






PSCAD

EMT Simulations to facilitate large scale renewable generation connections

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Outline

- General Introduction - Applications of EMT simulations to facilitate Inverter based systems
- Demonstration of PSCAD – Basic maneuvers (loading and creating study cases, Master Library, building a study case, data entry, metering and plotting, applying contingencies….) to get participants ready for the upcoming tutorials.
- Direct conversion of data from PSSE (or other data bases)
  - Wide Area simulation study approach
    - Re-dispatch and future operating scenarios
    - Deriving smaller areas from a wide area PSCAD case
    - Scripting and automation

Electromagnetic Transient simulation plays an important role during integration of wind and other renewable energy-based generation to transmission networks. This is mostly because renewable generation is connected to grids through **power electronic inverters**.

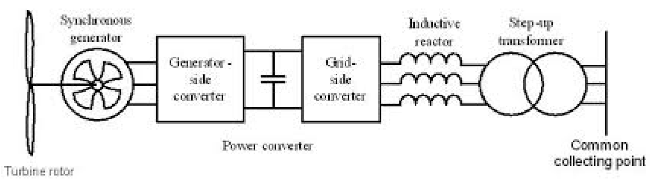
A number of dynamic response issues are identified when inverter-based generation is connected to 'weak' (low short circuit levels) locations of transmission network.

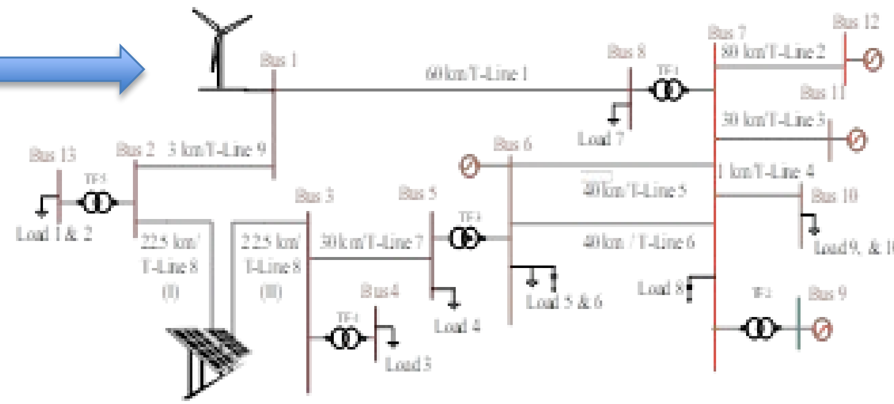
- The voltage (specially the phase angle) at weak grid locations show pronounced variations following a system disturbance such as fault clearing. The "**GRID Following**' inverter response is critically dependent on measuring such phase angle changes (instantaneous response as opposed to rms) accurately through the Phase Locked Loop (PLL) and other signal measurements at the connection point. Inability of PLL to correctly track the voltage changes has resulted on poor fault recover response of the inverter or tripping of the unit in violation of grid codes.

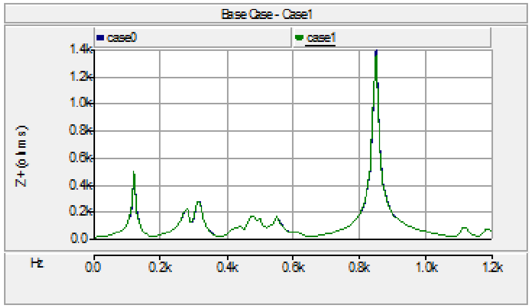
- The voltage control at weak locations is challenging. When multiple inverter-based devices are located in close vicinity in a weak grid area, there is a risk of these fast acting (fast reactive current control) devices interacting in an unstable manner and leading to a multitude of issues, generally classified as 'control interaction'.

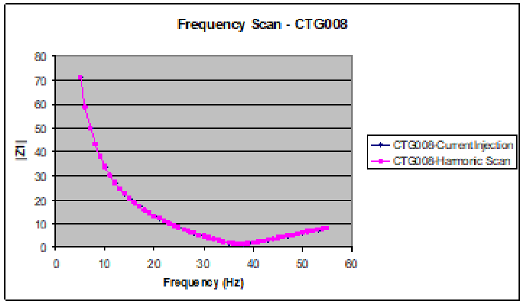
IBRs and influence of Transmission System Characteristics

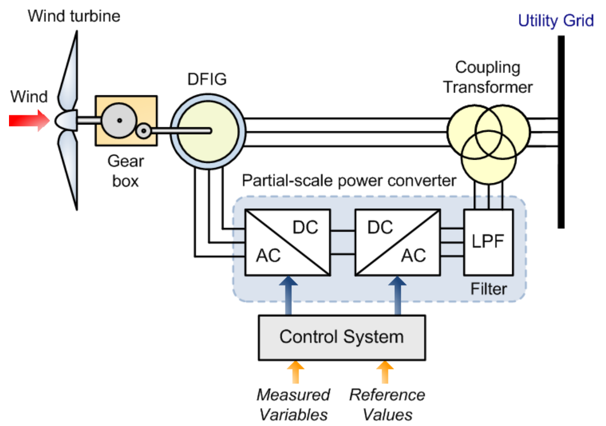
- The characteristics of wind generators are much different from traditional synchronous machine-based generation.
- Nature of AC or HVDC transmission used to connect wind to the transmission grid (long ac cables, filters, weak grids, series compensation)

