

# Network Loss Study in PowerFactory™

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**Abstract—** This paper describes Endeavour Energy’s approach to calculating distribution loss factors and its experience in implementing the loss factor study in DigSILENT PowerFactory. The paper also discusses performance issues experienced with a computationally intensive methodology for a large model.

**Index Terms -** DigSILENT PowerFactory, Distribution loss factor, Network Losses, Load flow, Sensitivity Analysis.

## I. INTRODUCTION

For the past few years Endeavour Energy has developed and utilised an approach to loss factor calculation that includes performing a year’s worth of 15-minute load flows in combination with sensitivity load flows to determine the sub-transmission network loss component [1]. The development of a PowerFactory network model presented an opportunity to overcome many of the challenges experienced previously in implementing this methodology using another load flow package.

This paper describes Endeavour Energy’s network model, the method of calculating distribution loss factors and its implementation in PowerFactory using DigSILENT Programming Language (DPL) scripts. The paper also discusses the results obtained and the experience gained around performance issues of this computationally intensive approach to loss calculations in PowerFactory.

## II. NETWORK LOSS FACTOR CALCULATIONS

### A. National Electricity Rules Requirements

The National Electricity Rules [2] require that Distribution Network Service Providers (DNSPs) calculate Distribution Loss Factors (DLFs) for the next financial year and submit them to the Australian Energy Market Operator (AEMO) following approval from the Australian Energy Regulator (AER).

The NER require an annual calculation of site specific DLFs for major customers (>10MW or >40GWh), while loss factors for each tier of the network should be provided to calculate the losses attributable to the remainder of the customers.

### B. Historic Method

Historically, Endeavour Energy has used a hierarchical approach to determine the distribution loss factors. In general, the method used to calculate series energy losses has been to first calculate the loss on the relevant part of the system under peak load conditions using a load flow package. This includes Sub-transmission (132-33kV) and distribution (22-11kV).

The associated energy losses as in (1) incorporates the Load Loss Factor (LLF) which is the ratio between the instantaneous losses incurred at peak load and the average instantaneous losses over a year as in (2).

$$Losses_{Series}(kWh) = Losses_{Peak}(kW) \times 8760(hours) \times LLF \quad (1)$$

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

These LLFs were traditionally calculated for all Bulk Supply Points (BSP’s), major generators, transmission substations, zone substations and major customers. These LLFs were evaluated using metering data at each location if available, or alternatively, SCADA data. Peak losses were then modeled using location specific demand forecasts for the coming year.

Within substations, transformer no-load shunt losses have been calculated using manufacturer’s data if available as in (3). Since these losses are independent of the transformer loading, no LLF is applied.

$$Losses_{Shunt}(kWh) = Losses_{Shunt}(kW) \times 8760(hours) \quad (3)$$

The main limitations to this approach were:

- Manual intervention is required to determine the LLF for each customer or network tier, as well as in calculating the final loss factors. This is generally an iterative process.

- 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.

### C. Current Methodology

In the current methodology, the series losses on the sub-transmission network (132kV to 22/11kV substation busbars) are calculated by incorporating the 15 minute metering data from the previous financial year in a load flow routine. In each metering interval, one load flow solution is obtained to determine the total network losses and the accumulated network losses within each tier.

