Justification of Business Process Change to Enable Higher Levels of TSO-DSO Interaction

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Contents

- National Grid (NG)
  - Offline modelling strategy
  - Modelling requirement
- Critical Challenges
- Proposed modelling strategy
- Operational analysis
- Final Remarks

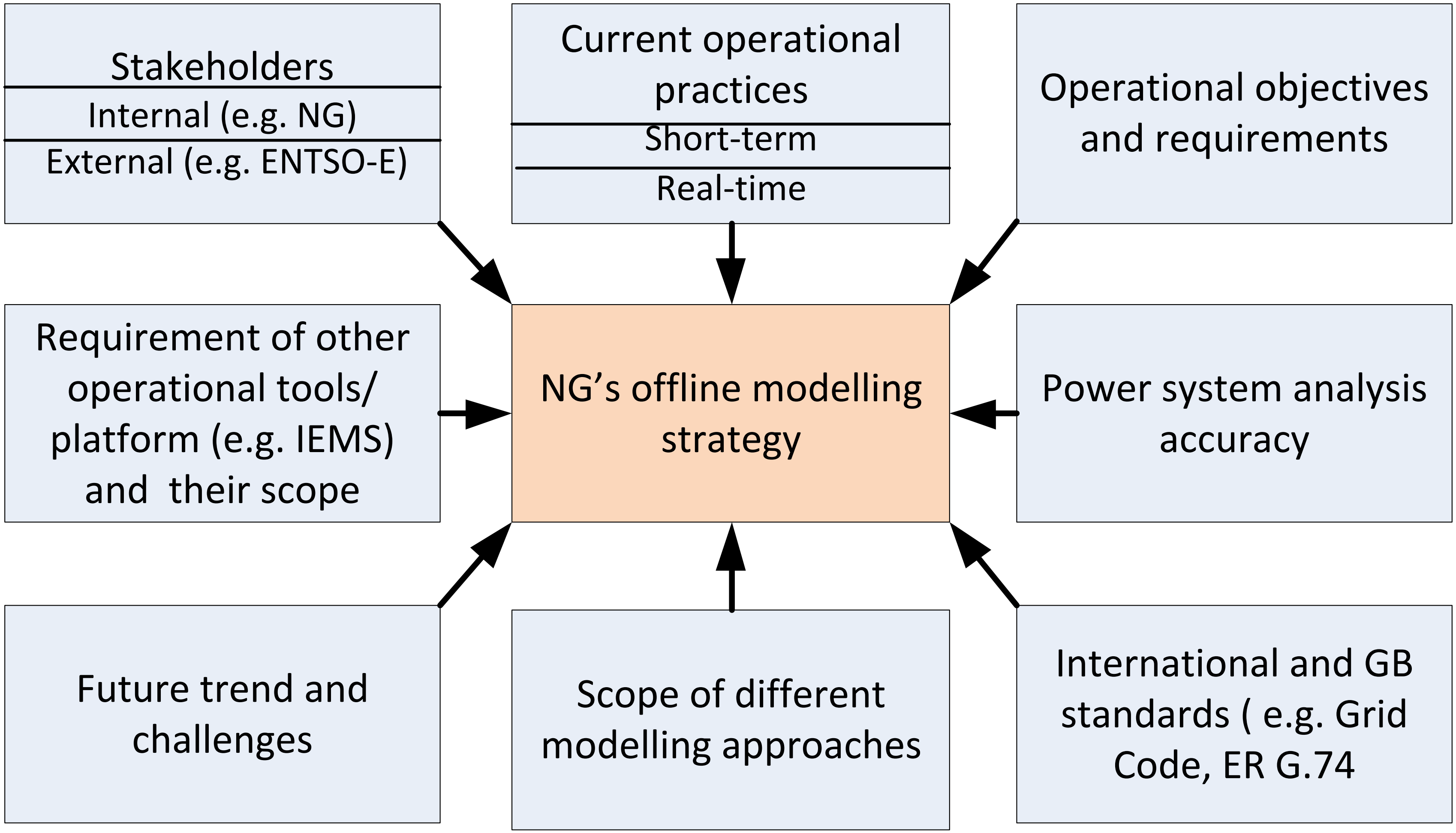
Main Acronyms

- National Grid (NG)
- Stability Analysis (SA)
- Fault Level Analysis (FLA)
- Contingency Analysis (CA)
- Engineering Recommendation (ER)
- Active Distribution Networks (ADNs)
- Enhanced Extended Ward Equivalent (EEWE)

Coping with Future Trends

- Active participation of different stakeholders
- Exploration of alternative approaches and adoption of new methods and strategies
- Consideration of ADNs in planning procedures
- Integration of various state-of-art developments to enhance and optimize the short term planning and real time operation
- Coordination of the different platforms

NG's Offline Modelling Strategy



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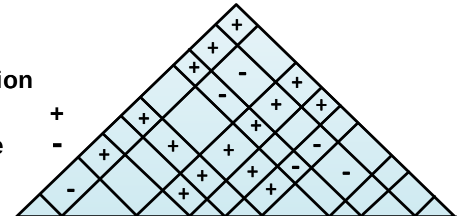
Benefits of the Dynamic Equivalent

Tangible Benefits	Intangible Benefits
i. Reduction in model size and data volume. ii. Less manual intervention by automating the network modelling processes. iii. Simpler to utilize the real time metering data as they are readily available at the GSP level iv. Equivalences small embedded generators and radial networks v. Lessens the work load in network validation process vi. Supports better TSO-DSO interaction vii. Faster simulation viii. Enabling more users to be supported by the same hardware	i. Reduces non-convergence scenarios in system analysis caused by improper LV network configuration. ii. Improves and standardizes dynamic load models (in accordance with ER G.74). iii. Improves platform interoperability iv. Eases the data exchange process with DNOs. v. Improves accountabilities in the modelling process, by limiting full detail to areas for which NG is operationally responsible.

HOQ considering the NG's business requirement

Correlation
Positive +
Negative -

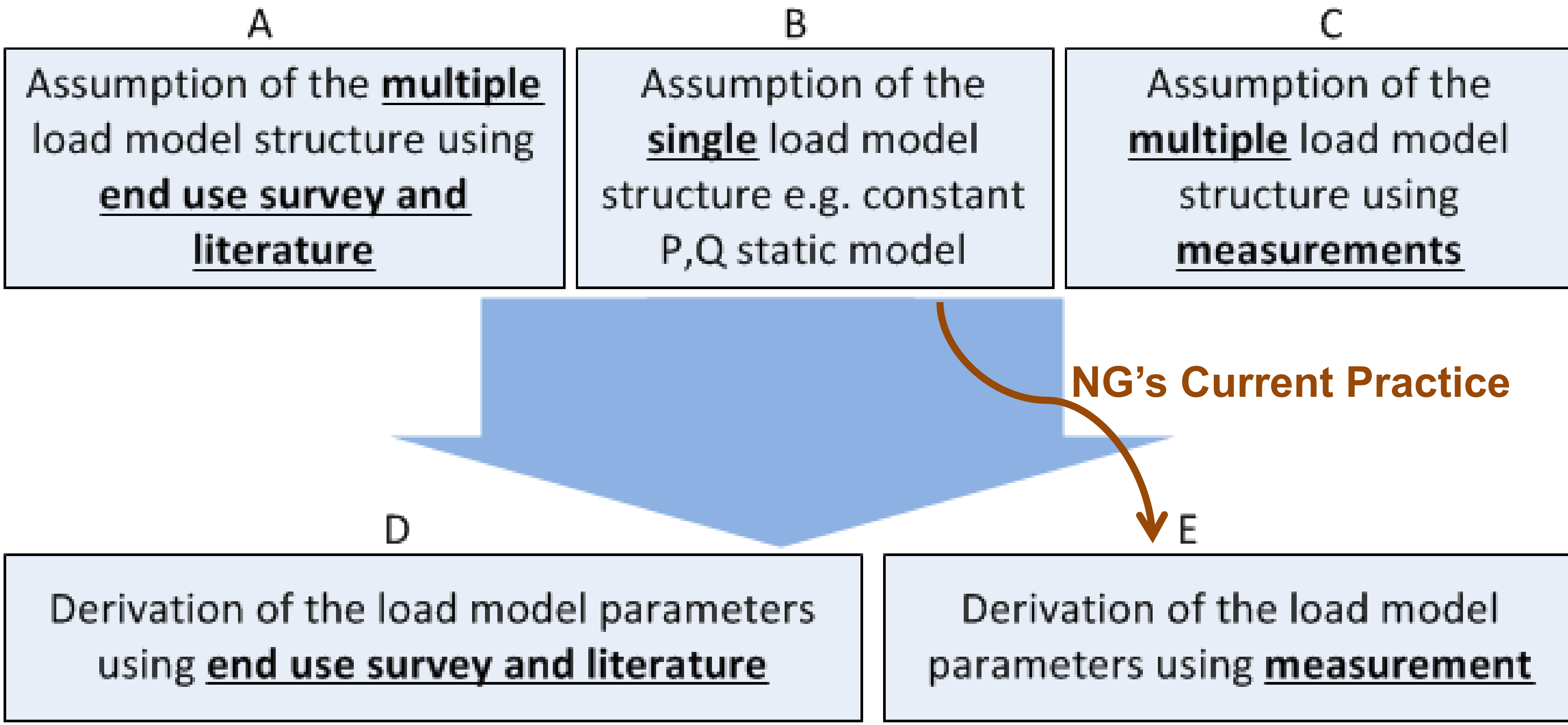


Strength of the Relation
Strong 5(■)
Moderate 3(●)
Weak 1(▲)

