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

Stakeholders
Internal (e.g. NG)
External (e.g. ENTSO-E)

Requirement of other operational tools/platform (e.g. IEMS) and their scope

Current operational practices
Short-term
Real-time

Operational objectives and requirements

Power system analysis accuracy

International and GB standards (e.g. Grid Code, ER G.74)

Future trend and challenges

Scope of different modelling approaches
## Benefits of the Dynamic Equivalent

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

**Stakeholders' Requirements**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Importance Factor</th>
<th>Relative Importance (Row)</th>
<th>Relative Importance (Column)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create simple structure</td>
<td>5</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td>Reduced network</td>
<td>3</td>
<td>42</td>
<td>7</td>
</tr>
<tr>
<td>Dynamic load representation</td>
<td>3</td>
<td>24</td>
<td>7</td>
</tr>
<tr>
<td>Reduce data volume</td>
<td>4</td>
<td>30</td>
<td>9</td>
</tr>
<tr>
<td>Automate operation process</td>
<td>5</td>
<td>64</td>
<td>19</td>
</tr>
<tr>
<td>Less LV points</td>
<td>2</td>
<td>30</td>
<td>9</td>
</tr>
<tr>
<td>Limited validation procedure</td>
<td>4</td>
<td>52</td>
<td>16</td>
</tr>
<tr>
<td>Avoid LV load apportionment</td>
<td>2</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Ease data flow and connectivity configuration</td>
<td>4</td>
<td>56</td>
<td>17</td>
</tr>
</tbody>
</table>

**Resultant Column Weight**

<table>
<thead>
<tr>
<th></th>
<th>56</th>
<th>19</th>
<th>60</th>
<th>29</th>
<th>38</th>
<th>21</th>
<th>#</th>
<th>52</th>
<th>32</th>
</tr>
</thead>
</table>

**Relative Importance (Column)**

|                        | 17 | 6  | 18 | 9  | 11 | 6  | 8  | 16 | 10 |

**Column Ranking**

|                        | 2  | 9  | 1  | 6  | 4  | 8  | 7  | 3  | 5  |

**Technical capabilities of Dynamic Distribution System Equivalent**

<table>
<thead>
<tr>
<th>Importance Factor</th>
<th>Strength of the Relation</th>
<th>Stakeholders' Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive</td>
<td>Reduced network</td>
</tr>
<tr>
<td></td>
<td>Negative</td>
<td>Dynamic load representation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduce data volume</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automate operation process</td>
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<td>Less LV points</td>
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<td></td>
<td>Limited validation procedure</td>
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<td></td>
<td></td>
<td>Avoid LV load apportionment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ease data flow and connectivity configuration</td>
</tr>
</tbody>
</table>

**Correlation**

- Positive
- Negative
Load Modelling Strategy

A. Assumption of the **multiple** load model structure using **end use survey and literature**

B. Assumption of the **single** load model structure e.g. constant P,Q static model

C. Assumption of the **multiple** load model structure using **measurements**

D. Derivation of the load model parameters using **end use survey and literature**

E. Derivation of the load model parameters using **measurement**

NG’s Current Practice
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

System of Interest (Observable)

Internal System
(400kV, 275kV)

Buffer Zone
(132kV with GSP Interconnection)

System to be equivalenced (Unobservable)

External System
(non-associated objects at 132kV and below 132kV)

Internal Buses (i)
Buffer Buses (b)
External Buses (e)

Tie-Lines
Proposed Transition

Substation (400kV/275kV)

Substation (132kV/33kV)

EEWE

Proposed Transition

DNO LV Network

Substation (132kV/33kV)

Substation (400kV/275kV)

Dynamic Distribution System Equivalent
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

GSP Interconnectors

--- LV Equivalent Lines

NORTHFLEET EAST (132kV)

BOLNEY (132kV)

KINGSNORTH (132kV)

CANTERBURY (132kV)

NINFIELD (132kV)

