\\Training_employee41	Training	Employees	Training Standards

APPENDIX K: The relative importance index of CSFs of PQP implementation

Item No	Factor	West Network		East Network		South Network		Overall	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
X2.1:Definitions (D)									
7	D/Reliability and Availability	0.833	9	0.832	9	0.861	5	0.842	6
8	D/Satisfy Customers	0.821	10	0.809	12	0.828	8	0.819	9
9	D/Reduce Losses	0.841	8	0.851	6	0.801	11	0.831	8
10	D/Customers Awareness	0.691	22	0.671	27	0.719	20	0.693	22
11	D/Increase Efficiency	0.855	6	0.847	7	0.856	6	0.852	5
X2.2:Customers Satisfaction (CS)									
12	CS/Customer Complaints	0.671	24	0.681	26	0.651	26	0.667	26
13	CS/Customer Satisfactions	0.583	33	0.621	29	0.594	33	0.599	32
14	CS/Customers' Needs	0.661	25	0.651	28	0.631	27	0.647	28
15	CS/Improvement for Customers	0.594	32	0.587	31	0.614	29	0.598	33
16	CS/Customer Awareness	0.641	28	0.688	24	0.681	22	0.668	25
X2.3:Management Commitment (MC)									
17	MC/Identifies The Causes	0.773	17	0.748	19	0.732	17	0.751	17
18	MC/Inaccurate Managerial Decision	0.805	12	0.775	15	0.775	14	0.785	14
19	MC/Planning Good Strategy	0.813	11	0.793	14	0.798	12	0.801	12
20	MC/Following the recommendations and studies	0.821	10	0.795	13	0.794	13	0.805	11
21		0.796	13	0.741	20	0.732	17	0.761	16
22	MC/Ensure Security and Quality	0.788	15	0.754	18	0.741	16	0.764	15
23	MC/International or a National Benchmarks	0.862	4	0.829	10	0.824	9	0.841	7
Item	**Factor**	**West Network**		**East Network**		**South Network**		**Overall**	

No		RII	Rank	RII	Rank	RII	Rank	RII	Rank
X3.1:Employees Participation and Training (EPT)									
24	EPT/Survey or Feedback Techniques	0.631	29	0.685	25	0.654	25	0.654	27
25	EPT/Sufficient Training	0.768	18	0.732	21	0.728	18	0.746	20
26	EPT/Employees Suggestion	0.738	21	0.763	16	0.728	18	0.744	21
27	EPT/Employees Strategies	0.753	20	0.748	19	0.743	15	0.749	18
28	EPT/Appropriate Qualifications	0.777	16	0.812	11	0.775	14	0.788	13
29	EPT/Employees Involvement	0.763	19	0.758	17	0.723	19	0.748	19
X3.2:Customers and Company Awareness (CCA)									
30	CCA/Waste Use	0.842	7	0.871	5	0.846	7	0.852	5
31	CCA/Faulty Connection	0.861	5	0.885	3	0.867	4	0.871	4
32	CCA/Mixed Users	0.911	1	0.911	2	0.931	1	0.916	1
33	CCA/Concept of Power Quality	0.875	3	0.922	1	0.921	2	0.903	2
34		0.877	2	0.876	4	0.911	3	0.886	3
35	CCA/Utility Faults	0.791	14	0.838	8	0.822	10	0.815	10
36	CCA/Illegal connect	0.647	27	0.696	22	0.672	23	0.671	24
37	CCA/Bad Design	0.685	23	0.691	23	0.654	25	0.678	23
X5.1:PQ Disturbances Affecting Networks (DANs)									
49		0.529	39	0.526	36	0.598	32	0.547	39
49		0.471	40	0.456	39	0.541	36	0.485	40
49		0.651	26	0.592	30	0.693	21	0.643	29
49	DANs/Transient, Surge and Unbalance.	0.564	35	0.521	38	0.579	34	0.554	37
50	DANs/Voltage Collapse and Stability	0.621	30	0.569	32	0.661	24	0.615	30
50	DANs/Low Power Factor	0.548	37	0.523	37	0.607	31	0.556	36
50	DANs/Over Voltage.	0.611	31	0.563	33	0.629	28	0.601	31
50	DANs/Under Voltage	0.559	36	0.541	34	0.613	30	0.568	34
50	DANs/Outage.	0.547	38	0.531	35	0.575	35	0.549	38
49	DANs/Voltage Sags and Swells.	0.573	34	0.531	35	0.579	34	0.561	35

APPENDIX L: EGCOL Completion Questionnaire Letter

اللجان في كل مكان

لا ديمقراطية بدون مؤتمرات شعبية

الجماهيرية العربية الليبية الشعبية الاشتراكية العظمى

الشركة العامة للكهرباء

الرقم الاشاري : 216/م/11/ح

التاريخ / /

الموافق 29/ 4/ 2010 م

إلي من يهمه الأمر

بعد التحية ،، ،،

بالإشارة... إلي مراسلتكم المتعلقة بدراسة حقلية لــلأخ/ **ســعد صــالح ســلطان** والخاصة بموضوع **جودة الطاقة الكهربائية**.

عليــــه** نفيدكم بأنه قد تم إنجاز الدراسة الحقلية المقررة لذلك حسب النمــاذج المرفقة.

نأمل الاستلام ،، ،،

«والســـلام عليكـــم»

مهندس /

﴿مصطفي حسن شرلالة﴾

﴿ مساعد مدير عام الإدارة العامة للتوزيع ﴾

صورة إلى:
- ملـــف الموضـــوع.
- الملـــف العـــام.

م.شرلالة**.رجاء

97-01443

مكتب السجل التجاري (طـــرابلس) رقـــم القـيـــد (10284) رأس مال الشركة (2,408,473.400) د . ل

مكتب أمين لجنة إدارة الشركة
021 (4808268 -4808424 -4807420) ☎
(بريد مصور 4803485)
بريد الكتروني (gecol@gecol.ly)

مكتب الأمين المساعد
021 (4811597) ☎
موقع الكتروني (www.gecol.ly)

دائرة مكتب أمين اللجنة
بريد مصور (4808915)
ص . ب (668)