Technical capabilities of Dynamic Distribution System Equivalent

Stakeholders' Requirements	Importance Factor	Simplify network representation	Capture the dynamic nature of the reduced network	Eliminate unnecessary objects	Highly scalable	Robust network	Possibility of frequent LV points update and higher TS0-DSO interaction	Faster Simulation	Reduced data acquisition and processing	Ease data exchange process	Resultant Row Weight	Relative Importance (Row)	Row Ranking
Create simple structure	5	■		■							50	15	4
Reduced network	3	▲		■	■	●					42	13	5
Dynamic load representation	3		■			●					24	7	7
Reduce data volume	4	●		●					■	■	64	19	1
Automate operation process	5						●	●			30	9	6
Less LV points	2			●							6	2	9
Limited validation procedure	4	●				■			■		52	16	3
Avoid LV load apportionment	2			▲	▲		●				10	3	8
Ease data flow and connectivity configuration	4	▲	▲		●			●	●	●	56	17	2
Resultant Column Weight		56	19	60	29	38	21	#	52	32			
Relative Importance (Column)		17	6	18	9	11	6	8	16	10			
Column Ranking		2	9	1	6	4	8	7	3	5			

Load Modelling Strategy



Nine Critical Problems for NG's offline network modelling

i. Structural issues e.g. discrepancy in the model depths.

ii. Poor scalability as LV networks are expanding and becoming more active.

iii. Static load representation.

iv. Large volumes of data exchange, both internal and external.

v. High manual intervention.

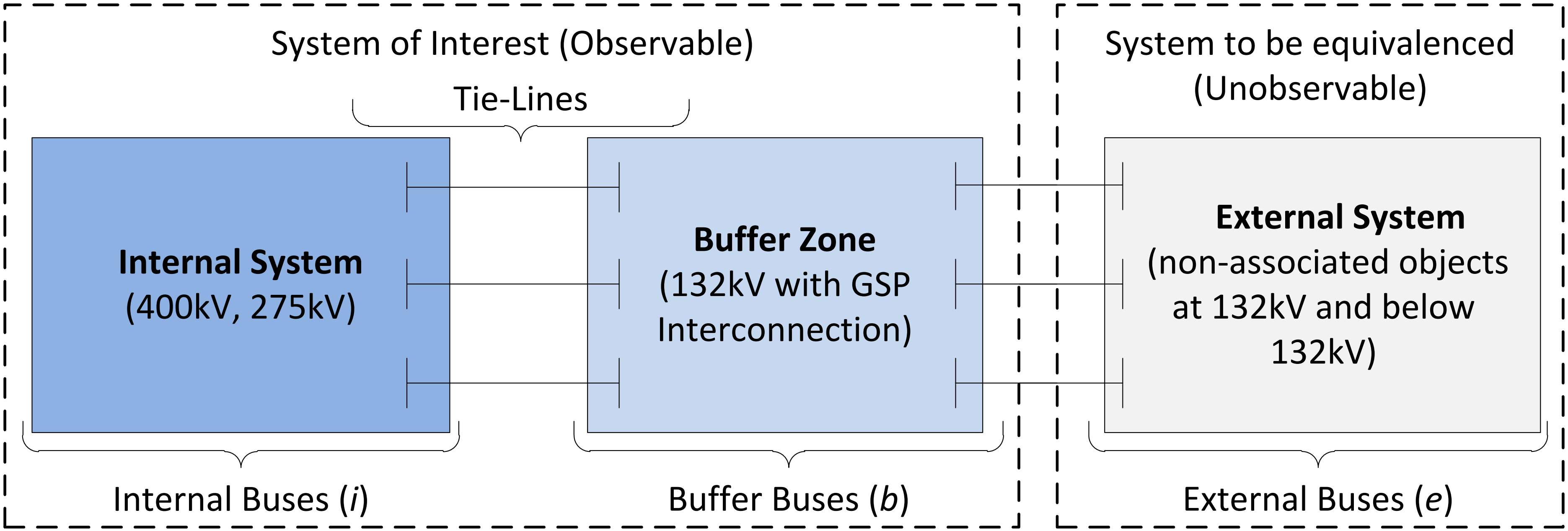
vi. Infrequent updates to LV data (mostly annual)

vii. Extensive validation procedures required.

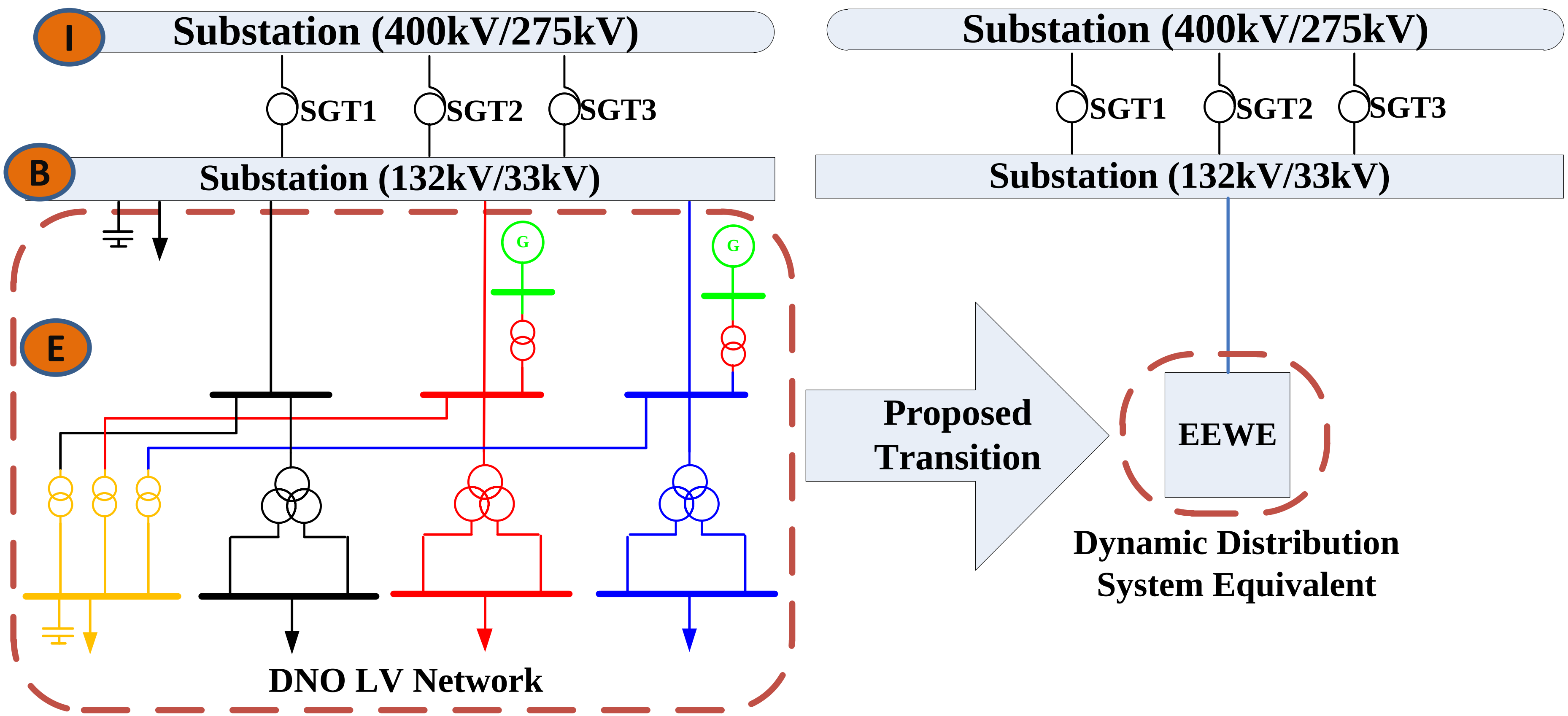
viii. Reliance on apportionment of loads to LV points.

ix. Extensive modelling of LV networks for which NG has no operational accountability.