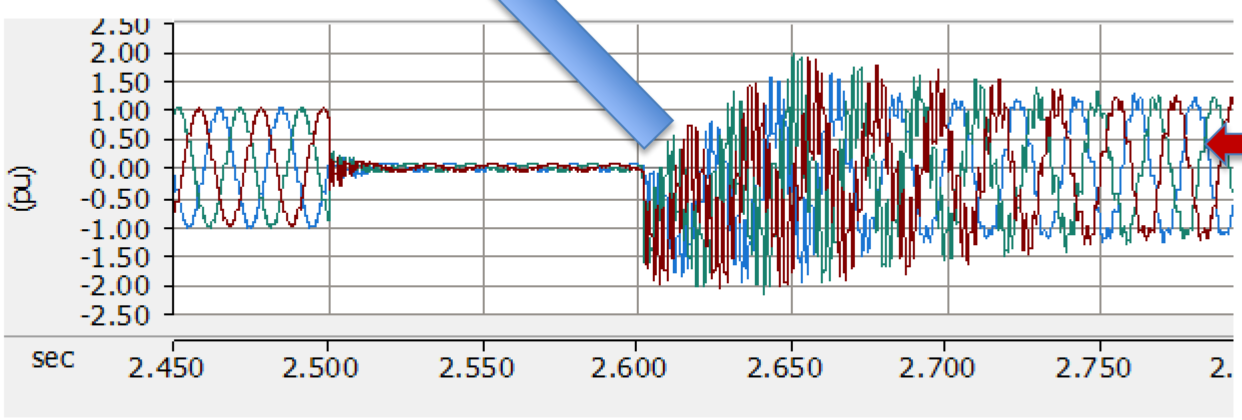








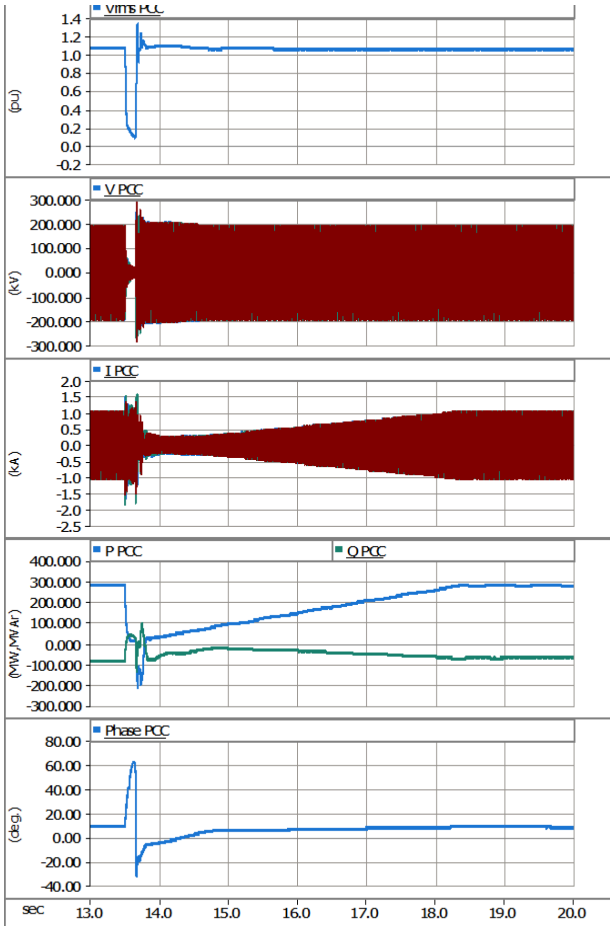


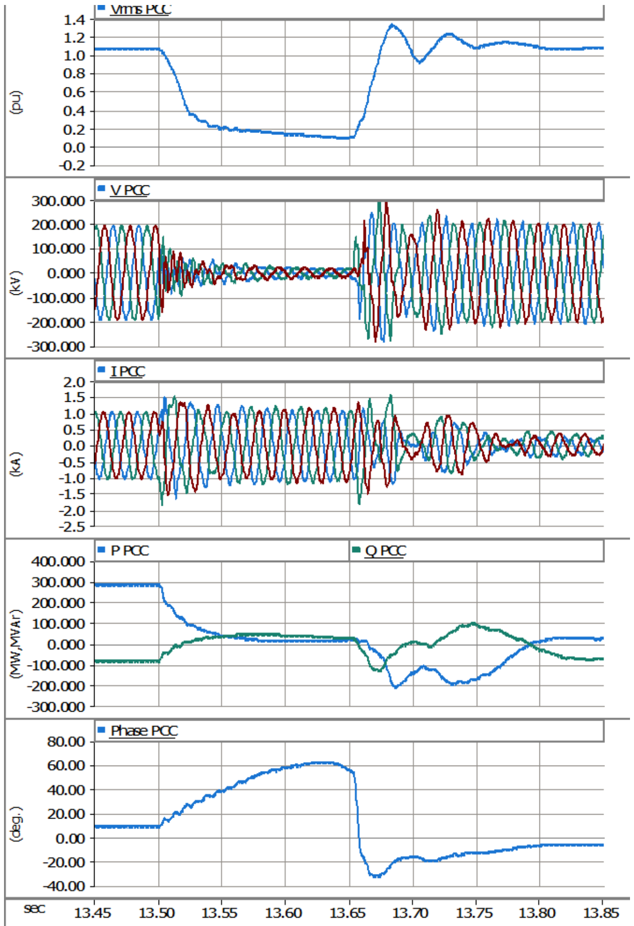


Bus voltage following a fault

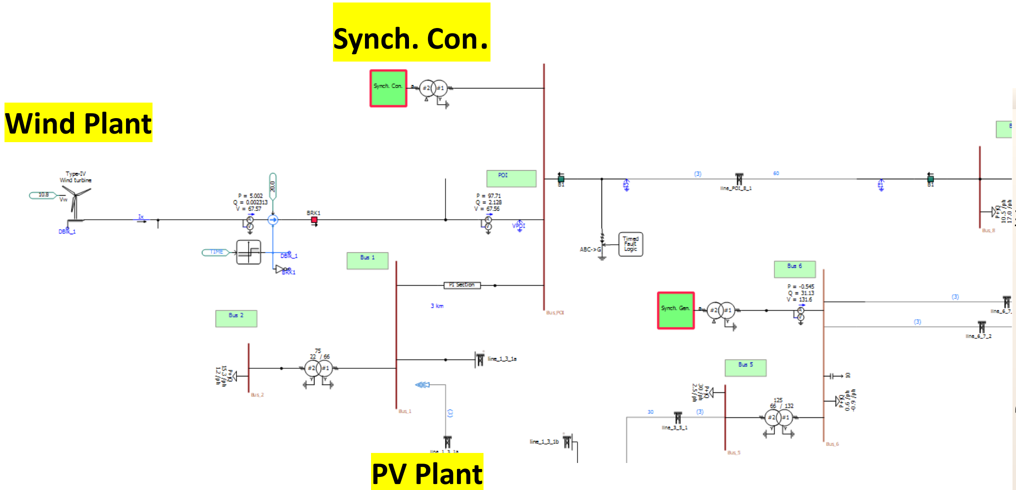
This voltage must be tracked and phase angle shifts estimated accurately and fast to ensure stable operation

