Network Loss Study in PowerFactory

Harshul Dalal

Albert Pors

Endeavour Energy

Introduction

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- Current Methodology
- PowerFactory Network Model
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National Electricity Rules Requirements

- The National Electricity Rules (Chapter 3, Section 3.6.3) requires that:
  - Distribution Network Service Providers (DNSPs) calculate Distribution Loss Factors (DLFs) for the next financial year
  - Submit these loss factors to the Australian Energy Market Operator (AEMO) following approval from the Australian Energy Regulator (AER).
  - DLF's for site specific major customers (>10MW or >40GWh)
  - DLF's for each tier of the network should be provided to calculate the losses attributable to the remainder of the customers.
- Done on an annual basis.

Endeavour Energy's Historic Methodology

- Calculated using Load Loss Factors (LLFs)

$$LLF = \frac{\sum_{n=1}^{35040(Iterations_{15-\min})} \left(\frac{Load_n^{\,2}}{Load_{Peak}^{\,2}} \right)}{35040}$$

1. Calculate the series I^2R loss on the relevant part of the system under forecast peak load conditions.
   - Historically using DINIS models.
   - Sub-transmission (132-33kV) and distribution (22-11kV).
2. Metering data for all Bulk Supply Points (BSP), major generators, Transmission Substations, Zone Substations and major customers:

Endeavour Energy's Historic Methodology

3. Calculate the associated series energy losses using peak load flow losses and calculated LLFs.

$$Losses_{Series}(kWh) = Losses_{Peak}(kW) \times 8760(hours) \times LLF$$

4. Transformer no-load shunt losses calculated using manufacturers data. No LLF applied as independent of transformer loading.

$$Losses_{Shunt}(kWh) = Losses_{Shunt}(kW) \times 8760(hours)$$

Endeavour Energy's Historic Methodology

- Limitations:
  - The LLF is a function of the instantaneous losses at peak load and the average losses over one year.
  - This single snapshot of the power system fails to account for changes in the network operating point as generation and load vary.
  - Manual intervention is required to determine the LLF for each customer or network tier, as well as in calculating the final loss factors.
  - Time consuming iterative process.