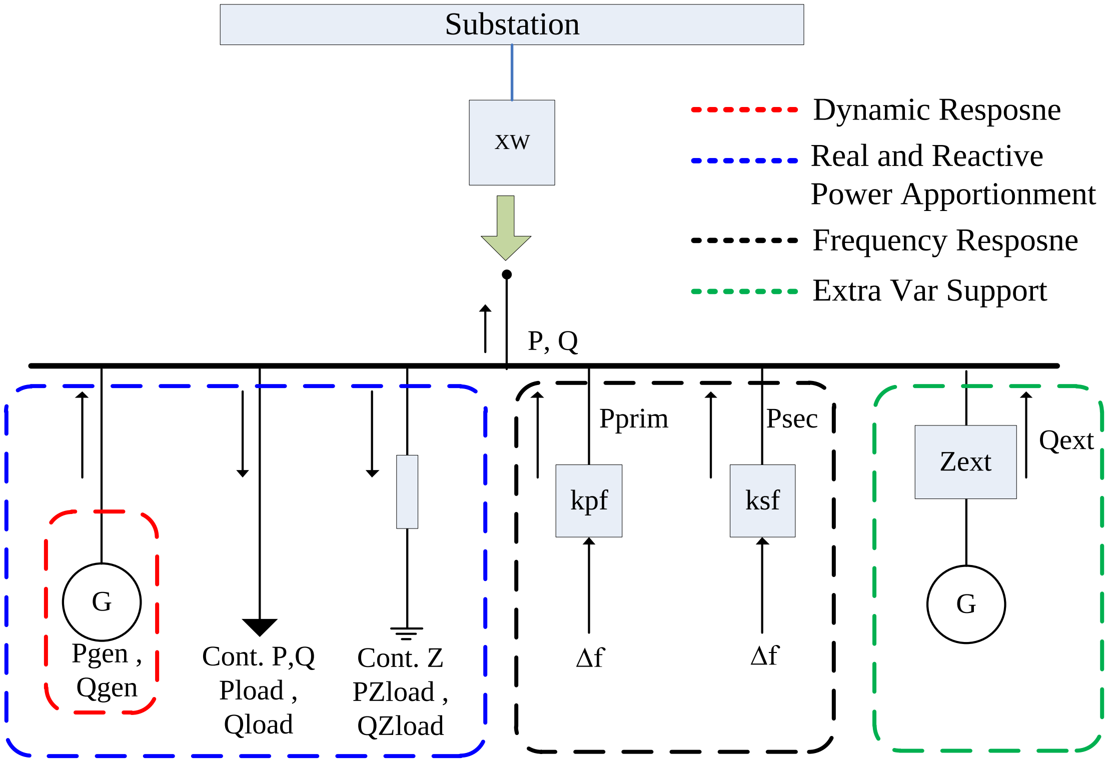
Internal, Buffer and External Zone



Proposed Transition

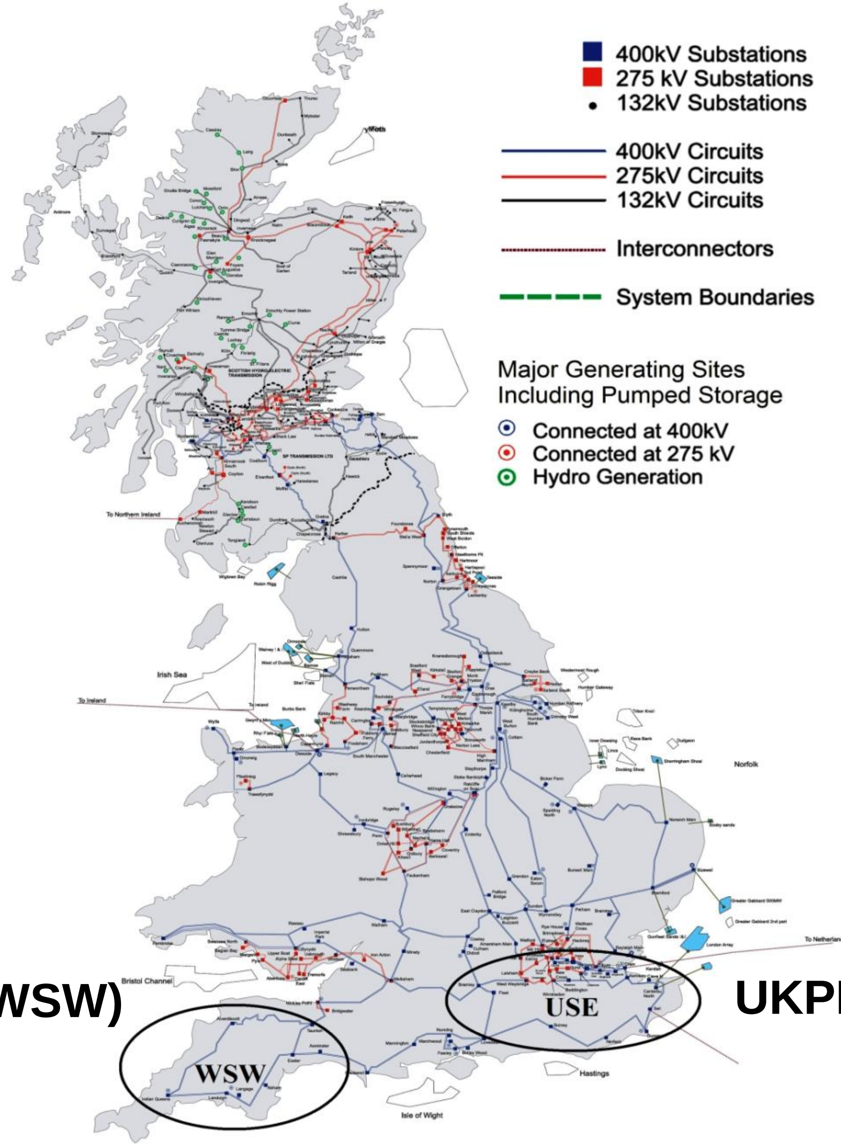


Enhanced Extended Ward Equivalent (EEWE)



- Fundamental structure based on Extended Ward Equivalent
- Enhanced by:
  - Including the multiple *X/R* ratios
  - Apportioning the real and reactive power
  - Including the frequency dependency components
- ER G.74 Compliant Equivalent and also follow IEC 60909