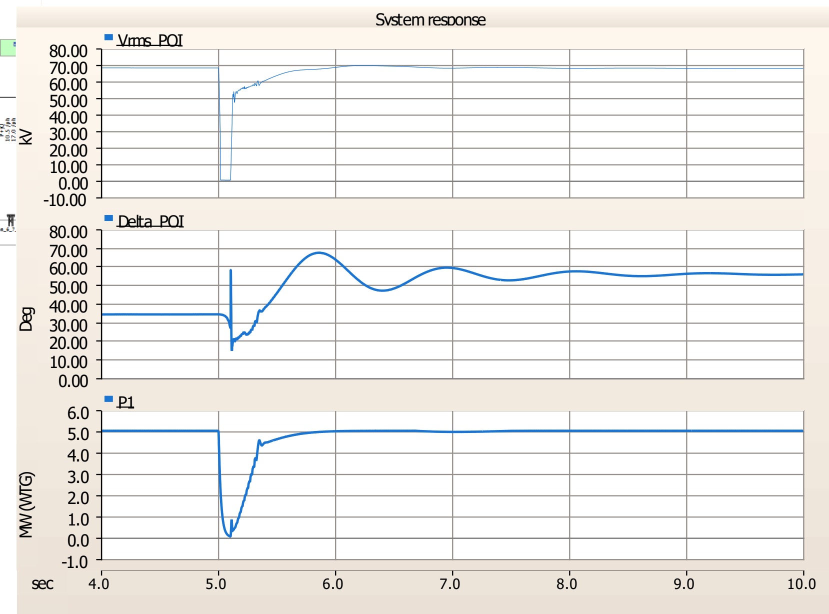
Power reversal as an example - Fault Recovery of an offshore windfarm