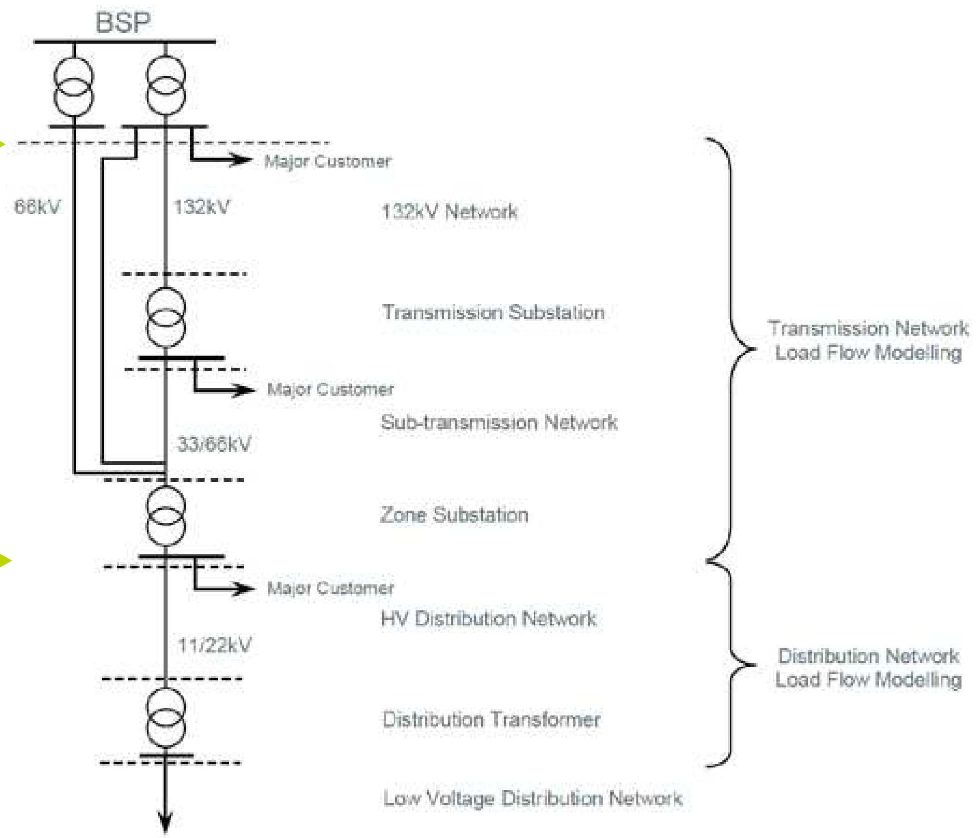
Endeavour Energy’s Current Methodology

- New methodology over past few years.
- Overcomes some of the limitations of the historic method
- Series losses on the sub-transmission network calculated by including 15 minute metering/SCADA data from the previous financial year in a load flow routine.
  - Much more load flow intensive.

Endeavour Energy's Current Methodology

Interface with TNSP

Zone Substation Busbar



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Endeavour Energy's Current Methodology

Summary of the Approach:

1. For each 15 minute metering interval, one load flow solution provides:
   - Total network losses
   - Accumulated network losses within each voltage level (or also called network tier).
2. Network tier losses must now be fairly apportioned between the customers connected to that part of the network.
   - Losses are non-linear (I^2R)
   - The contribution of each major customer or network tier to the total losses can be thought of in terms of sensitivity coefficients.

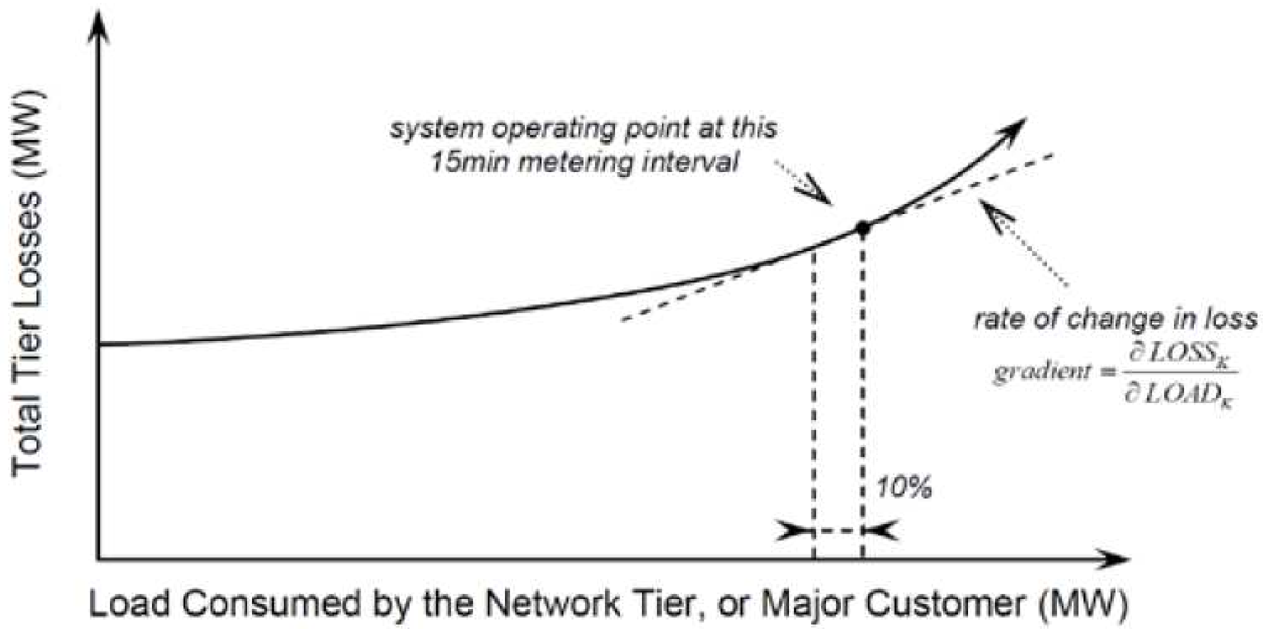
Endeavour Energy's Current Methodology

$$Losses(Total)_{Series} = \sum_{i=1}^{K} A_i Losses(Total)_{Series}$$

$$Losses(i)_{Series} = A_i Losses(Total)_{Series}$$

- Sensitivity coefficients A, Major customer or Network Tier K.
- In reality, best you can do is derive an approximation to the sensitivity coefficient.
- Approximation done through linearizing the network losses at each 15-minute operating point.
- 10% perturbation to the loading of each major customer or network tier around the operating point.