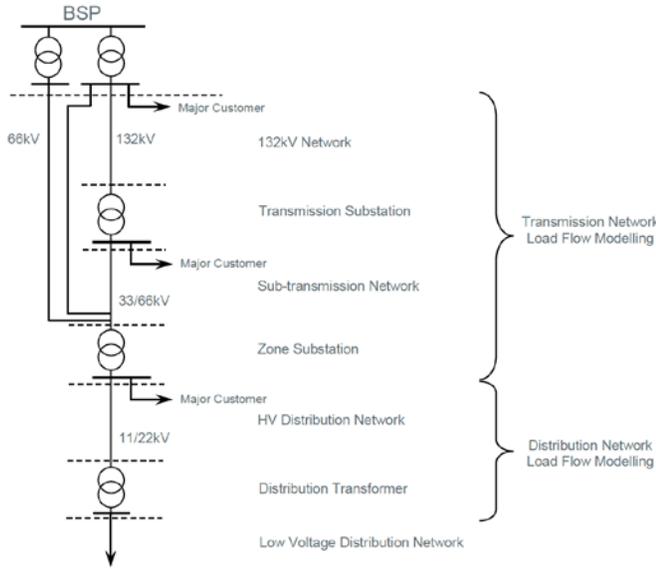


Figure 1

However, this is the total system losses incurred at a particular voltage level and not the total network tier losses attributable to that particular customer, or network tier. Therefore, the total losses at each voltage level (or network tier) must be apportioned between the customers connected to the network.

This is achieved by linearising the network operating point, which is a function of all the site specific loads or network tier pools. This operating curve has  $K$  dimensions and may be linearised by assuming the relationships of (4) and (5)

$$Losses(Total)_{Series} = \sum_{i=1}^K A_i Losses(Total)_{Series} \quad (4)$$

$$Losses(i)_{Series} = A_i Losses(Total)_{Series} \quad (5)$$

Where,  $A_i$  is the sensitivity coefficient for the particular customer or tier and  $Losses(Total)_{Series}$  is the total series loss incurred within that tier of the network. This equation implies that the sum of these sensitivity coefficients must sum to unity.

It is clear that this assumes that both the tier losses, and consequently the total losses, will equal zero when no energy is supplied by the network. This is not actually the case, primarily due to charging currents. Nevertheless, it is a reasonable means of apportioning the losses between each major customer or network tier.

This sensitivity coefficient can be determined from the rate of change in network tier loss with respect to a change in network load at the current operating point of the system as per (6)

$$RateOfChange = \frac{\partial Loss_K}{\partial Load_K} \quad (6)$$

To derive this rate of change in loss, the load consumed by the specific network tier, or major customer, is perturbed by 10% and the resulting change in loss is noted. This is shown graphically in Figure (2).

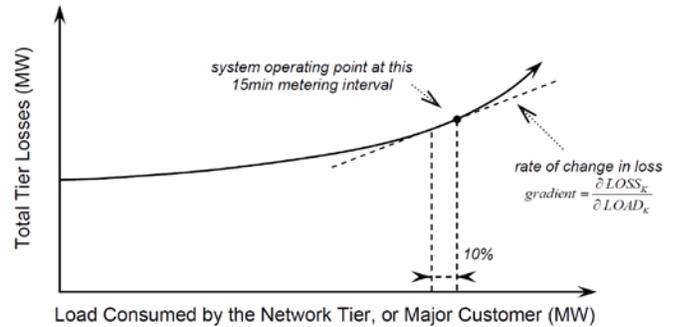


Figure 2

Due to the fact that the network losses ( $I^2R$ ) are not linearly proportional to the total network tier load, the rate of change derived will not equal the sensitivity coefficient. Consideration was given to utilizing a further compensation factor based on the sensitivity of the network tier losses to the total system load, however from experience with real metering data this compensation factor had mixed results. Therefore each individual sensitivity coefficient is simply scaled for each network tier such that they sum to unity.

This approach still fails to cater for variations in the network configuration; however the network model is set up to represent the switching configuration which is true for most of the year.

The loss factor calculations have been achieved by calculating the losses attributable to each major customer, or load group, within each tier of the network, at each 15 minute interval including shunt losses. In this case, the loss factor LF for tier  $K$  can be given by

$$LF = \frac{\sum_{N=1}^{35040} Losses(K)_{Series} + \sum_{N=1}^{35040} Losses(K)_{Shunt}}{\sum_{N=1}^{35040} Energy(K)} \quad (7)$$

### III. POWERFACTORY NETWORK MODEL

Endeavour Energy has a sub-transmission model built in DigSILENT PowerFactory, which covers from the interface with the Transmission Network Service Provider (TNSP) injection point, usually a 330/132kV substation; down to the Zone Substation (ZS) level busbar, 11kV or 22kV. Upstream of the TNSP injection point is a reduced equivalent National Electricity Market (NEM) model. The 11 or 22kV distribution feeders are not captured in this model.