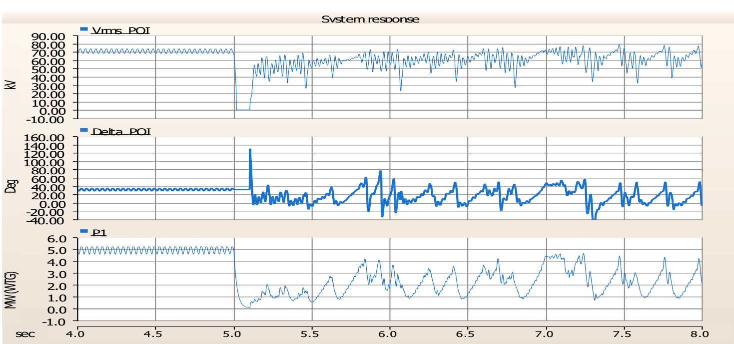


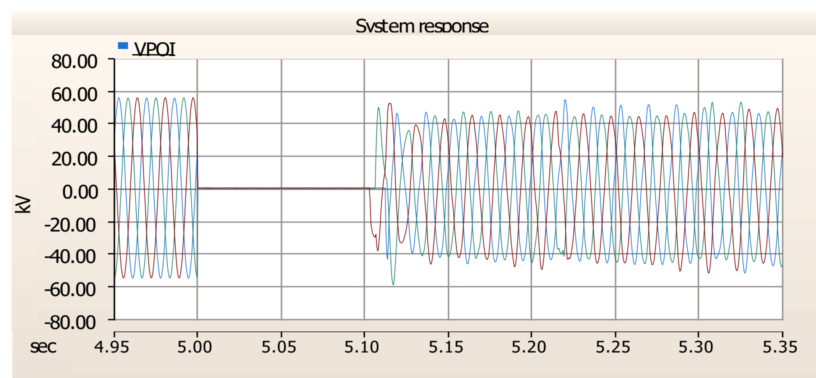
Identifying Mitigation Measures



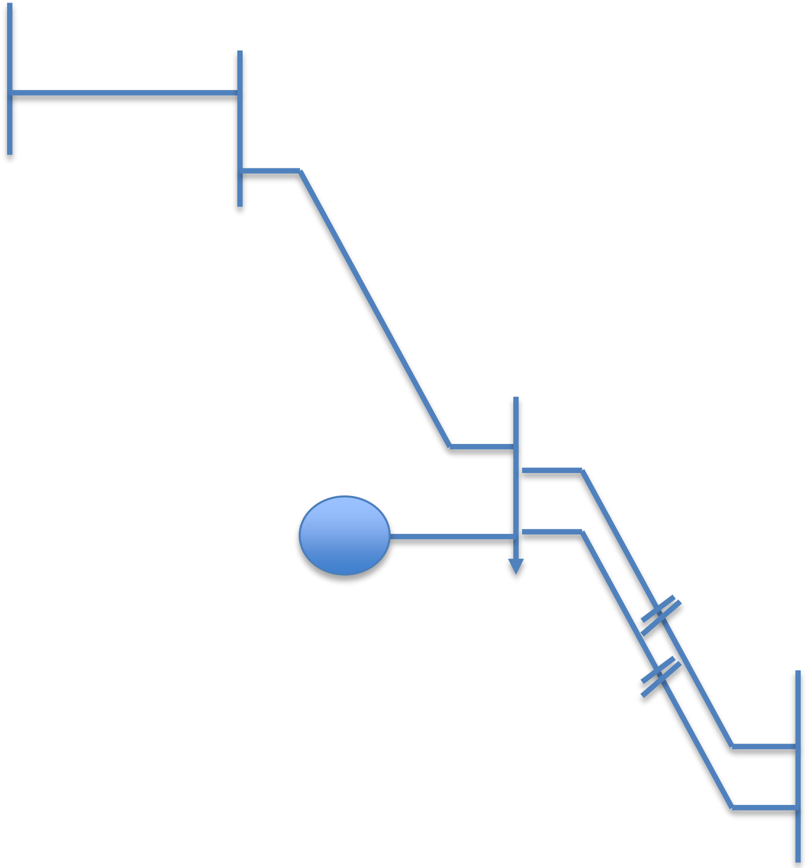


Without Synchronous Condenser

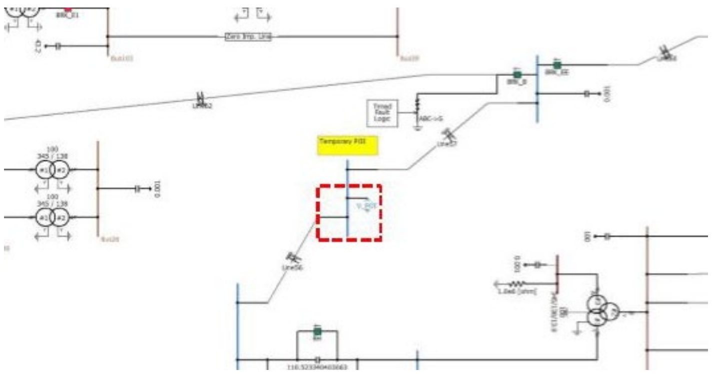


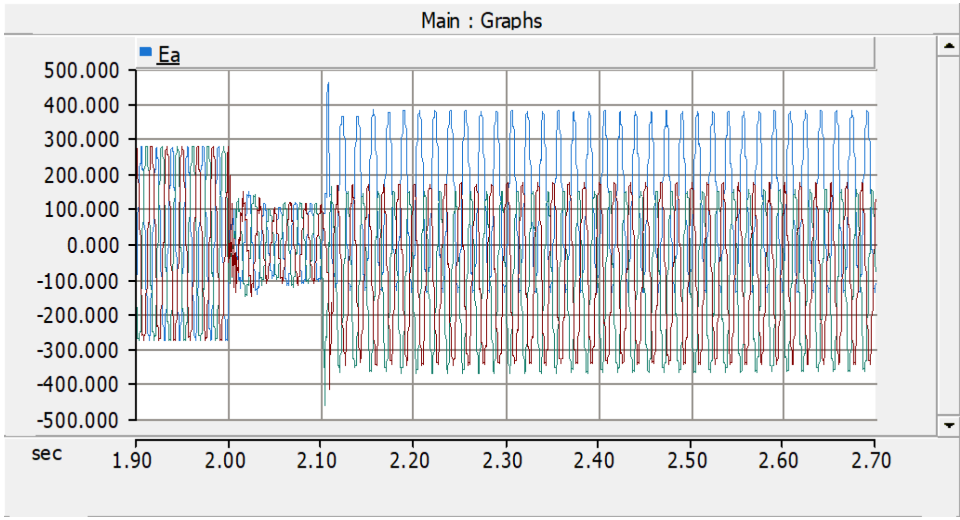


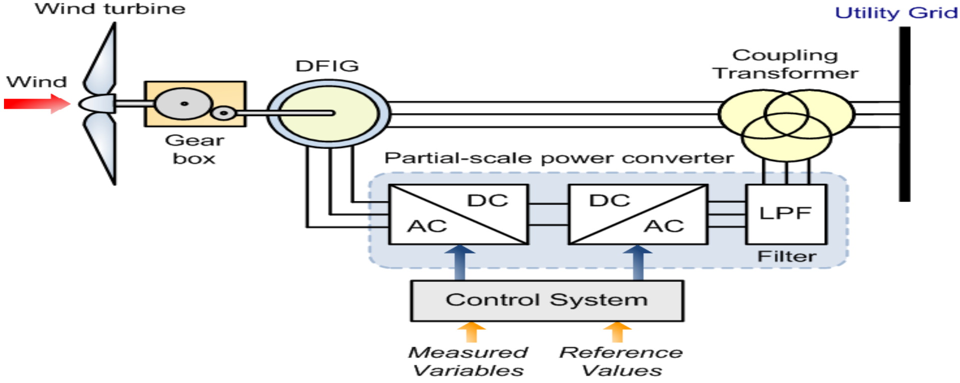
The series compensated line is tapped to facilitate the wind farm connection



Issue No.2: Wind Inverter response to system transients







The DC offset in the POI voltage caused the inverter DC link voltage to rise.

- Poor network side damping
- Excessive energy in DC link chopper resistance (resulted in a trip)

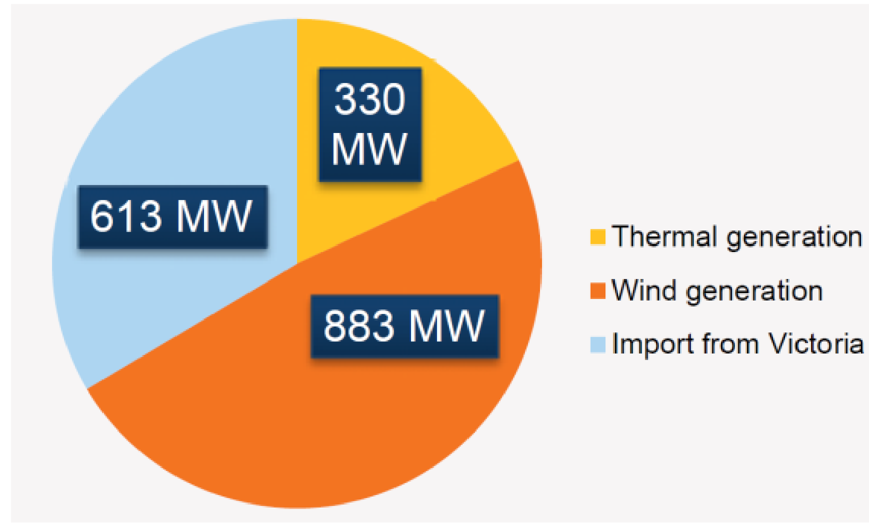
The need for EMT Simulation based analysis

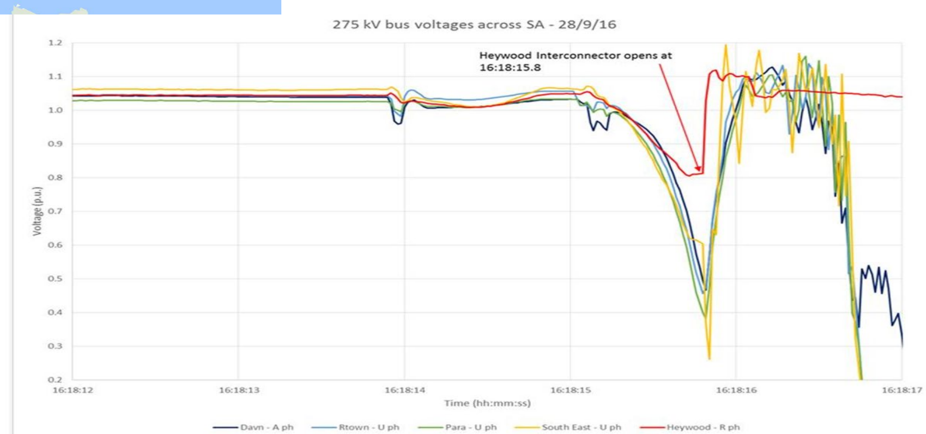
EMT analysis is essential to verify the design and stable operation of IBRs, specially when connecting to ‘weak’ grid locations.