Endeavour Energy's Current Methodology



- Naturally, the summation of these approximated sensitivity coefficients will not exactly equal unity and are therefore scaled.

Endeavour Energy's Current Methodology

3. Finally, each network tier or major customer loss factor can be derived.

$$LF = \frac{\sum_{N=1}^{35040} Losses(K)_{Series} + \sum_{N=1}^{35040} Losses(K)_{Shunt}}{\sum_{N=1}^{35040} Energy(K)}$$

- Substation transformer shunt losses assumed constant.
- 11kV and 22kV feeder distribution networks still calculated using LLF method.

PowerFactory™ Network Model

- Endeavour has a network model in PowerFactory. It includes:
  - TNSP injection point, usually a 330/132kV substation and upstream of this a reduced equivalent NEM source network.
  - 132kV, 66kV, 33kV sub-transmission feeders.
  - 132kV/66/33kV transmission substations
  - 132/22, 132/11, 66/11, 33/11 zone substations
  - Does not include 22/11 kV distribution feeders.
- Model is populated from a networks characteristics database using a DGS converter tool.
- Makes use of PowerFactory™ 'Variations' to capture future projects and network augments. These can be turned on and off as required.

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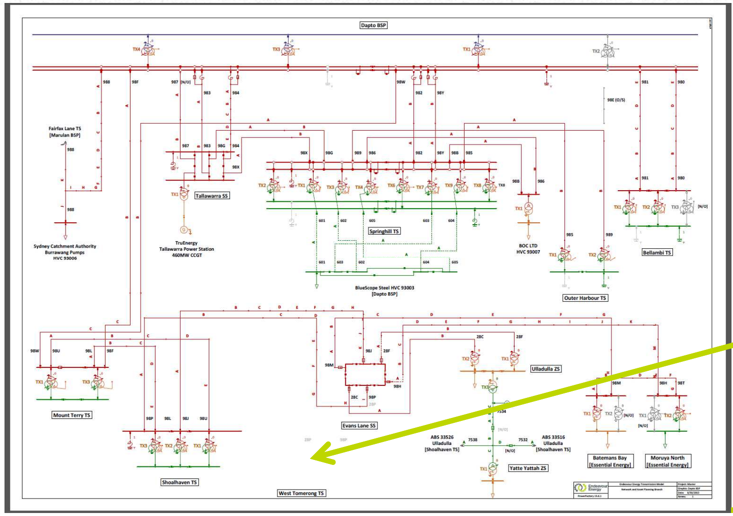
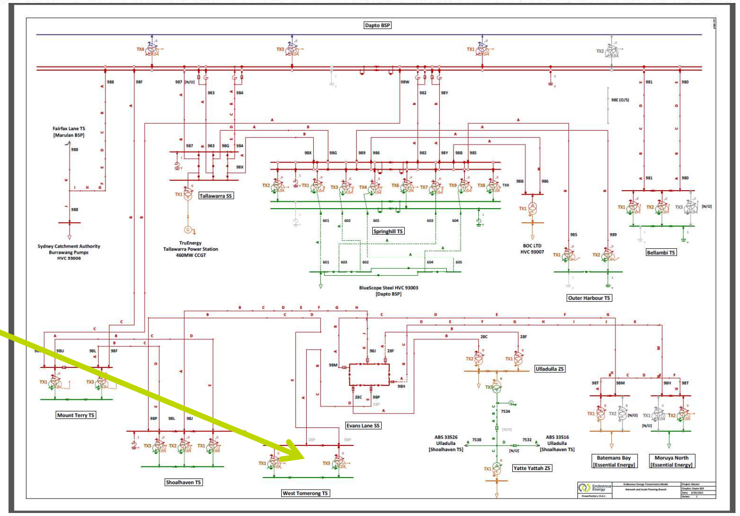
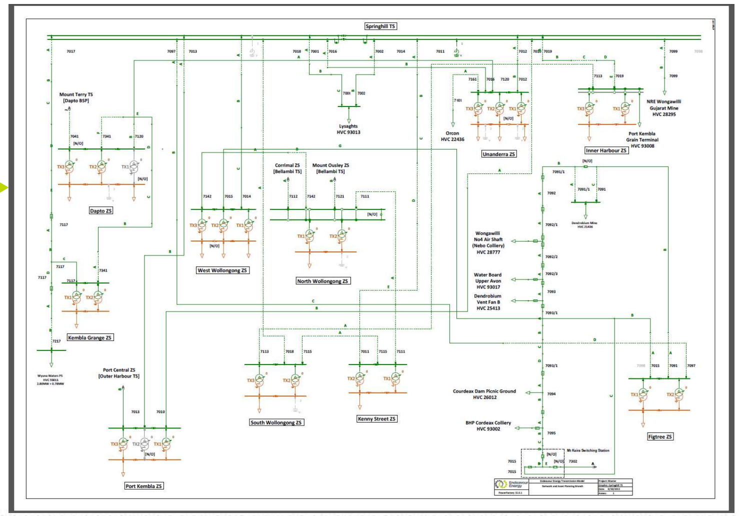
PowerFactory™ Network Model