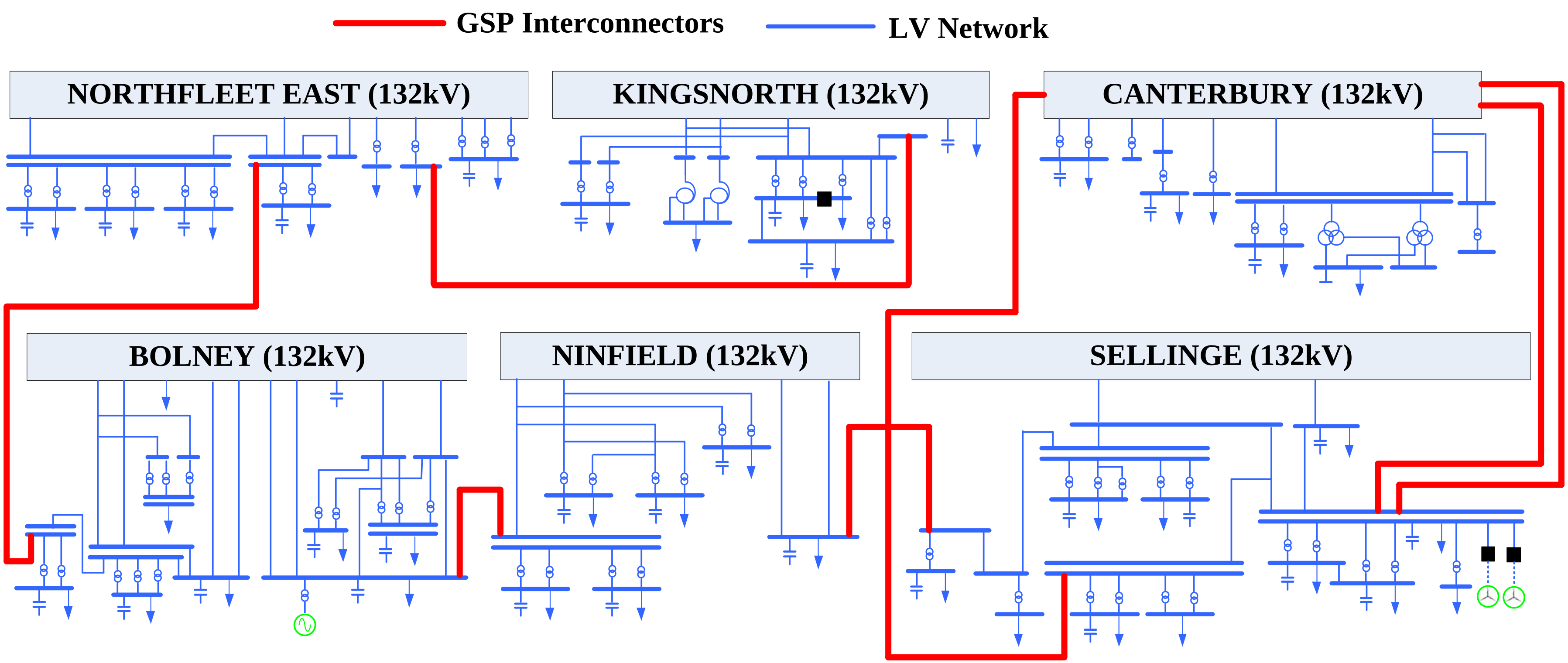
Studied Area



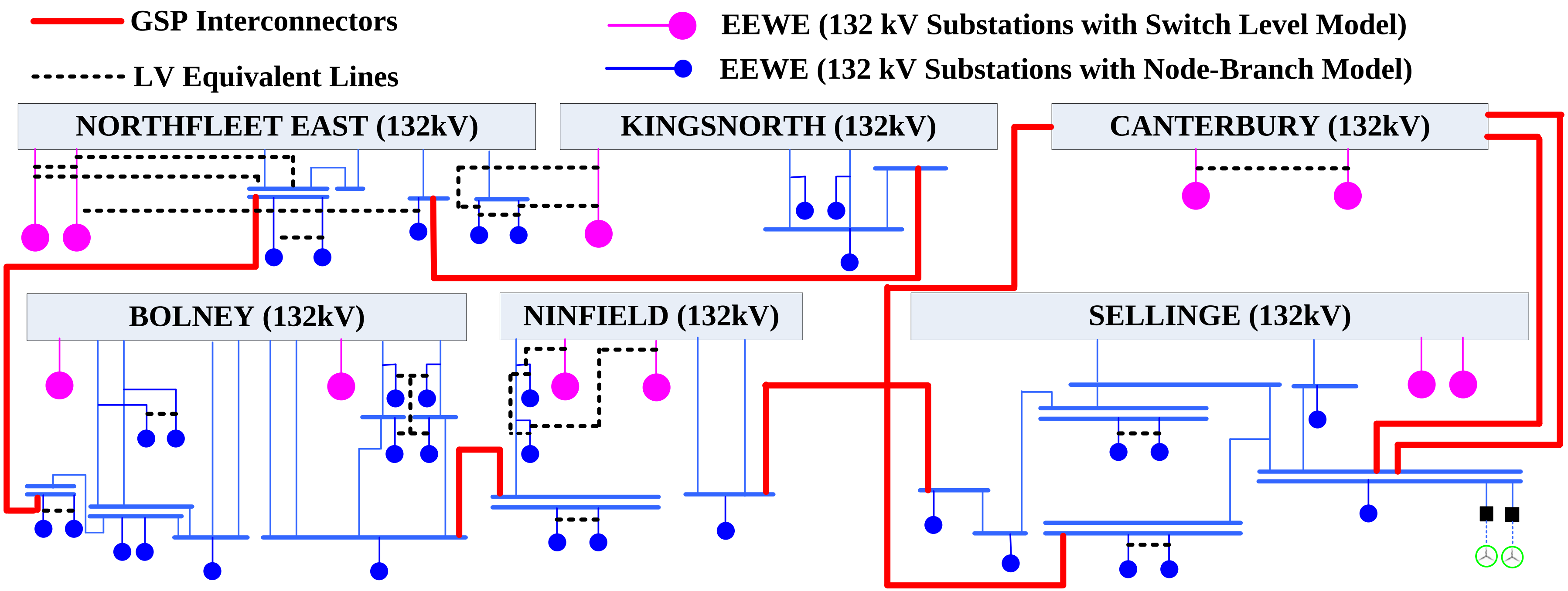
WPD South West (WSW)

UKPN South West (USE)

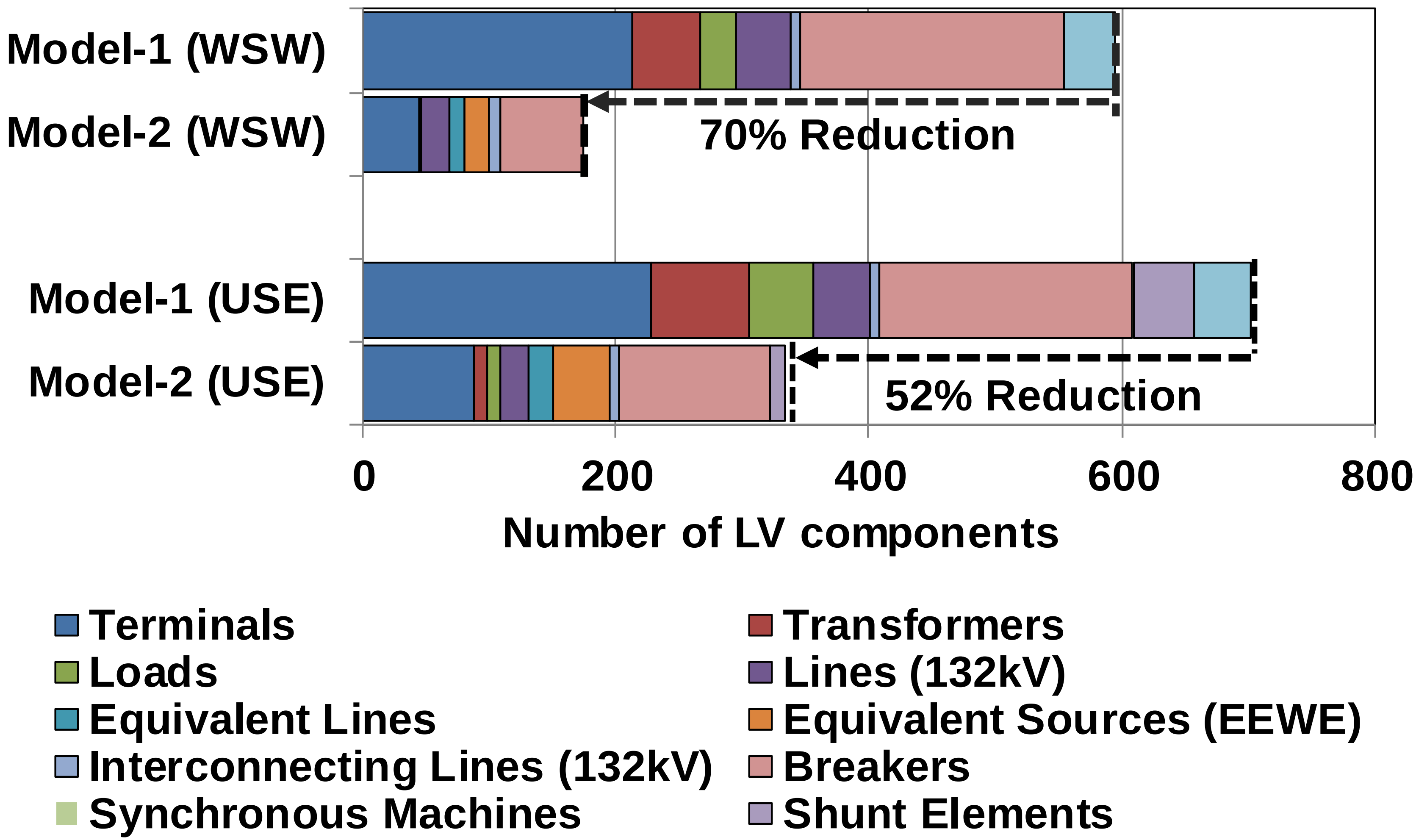
UKPN South West (USE)