Most design verification studies (previous examples) can be performed with a small area of the transmission network captured in the EMT circuit formulation.

However, there have been industry experience where a wider network had to be implemented to capture the overall system response accurately. This has led to a strong interest in ‘ Wide Area Emt Simulations.

Example 1 – Black System South Australia – September 28, 2016





Event Description

- Extreme weather conditions resulted in five system faults on the SA transmission system in the 87 seconds between 16:16:46 and 16:18:13, with three transmission lines ultimately brought down

- In response to these faults, and the resulting six voltage disturbances, there was a sustained reduction of 456 MW of wind generation to the north of Adelaide.

- Increased flows on the Heywood Interconnector counteracted this loss of local generation by increasing flows from Victoria to SA

- This reduction in generation and increase of imports on the Interconnector resulted in the activation of Heywood Interconnector's automatic loss of synchronism protection, leading to the 'tripping' (disconnection) of both of the transmission circuits of the Interconnector. As a result, approximately 900 MW of supply from Victoria over the Interconnector was immediately lost.

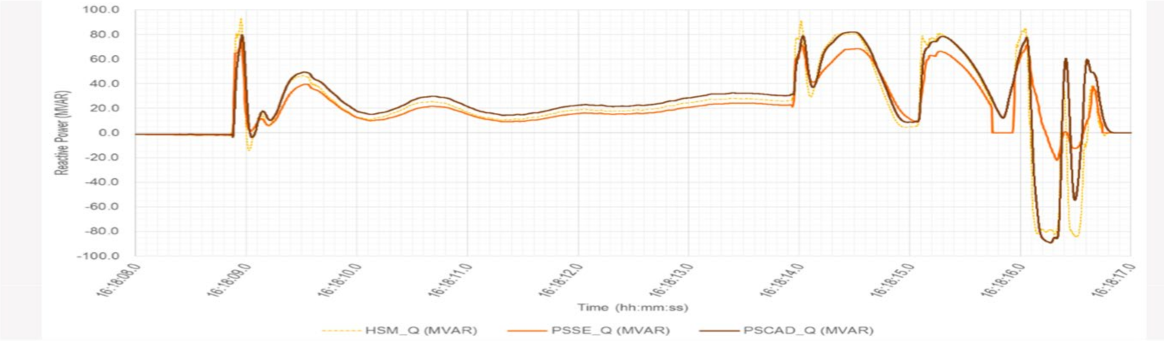
- This sudden and large deficit of supply caused the system frequency to collapse more quickly than the SA Under-Frequency Load Shedding (UFLS) scheme was able to act.

- Without any significant load shedding, the large mismatch between the remaining generation and connected load led to the system frequency collapse, and consequent Black System.

Lessons Learned and Recommendations

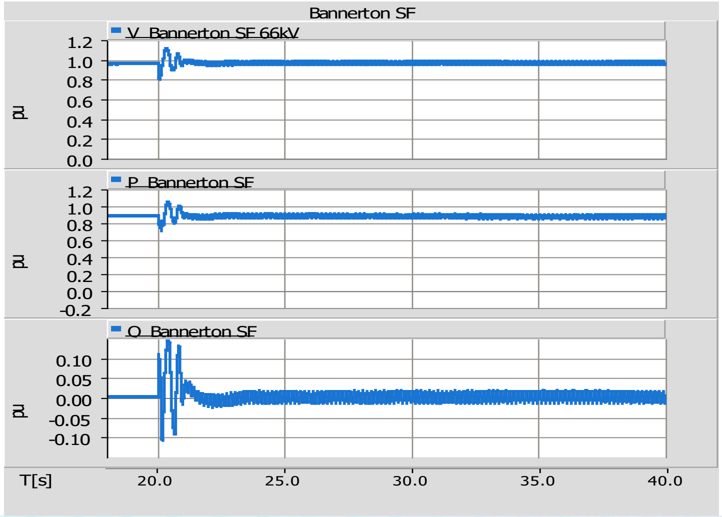
Generation Mix and System Inertia:

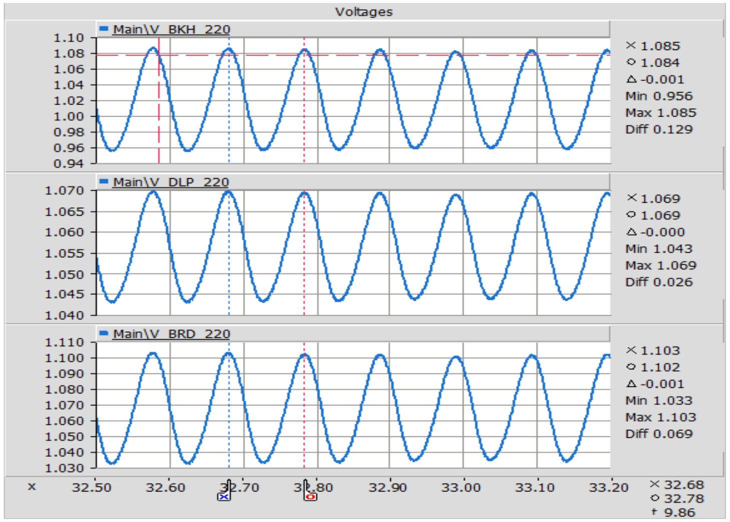
- The system inertia on the SA side was not sufficient to maintain the frequency drop (once the Haywood interconnector tripped) and to make the under frequency load shedding (UFLS) effective.
- 'Must run' thermal generation may have to be identified.
- Synchronous condensers may be investigated as a potential solution if the thermal generation dispatch is expected to be low under specific load conditions.
- Load shedding



Example 2 – Low Frequency Voltage Oscillations (8- 10 Hz range)