SELLINGE (132kV)

EEWE (132 kV Substations with Switch Level Model)

EEWE (132 kV Substations with Node-Branch Model)

LV Equivalent Lines

IEEE PES Power & Energy Society
Number of objects for different network models

Model-1 (WSW)
Model-2 (WSW)
Model-1 (USE)
Model-2 (USE)

Number of LV components

0 200 400 600 800

Terminals
Transformers
Loads
Lines (132kV)
Loads
Lines (132kV)
Equivalent Lines
Equivalent Sources (EEWE)
Interconnecting Lines (132kV)
Shunt Elements
Synchronous Machines
Transformers
Breakers

70% Reduction
52% Reduction
Model Validation

\[ \min f(x) = \int_{t_{\text{initial}}}^{t_{\text{final}}} \sum_{n_R} \left( (\text{Parameter})_{\text{org}} - (\text{Parameter})_{\text{equa}} \right) \left\| n_R^i \neq 0, i = 1, 2, \ldots, N_R \right\| \]

\( x \Rightarrow \)
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.
CA Results

Model-2 (MAX) vs Model-2 (MIN) for Sample Points of Different Substations

Model-2 (MAX) vs Model-2 (MIN) for Sample Points for Different Substations

Sample Points of Different Substations

Sample Points for Different Substations
SA Results

Load Transferred Equivalent (LTE)

P, Q Values are transferred from EEWE

Cont. Z (%)
Dynamic. Load (%)

P, Q Values are transferred from EEWE

- Original Network  - LTE  ----- EEWE

- Original Network  - LTE  ----- EEWE

- Original Network  - LTE  ----- EEWE

- Original Network  - LTE  ----- EEWE
Wavelet Decomposition

Wavelet Decomposition Result and Time Constant

<table>
<thead>
<tr>
<th>Original Network</th>
<th>Wavelet Decomposition Technique</th>
<th>Reduced Network with LTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.715</td>
<td>2.649 (2.43%)</td>
<td>2.715 (0%)</td>
</tr>
<tr>
<td>3.456</td>
<td>3.469 (0.37%)</td>
<td>3.456 (0%)</td>
</tr>
<tr>
<td>1.245</td>
<td>1.295 (4.01%)</td>
<td>1.246 (0.7%)</td>
</tr>
<tr>
<td>5.673</td>
<td>5.802 (2.27%)</td>
<td>5.673 (0%)</td>
</tr>
<tr>
<td>7.345</td>
<td>7.401 (0.76%)</td>
<td>7.347 (0.03%)</td>
</tr>
<tr>
<td>Average Error</td>
<td>1.97%</td>
<td>0.02%</td>
</tr>
</tbody>
</table>
NG will be able to adopt a dynamic load model consisting of multiple components
Methodology and Strategy

For LF, FLA and CA

- Case-A: Detail Model at MAX Demand Point
- Case-B: EEWE at MAX Demand Point
- Case-C: Detail Model at MIN Demand Point
- Case-D: EEWE at MIN Demand Point

Network Reduction
Load Flow, Fault Level Analysis (FLA), Contingency Analysis (CA)

Comparative Result of Case-A & B And Case- C & D

Operational Data
Model Structure with Topological Data

Data for comparison
Actual operational data to be used at the planning stage

For SA

- Case-A: Detail Model at MAX Demand Point
- Case-B: EEWE at MAX Demand Point
- Case-C: Detail Model at MIN Demand Point
- Case-D: EEWE at MIN Demand Point

Load Transferred Equivalent (LTE) Representation
Model Structure with Topological Data

Final Equivalent for Max Demand Point (Case-B)
Final Equivalent for Min Demand Point (Case-D)

Stability Assessment
- Listed Parameter for Observation for Planning
  1. Damping constant
  2. First Swing Nature
  3. Absolute value of Rotor Angle

Comparative Result of Case-A & B And Case- C & D

Through DPL scripting
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


Thanks