Reduced Network of USE area



Number of objects for different network models

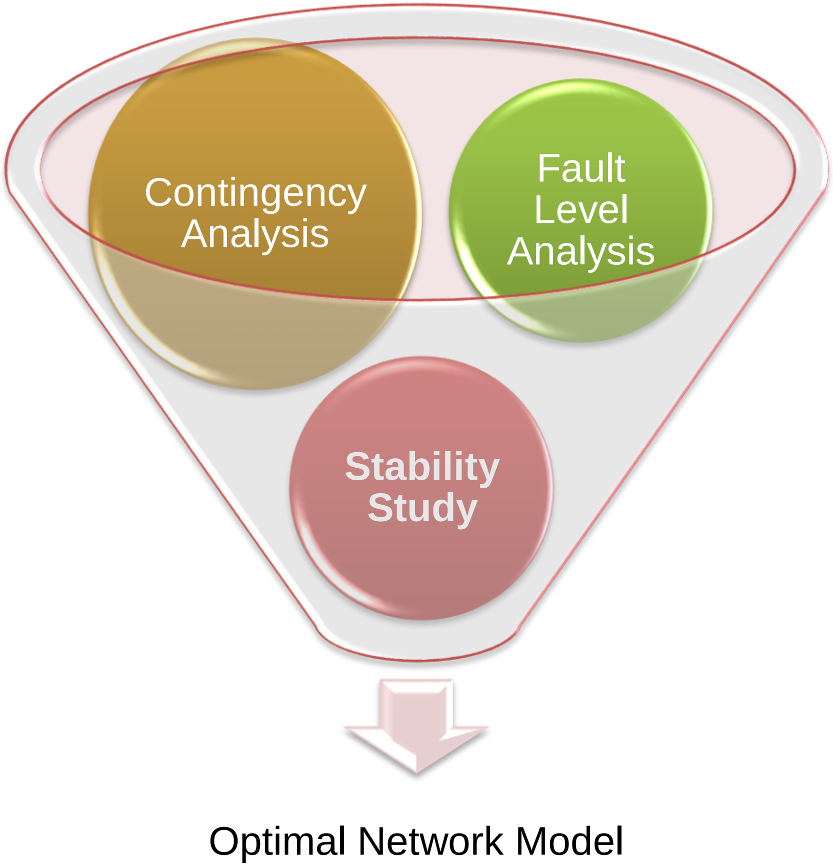


Model Validation

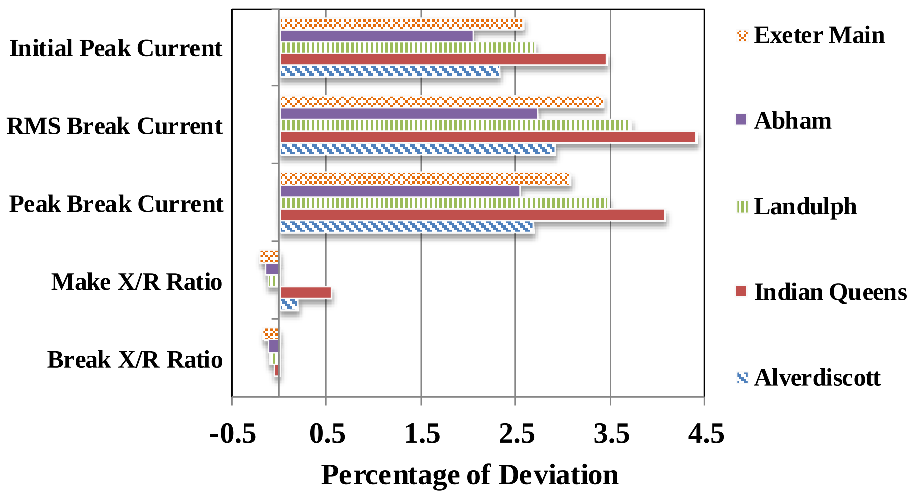
$$\min f(x) = \int_{t_{initial}}^{t_{final}} \sum_{n_R^i}^{N_R} \left\| (Parameter)_{org} - (Parameter)_{equ} \right\| \qquad s.t.\ n_R^i \neq 0,\ i = 1, 2, \ldots\ldots, N_R$$

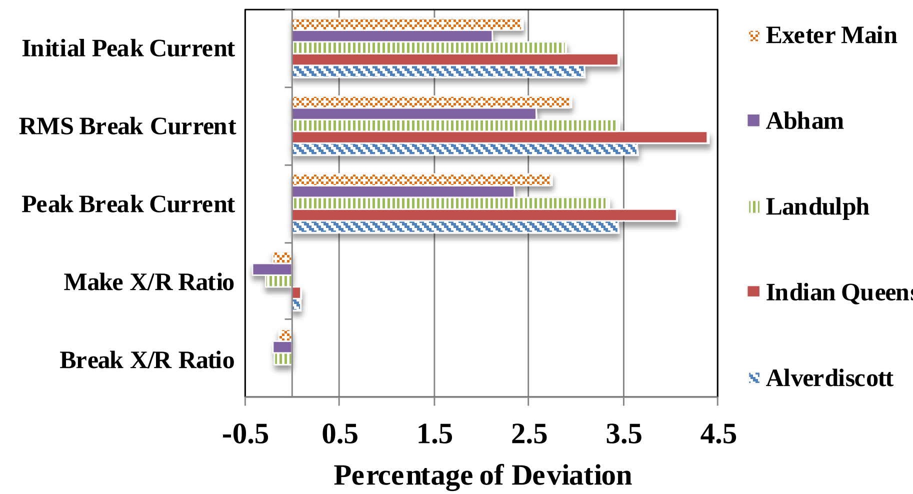
x =>
Voltage magnitude
Real and reactive power flow
Make and Break *X/R* ratio,
Initial peak current
rms break current
Peak break current
Generator rotor angle with respect to the reference machine.

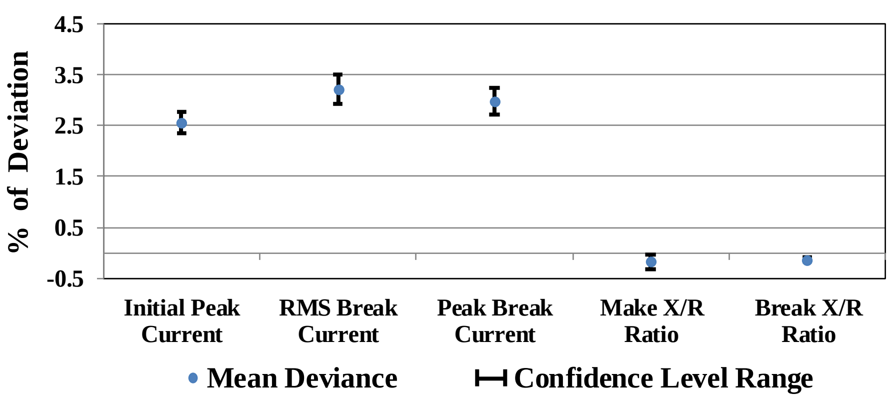
Objective function considers a predefined integration time, thus parameters can reflect non-linear nature as well.

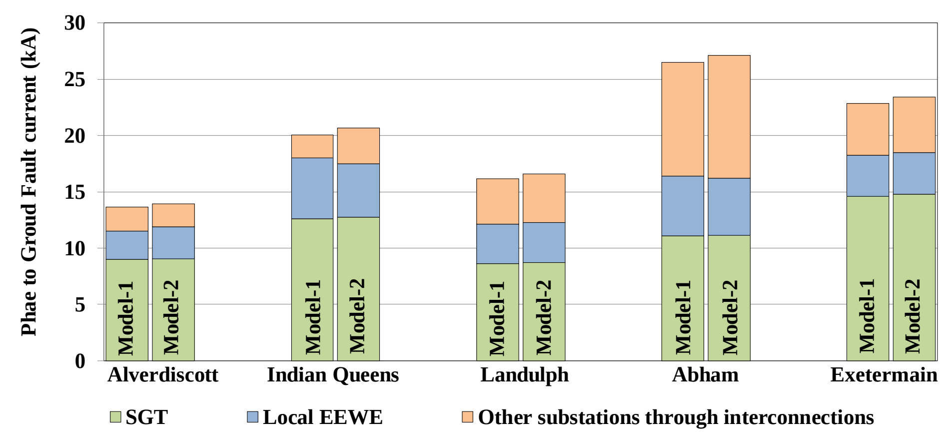


FLA Results

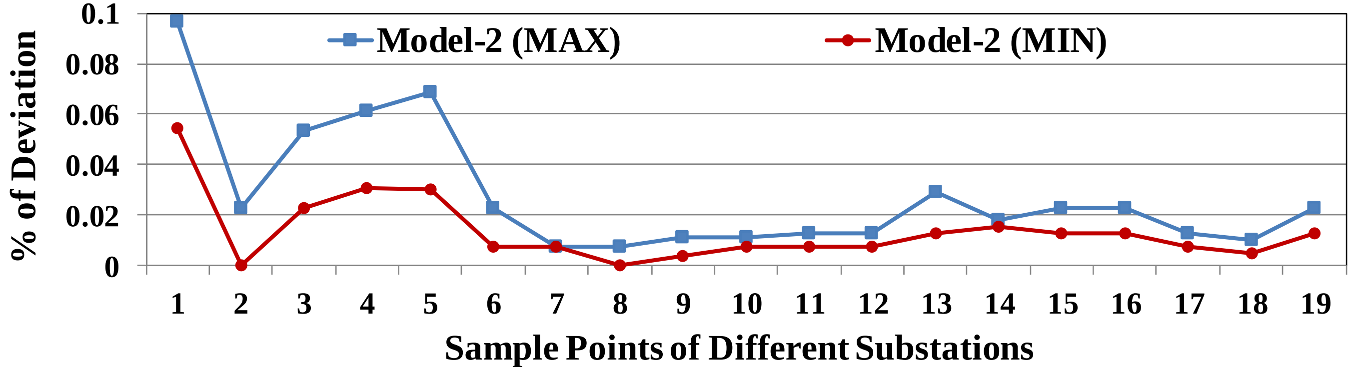

Initial Peak Current
RMS Break Current
Peak Break Current
Make X/R Ratio
Break X/R Ratio
-0.5 0.5 1.5 2.5 3.5 4.5
Percentage of Deviation
Exeter Main
Abham
Landulph
Indian Queens
Alverdiscott