The model is populated from a network characteristics database using a DGS converter tool, which is continuously updated as projects are commissioned. It also makes use of the PowerFactory ‘Variations’ function so as to capture future network expansion, changes and variations which can be turned on and off as required.

Substations are represented by their true busbar configurations. Lines are broken up as individual pi equivalent sections representing change in construction such as conductor changes or tee off points. Where lines are mutually coupled the coupling data is entered using the tower type model. Loads and generation are included with values for the forecast period.

### IV. LOSS STUDY SCRIPT DEVELOPMENT

To perform the network loss factor study in the PowerFactory sub-transmission network model, a DPL script was developed which implements the previously described calculation methodology.

A high level overview of the functions of the script is as follows:

- Import from file the 15-minute metering data which has been scaled to forecast values for zone substation loads, special customer loads and generator load into chavcefiles within PowerFactory.
- Identify from an input file the special customers that require individual loss factors and note them in a matrix.
- Run the individual load flows, including perturbation load flows, for each 15-minute interval. This results in approximately 30 load flows per 15-minute time interval. The taps are locked after the first run for each load flow in the interval. Non-convergent load flows are reported on if they occur.
- Record individual interval results in matrices.
- Export results matrices to an output file at the end of the year’s worth of runs.

Perturbation was achieved using the “Scaling Factor” of the load element by setting it to 90% for the individual loads or load elements in the tier.

### V. RESULTS AND PERFORMANCE

The PowerFactory model captures the network in a high level of detail as it is used for a wide variety of studies. As such, the number of nodes in the model is relatively high. The previous model which was text based was only used for loss

factor studies; this meant it was separately maintained which alone required significant effort. However, the previous model had considerably fewer nodes as lines were not sectionalised and the substation busbars were generally represented by a single node.

The current methodology as previously described requires approximately 30 load flows (dependent on number of site specific customers) per 15-minute metering data interval which results in a total of 1,051,200 load flows for a full year’s calculation.

To address the long processing time that results from the large number of nodes and number of load flows, the script includes the ability to break up the runs so sections of the full study can be run across multiple computers. For the full study run four computers were utilised.

A comparison of the computational performance between old and new models is given below in Table (1)

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%	

Table 1

While the overall run time has increased due to the node count in the new model, a few significant advantages have been achieved which far outweigh the additional run time. By using a common model which is regularly updated for multiple studies and is linked to a common characteristics database, several weeks of model preparation and updating can be avoided. The new model is easily adapted for a future study period using the variations built into the model. The confidence in the accuracy of the loss study result has also improved as evidenced for example by zero non-convergent load flows. Furthermore, since the model is graphical and provides detailed output run information, the sources of errors and divergence are relatively easily found and corrected.

### VI. FUTURE WORK

To improve performance of running the loss factor study, some areas of further development which may result in significant speed improvement have been identified as:

- Creating a script to remove unnecessary nodes prior to a loss study run. For example nodes between consecutive line sections could be collapsed without loss of accuracy. It was found that speed performance could be improved by a percentage approximately equal to the square root of the percentage reduction in nodes.
- Utilise multiple instances of PowerFactory running on individual processor cores. Most PCs these days have quad-core processors and this would better utilise processor capability.
- Investigating the potential use of the contingency analysis functionality in PowerFactory. This performs a base load flow from which further results can be computed without a load flow.

#### ACKNOWLEDGMENT

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#### REFERENCES

- [1] D. Spoor, C. Howat, "Evaluation of Distribution Loss Factors", Endeavour Energy internal Special Report No. S536, Australia, 2008.
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