Variation



Tiered Network Pages



- Detailed substation busbar arrangements.
- Lines broken into sections
- Total of ~8800 nodes

Loss Study Script Development

- A DIgSILENT Programming Language (DPL) script was developed to implement the previously described loss study methodology.
- A high level overview:
  - Import from file (csv) the 15-min metering data into chavecfiles within PowerFactory. The metering data is already scaled to forecast values for zone substations, generators and special customers.
  - Identify from an input file the special customers for individual LF’s
  - Run the individual load flows, including perturbation load flows for each 15-min interval (approx 30 load flows per interval).
  - Record individual results in matrices.
  - Export results matrices to an output file and end of years runs.

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Loss Study Script Development

- The total number of load flows that result from this method depends on the number of major customers.
- With 30 major customers and 15-minute metering data intervals a total of **1,051,200** load flows are required!
- Very computationally intensive.
- The first load flow at each time interval is a “flat start” load flow where tap changing occurs. Subsequent perturbation load flows are “locked tap”.

Loss Study Script Development

- Previously the loss study was implemented in another load flow engine with a linking script.
  - Text based, minimal detail, small node count ~600.
  - Required to be updated separately (only used for loss study).
  - Significant development time to prepare models ~ several weeks.

- Implemented in PowerFactory
  - Graphically based, higher modelled detail, large node count ~8800
  - Updated as a matter of course, used for multiple studies.
  - Insignificant additional development time for loss study.

Results and Performance

- Summary of some performance measures

Measure	Nodes	Run Time (hrs)	Run Time / node (hrs)	Non-convergences
Old Model	600	96	0.160	0.23%
New Model	8800	302	0.034	0%
Variation	1466%	314%	21%	

- Overall runtime increased, but when split across three PC's, almost the same effective computational time.
- Non-convergent load flows reduced to 0, so no need to find sources of non convergences and re-run.
- Run time improved by a % ~ sqrt(% reduction in nodes).

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Results and Performance

- Overall Advantages:
  - Common model shared for other studies.
  - Regularly updated, links to our characteristics.
  - Scripting language within the same package.
  - Detailed outputs → locate sources of non-convergence.

Future Work

- Further improve results accuracy:
  - Currently shunt losses assumed constant. Transformer shunt losses vary with voltage → take this as an output from the model at each load flow as well.
- Further improve run time:
  - Create a script to remove/collapse unnecessary nodes prior to loss study run.
  - Utilise multiple instances of PowerFactory to make use of multicore PC's. Most PC's have quad core capability.
  - Contingency Analysis?

THANK YOU

Questions?