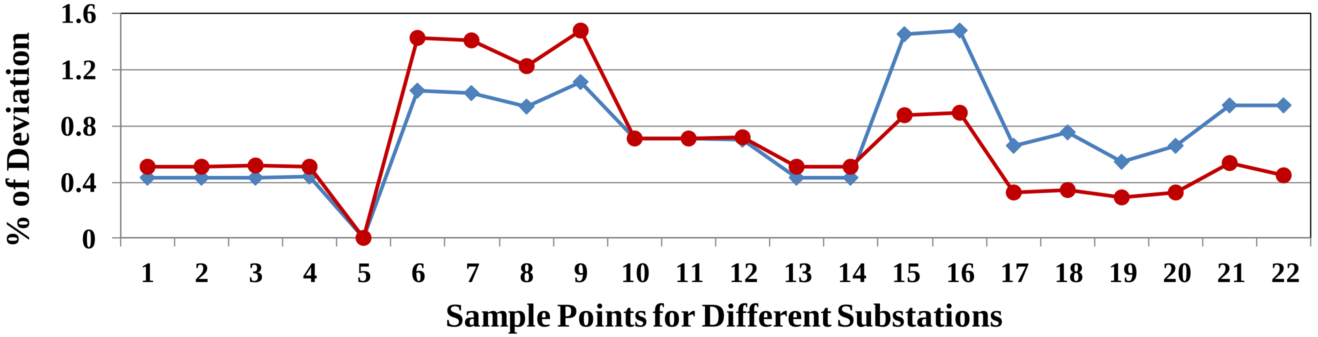

Initial Peak Current
RMS Break Current
Peak Break Current
Make X/R Ratio
Break X/R Ratio
-0.5 0.5 1.5 2.5 3.5 4.5
Percentage of Deviation
Exeter Main
Abham
Landulph
Indian Queens
Alverdiscott

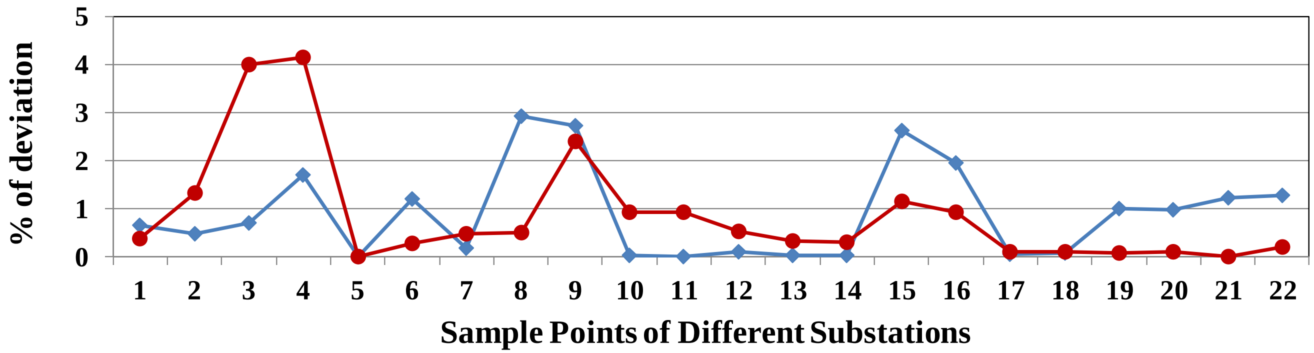

% of Deviation
4.5
3.5
2.5
1.5
0.5
-0.5
Initial Peak Current
RMS Break Current
Peak Break Current
Make X/R Ratio
Break X/R Ratio
Mean Deviance
Confidence Level Range


Phae to Groud Fault current (kA)
30
25
20
15
10
5
0
Model-1
Model-2
Alverdiscott
Indian Queens
Landulph
Abham
Exetermain
SGT
Local EEWE
Other substations through interconnections

CA Results







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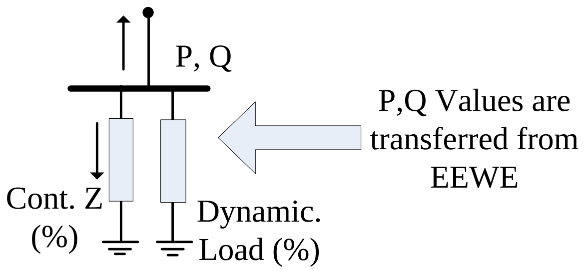
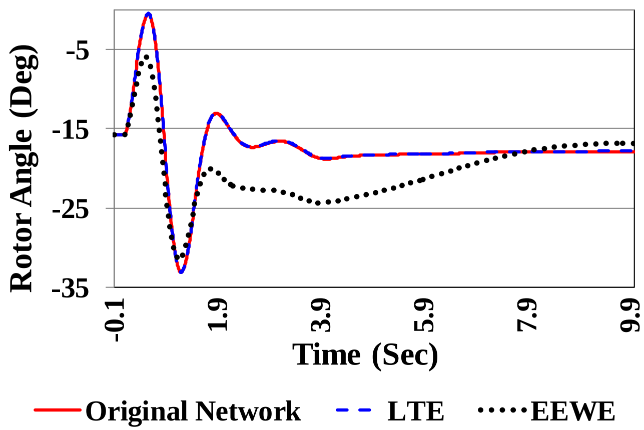
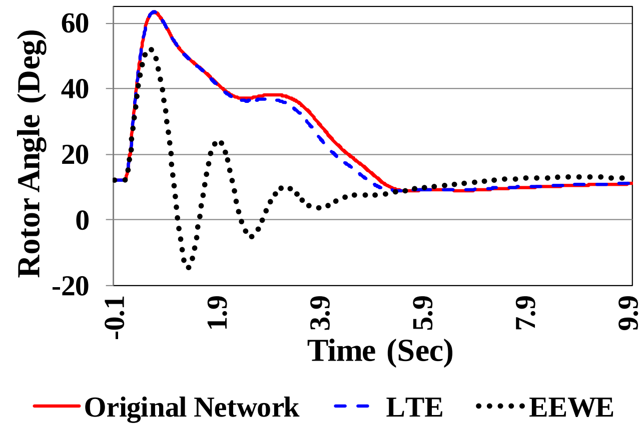
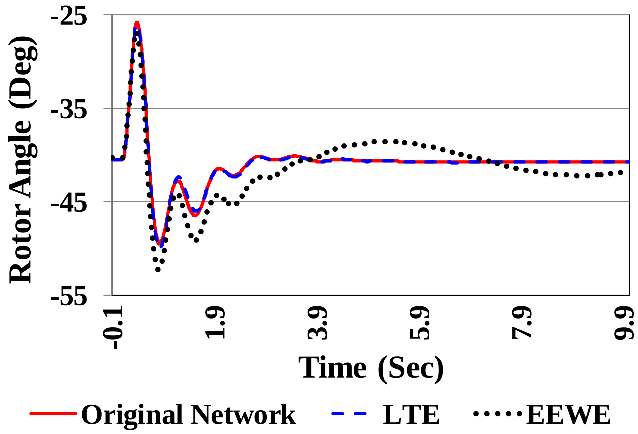
SA Results

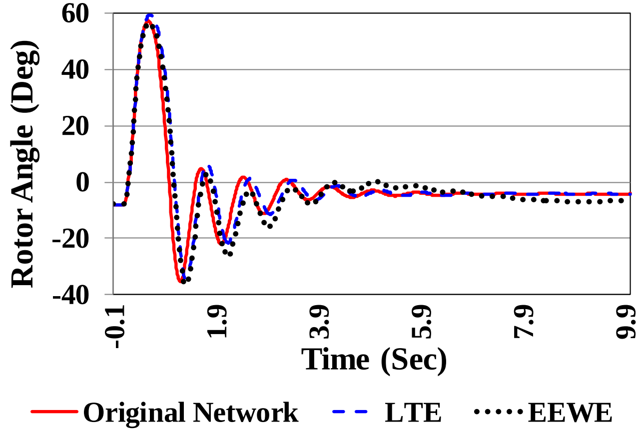
Load Transferred Equivalent (LTE)