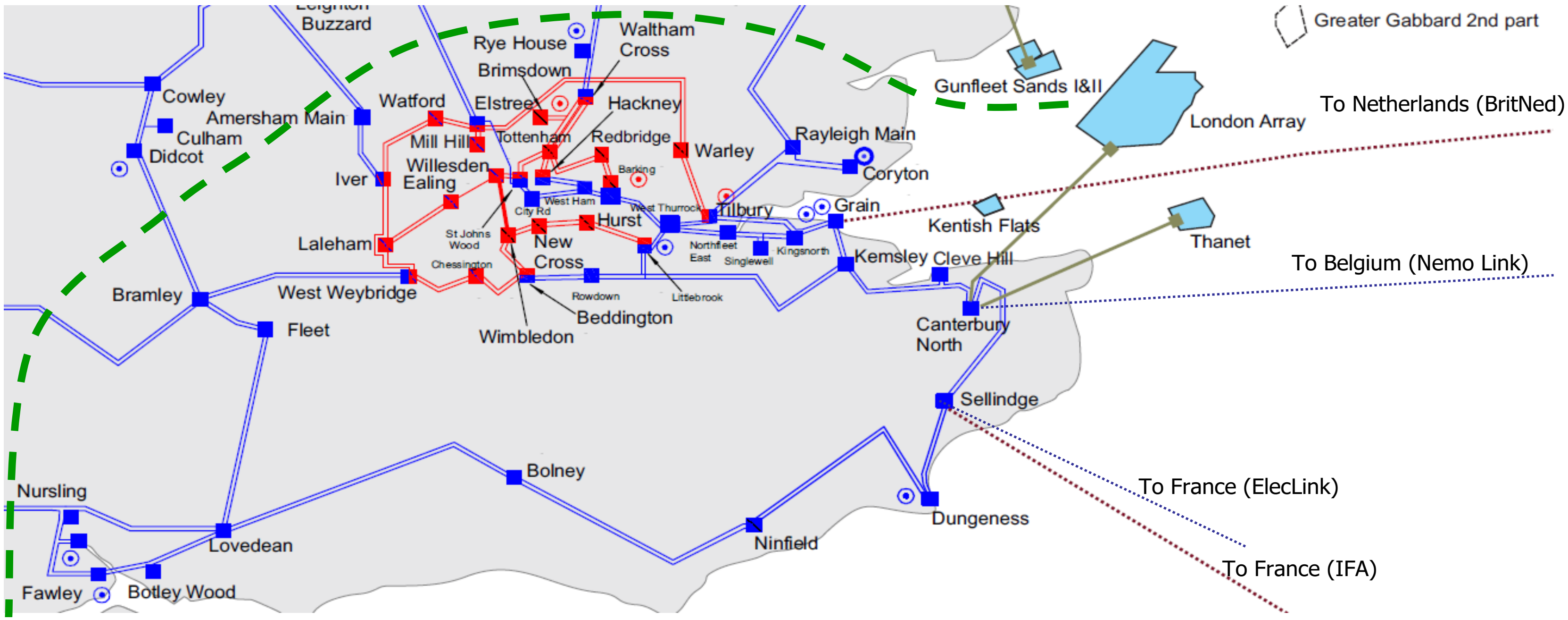
Low Frequency Voltage Oscillations – Interaction between multiple dynamic devices



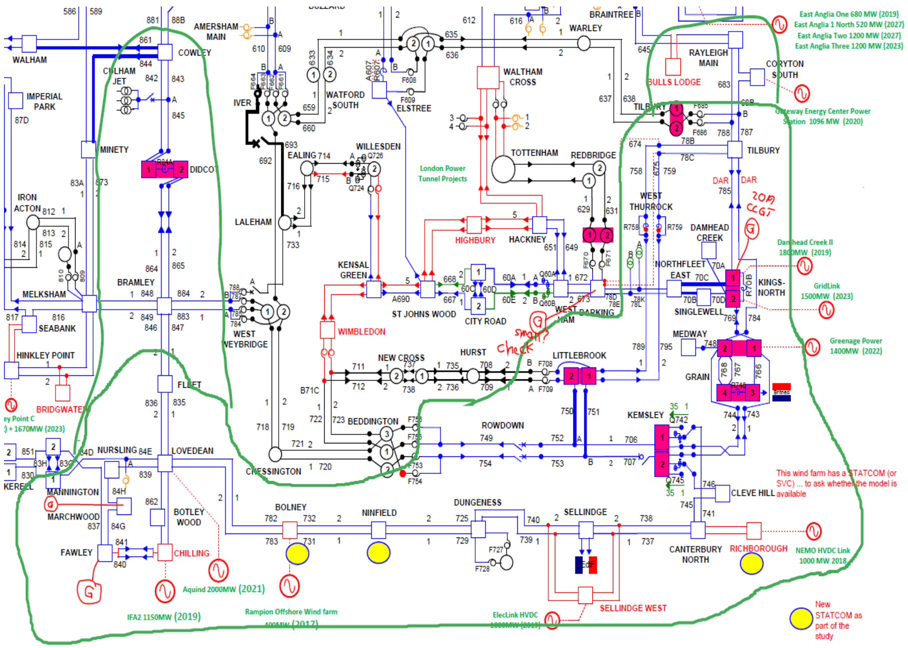


Potential Control Interaction and SSTI issues - South East England

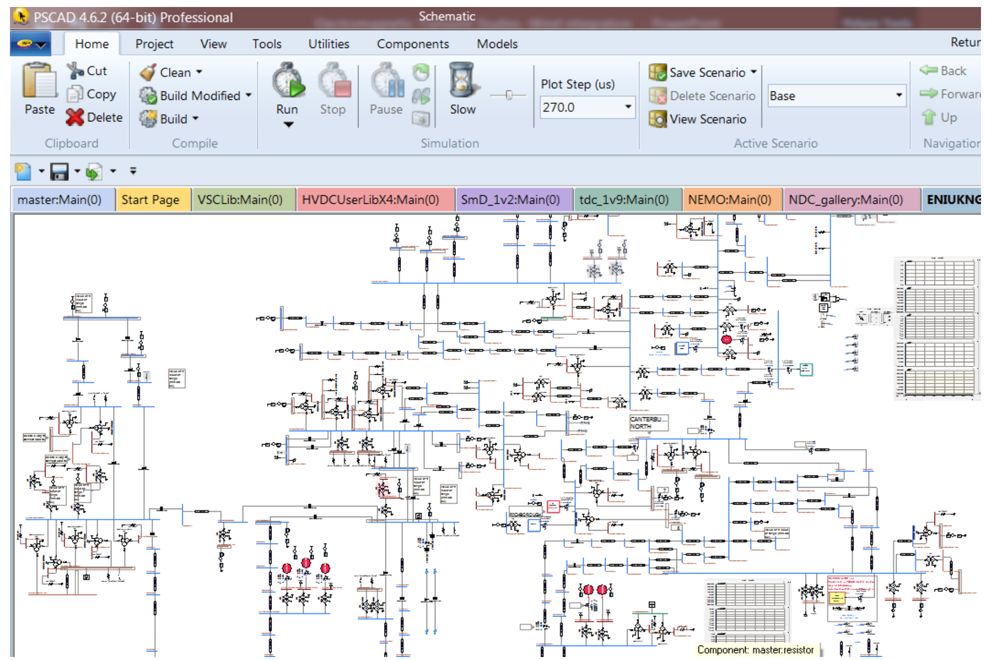
- South East England is where several HVDC interconnectors land and is a region that has little synchronous plants and even that is being displaced by offshore wind farms.
- Three STATCOMs commissioned to provide voltage support.
- The short circuit ratio is low and reactive current during a fault is sought.
- Control interactions and sub synchronous oscillations concerns given the ‘weak grid’