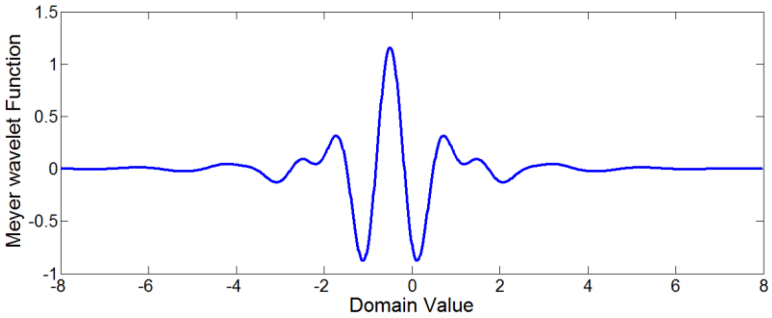




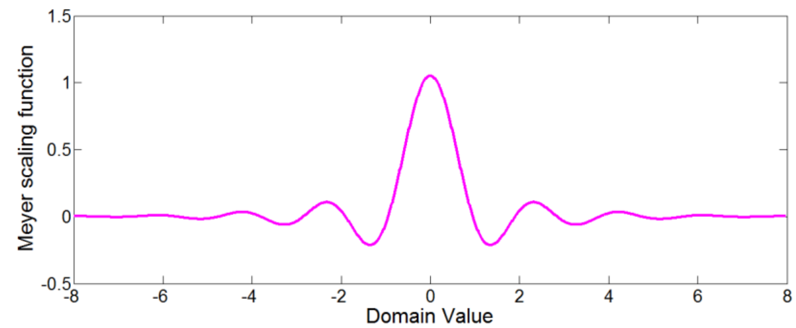


Wavelet Decomposition

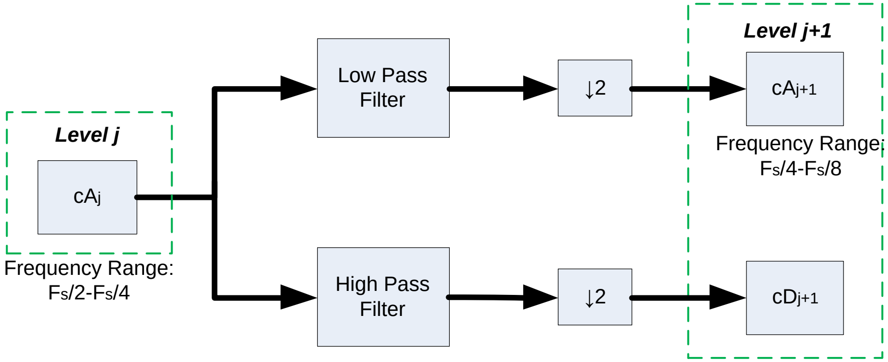
A Z M S. Muttalib, G. A. Taylor and M. E. Bradley, "Improvement of Stability Analysis and Assessment through Wavelet Decomposition", in *IET International Conference on the Resilience of Transmission and Distribution Networks* (**IET RTDN 2015**), pp.1-8, Birmingham, UK, 22-24 September 2015.



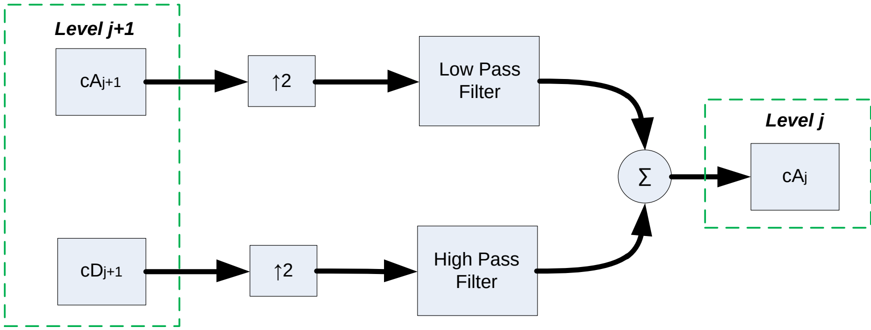
Meyer Wavelet



Scaling Function

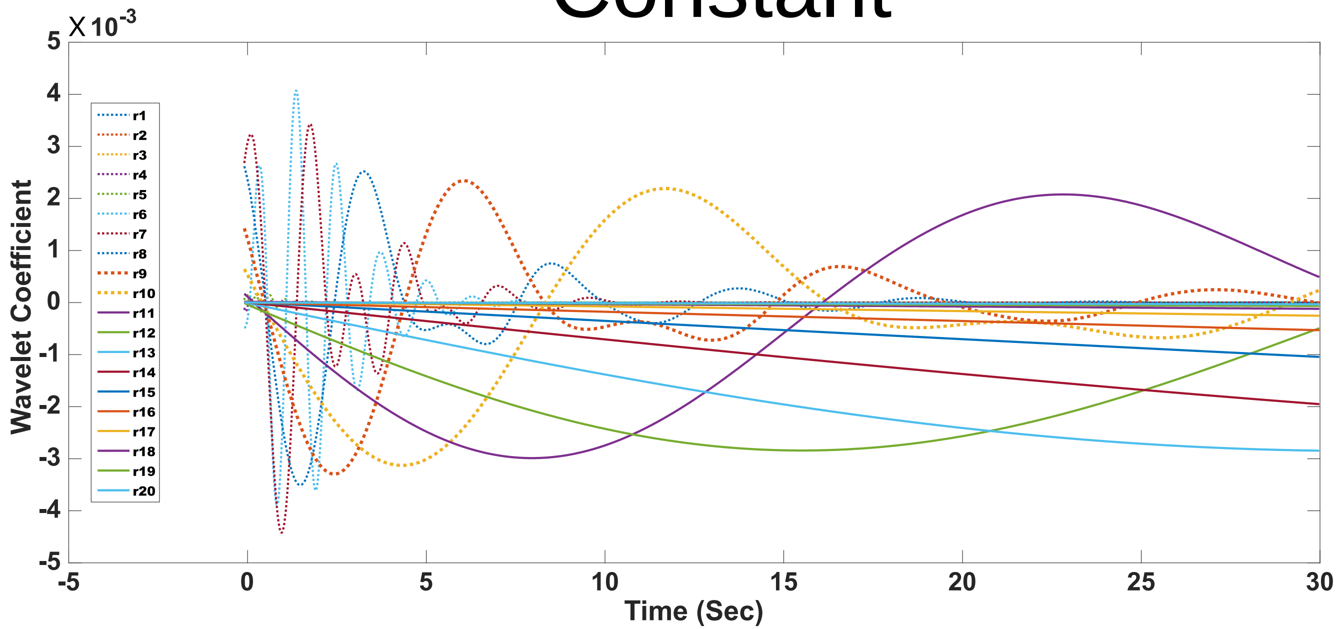


Decomposition steps of the signal



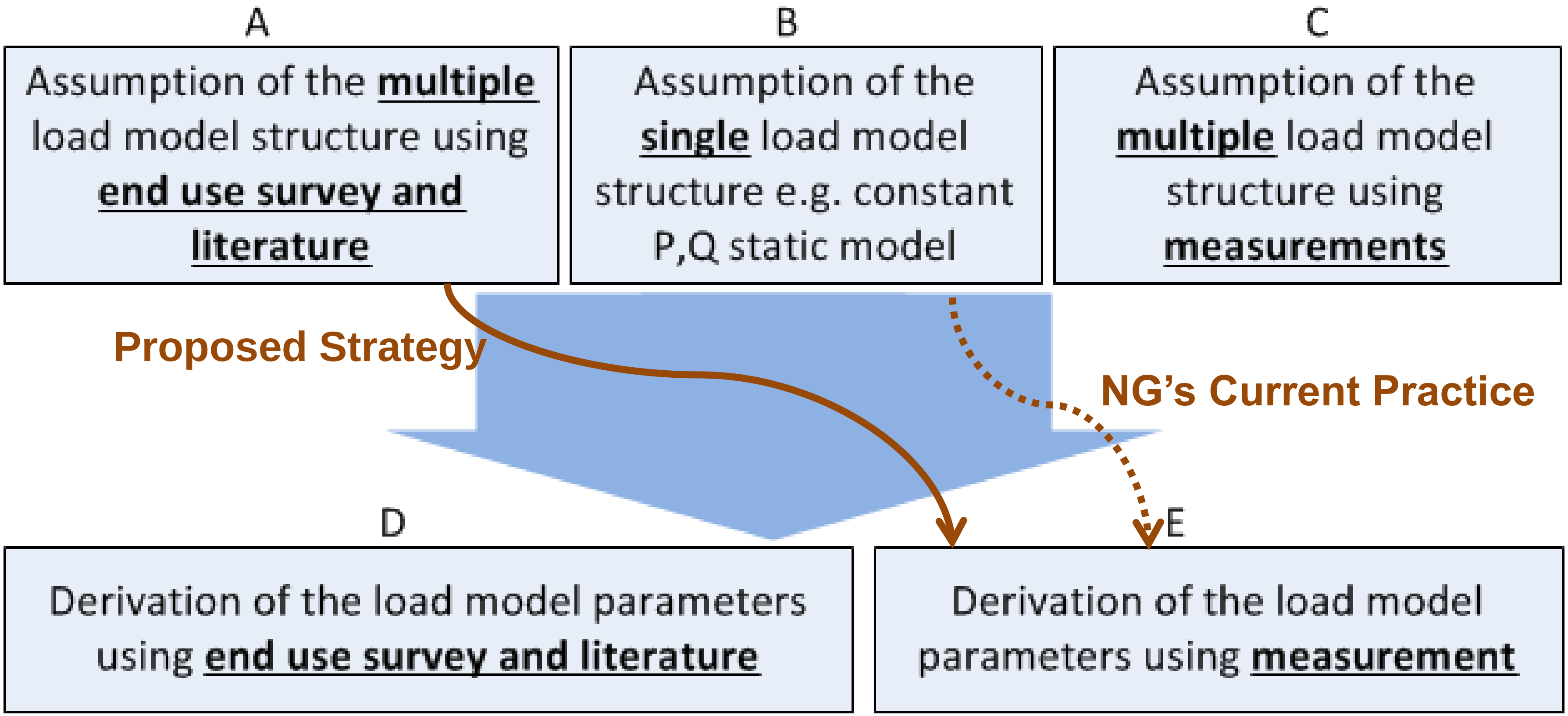
Multi-stage reconstruction with chosen decomposed signals

Wavelet Decomposition Result and Time Constant



Original Network	Wavelet Decomposition Technique	Reduced Network with LTE
2.715	2.649 **(2.43%)**	2.715 **(0%)**
3.456	3.469 **(0.37%)**	3.456 **(0%)**
1.245	1.295 **(4.01%)**	1.246 **(0.7%)**
5.673	5.802 **(2.27%)**	5.673 **(0%)**
7.345	7.401 **(0.76%)**	7.347 **(0.03%)**
Average Error	1.97%	0.02%

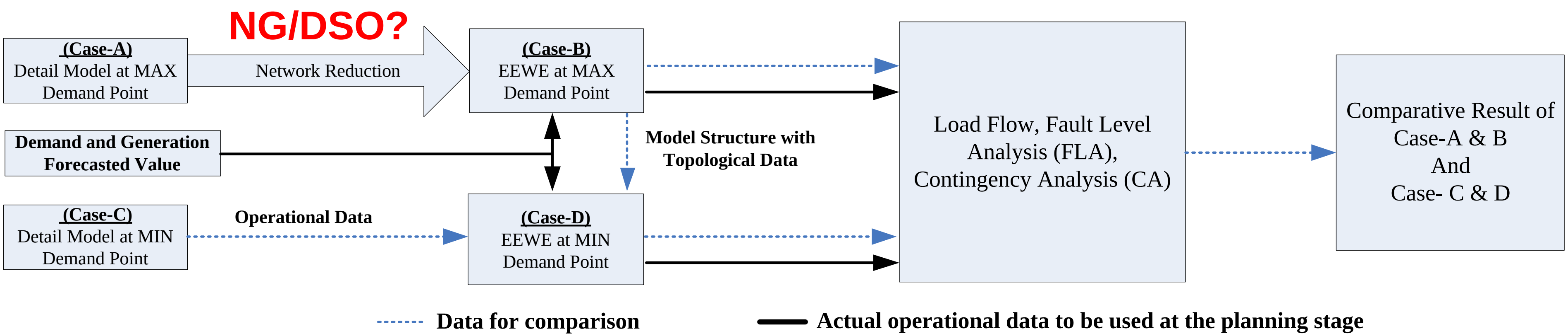
Load Modelling Strategy



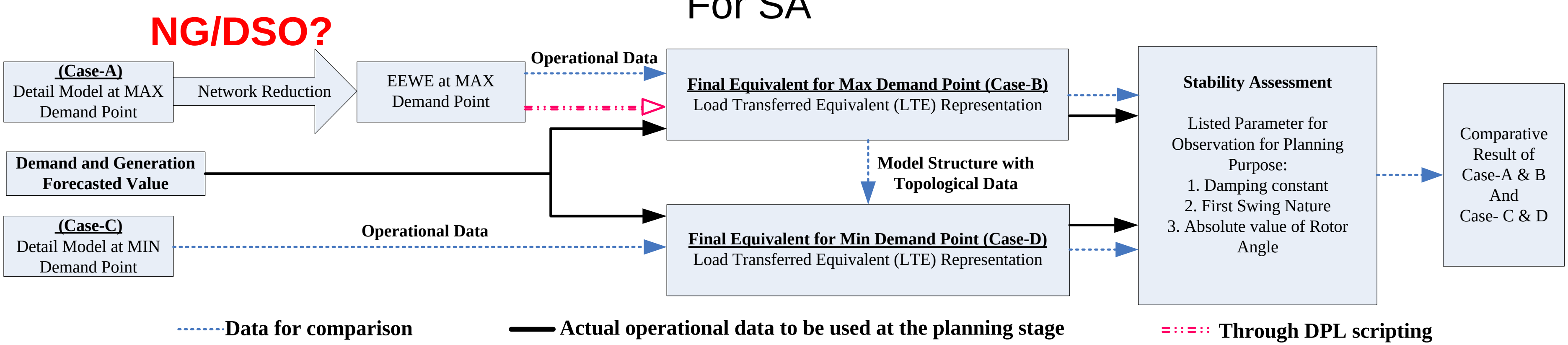
NG will be able to adopt a dynamic load model consisting of multiple components

Methodology and Strategy

For LF, FLA and CA



For SA



Challenges

- **Proper data availability** (e.g. updated load model parameters) to support the proposed load modelling approach.

- Model Derivation: An **additional task** for DSO. However, this change should be part of a wider development of data exchange between DSO and TSO (including real-time as well as planning data) which will bring **benefits to both parties**.

- Updating Codes and Standards: A permanent modification to data exchange practices should be reflected in a change to the codes, which would require the **agreement of all parties** involved.

Final Remarks

- EEWE which was designed according to ER G.74, showed **resilient results**
- For stability analysis, **LTE** was more appropriate option.
- Various operational study results outlined that EEWE and LTE in general produce **pessimistic results**
- Potentiality of reducing the **hardware size**
- Parameters that have been used to develop the equivalents established a **physical meaning**.
- Minor adjustment of the equivalents can be done **without re-computing.**
- Recommended to model in **full non-linear detail only at the transmission** level and equivalence the remainder provided that the **GSP interconnections are intact**.

Future Research

- As DG will continually grow and the nature of loads tend to change, there is a requirement for **tuning equivalent parameters** periodically.

- Identification of the **most significant parameters** within equivalent models for direct inclusion in the TSO-DSO data exchange process

See following references for more details

1. A Z M S. Muttalib, G. A. Taylor, and M. E. Bradley, "Investigating Scalable Computational Tools and Infrastructure to Enable Interoperable and Secure Control of Large-scale Power Systems", in *48th International Universities Power Engineering Conference (**UPEC 2013**)*, pp.1-6, Dublin, Ireland, 1-4 Sept. 2013.

2. A Z M S. Muttalib, G. A. Taylor, and M. E. Bradley, "Novel Approach to Updating Network Equivalents for Different Cardinal Points", in *49th International Universities Power Engineering Conference (**UPEC 2014**)*, pp.1-6, Cluj Napoca, Romania, 2-5 Sept. 2014.

3. A Z M S. Muttalib, G. A. Taylor and M. E. Bradley, "Modelling Enhancement of LV Network Equivalents for Accurate Operational Planning of the GB Power System", in *11th IET International Conference on AC and DC Power Transmission (***IET ACDC 2015***)*, pp.1-8, Birmingham, UK,10-12 Feb. 2015.

4. A Z M S. Muttalib, G. A. Taylor, and M. E. Bradley, "Contingency Analysis of Operational Planning Models with Distribution Network Reconfiguration", in IEEE Power & Energy Society General Meeting (**PESGM 2015**), pp.1-5, Denver, Colorado, USA, 26-30 July 2015.

5. A Z M S. Muttalib, G. A. Taylor and M. E. Bradley, "Improvement of Stability Analysis and Assessment through Wavelet Decomposition", in *IET International Conference on the Resilience of Transmission and Distribution Networks (***IET RTDN 2015***)*, pp.1-8, Birmingham, UK, 22-24 September 2015.

6. A Z M S. Muttalib, A. Ali, G. A. Taylor, and M. E. Bradley, "Enhancement of Operational Planning Processes though Automated Data Integration", in *50th International Universities Power Engineering Conference (**UPEC 2015**)*, pp.1-6, Staffordshire, UK, 1-4 Sept. 2015.

7. A Z M Shahriar Muttalib, G A Taylor, and M E Bradley, "Developing and Enhancing Business Processes to Enable Higher Levels of TSO-DSO Interaction", **CIRED 2016**, Helsinki, Finland, 14-15 June 2016.

8. A Z M Shahriar Muttalib, G A Taylor, and M E Bradley, "Novel Adaption of Distribution System Equivalents for Enhanced Operational Planning of Transmission Systems", in **IEEE Transactions on Power Systems** [Submitted Feb 2016]

Thanks