Potential Control Interaction and SSTI issues - South East England



- Modelling the entire South East England network including all vendor models for all HVDC, STATCOMS, Wind farms in EMT Platforms.



Model Validation of South East England between PSCAD and PF

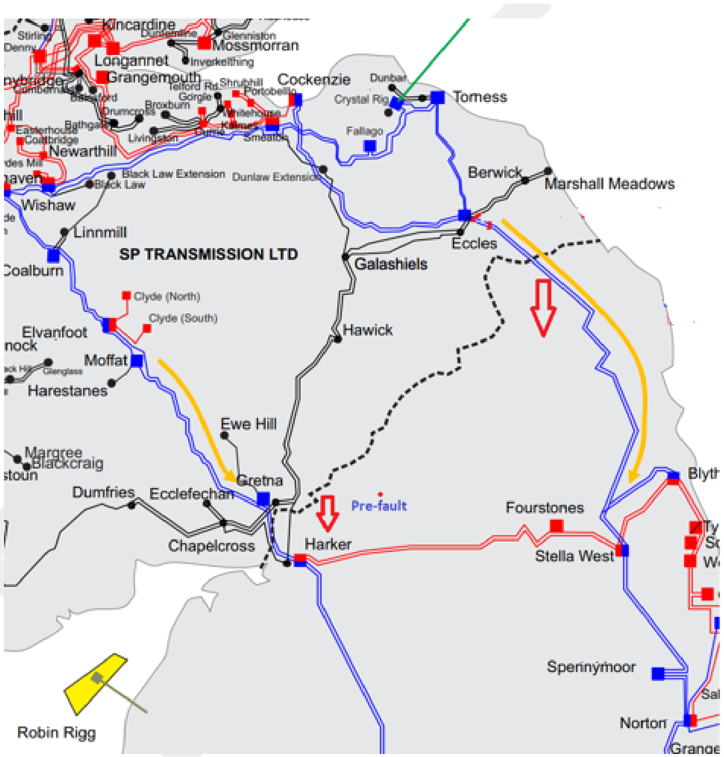
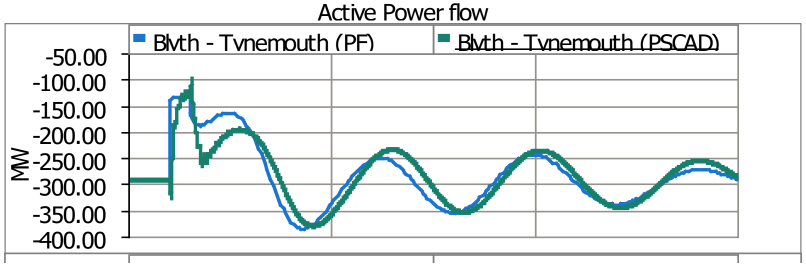
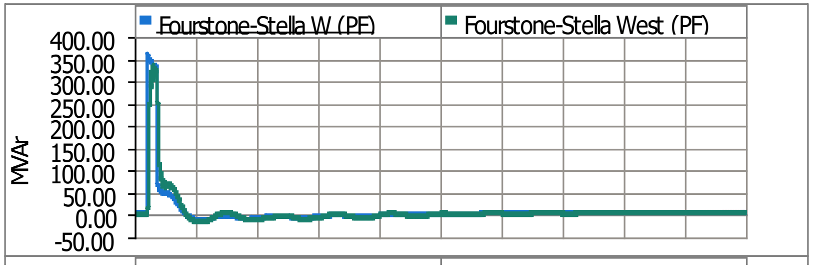
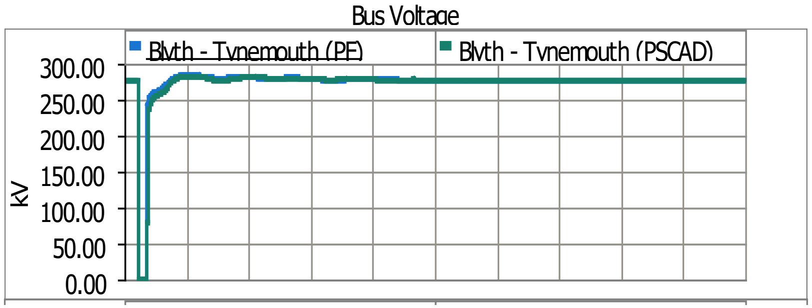


Figure 1: Two 400kV transmission corridors from Scotland to England







The PSCAD model was validated against dynamic response results of the full National Grid System model in Power Factory.

Way Forward for Wide Area EMT Simulations

EMT type calculations are inherently 'slow' compared to rms type calculations

- RMS type simulations

$$V(\omega) = R \cdot I(\omega) + j(L\omega) \cdot I(\omega)$$

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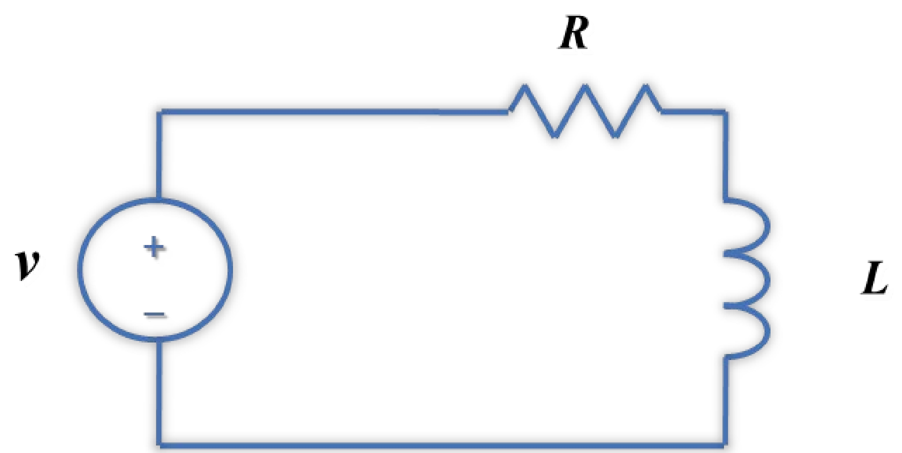
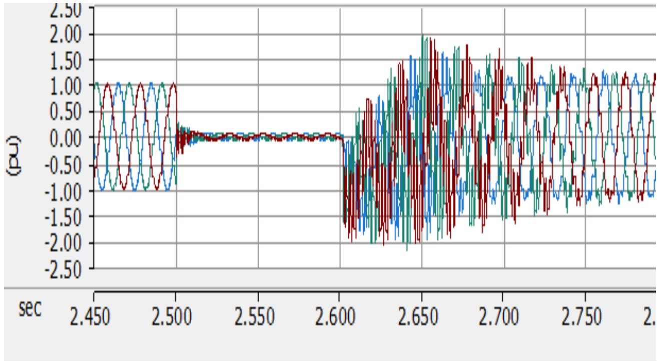


- Electro-Magnetic Transient Simulations (EMT)

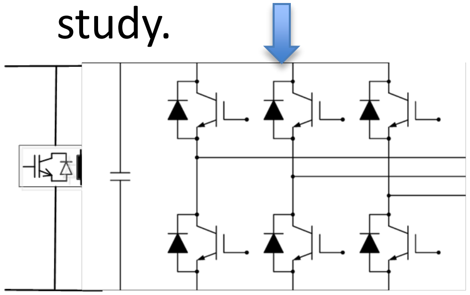
$$v(t) = R \cdot i(t) + L\frac{d}{dt}i(t)$$



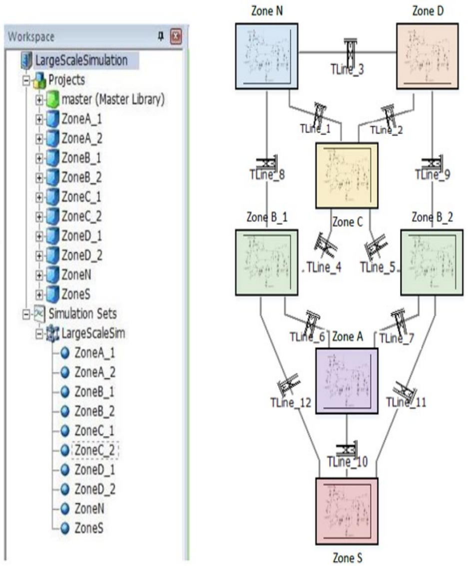
Challenges and solutions

Solutions provided to overcome the wide area EMT simulation Challenges:

- Improved mathematical algorithms to speed up any one given simulation.
- Parallel simulation of different parts of a network and IBR modules – use the inherent 'delay feature of a transmission line or cable connection to find a 'natural' break point.
- Non-switching type representation of IBR inverters – if done properly, these models will not impact overall conclusions of a study.



Representing 'switching devices' in an EMT simulation further compounds the simulation speed challenge.

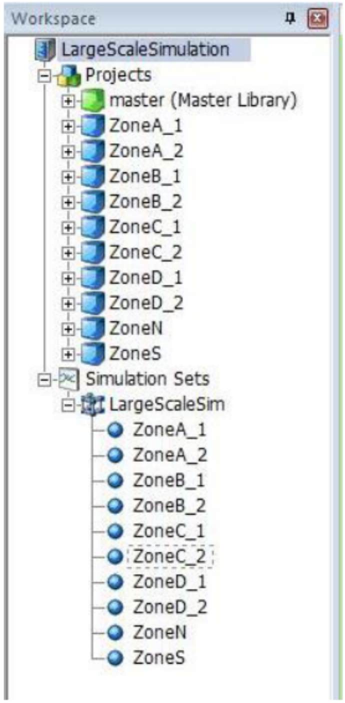


PSCAD Network Workspaces

Network Connected by Parallel EMT

Relatively fast simulation speeds can be achieved

Large Western Canada/USA system



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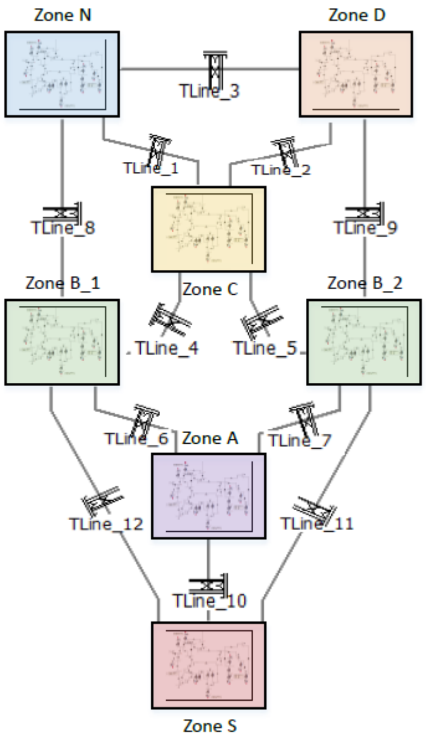

Network Connected by Parallel EMT

- Over 2500 buses
- Over 50 dynamic devices
- Did not model Power electronics (purpose was to get a measure of speed gain due to system node splitting)

- A 10 sec run was completed in 2.5 min

- Australian System Model
- Belgian System Model
- Scottish System model
- National Grid UK system model
- Spain – Balearic island system model
- Canadian and US regional system models

Data Conversion:

Typically, Utilities and TSOs maintain network data in standard software formats (PSS/E, PowerFactory).
Automated methods to import such data to EMT planforms are available (PRSIM/E-Tran tools converts data from other formats to PSCAD)

Thank You