Network Loss Factor Methodology 2009-2010

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Table of Contents

1. Introduction

The Electricity Governance Rules (EGR) requires that Electricity Distributors calculate and publish Reconciliation Loss Factor or Distribution Loss Factor (DLF) for each loss factor code in the registry each year.

This report presents the DLFs that can be applied to customer's metered energy to recover upstream losses on Top Energy's Network (TEN) for the financial year 2009-10. It also outlines the methodology, assumptions and data used for the calculation of the loss factors.

The methodology used in this calculation is based on the requirements set out in the Electricity Commission's (The Commission) "*Guidelines on the calculation and the use of loss factors for reconciliation purposes V2.0* [1] " issued on 18 September 2008. The methodology used is very similar to that used by Top Energy last year and is in line with the methodology proposed in the consultation paper. The most recent energy injection and consumption data for the last 24 months is used in the Loss Factor calculation. The peak demand data for the calculation is extracted from the most recent SCADA data in addition to the forecast demand information as disclosed in Top Energy's Asset Management Plan. The Network model is built using DigSilent Powerfactory, detailed to the HV terminal of distribution transformers in order to calculate the Technical Losses at each stage of the Network.

This Network Loss Factor Methodology is available from Top Energy's website at www.topenergy.co.nz/disclosurenetworkonly.htm

2. Background

Electrical Energy Losses are the losses incurred in the transfer of electricity over a distribution network. Losses vary with line length and depends on the amount of power being transferred. Overall losses can vary from year to year as they depend on factors such as network configuration, utilization level, load profile and power factor of the system (level of reactive power support), etc.

It is important to calculate the losses attributable to the customers connected at each stage of the Network so they can be accurately charged for the portion of losses incurred to supply demand. Due to the vast number and significant diversity of the customers connected to the distribution network, it is not feasible to measure or calculate the losses caused by each individual customer.

A DLF, normally expressed as a multiplier, is used to estimate the difference between metered quantities at the input of a network and the sum of metered quantities at customer's metering points over a period of time. The DLF is calculated as 1/(1-loss ratio) where the loss ratio equals the average proportion of losses over the network.

EGR require DLF to be site-specific for certain types of connection points based on voltage or connection point classes. More specifically, the site-specific DLFs will be determined for a connection point:

a. for an embedded generating unit with a name plate rating of 10MW or more;
b. for a customer with actual or forecast load of more than 40GWh or an electrical demand of more than 10MW;
c. for a market network service provider;

1 This document can be made available from http://www.electricitycommission.govt.nz/ This document contains detail requirements and criteria required by The Commission for loss factor calculation, methodologies and processes.

d. for the interconnection point between two or more distribution networks;

On the other hand, the non-site specific DLFs calculated in this report are to be applied to the metered energy at each stage of the Network. The DLFs representing the energy losses at each stage of the network are expressed as a percentage of the energy delivered at that level of the network, irrespective of whether it is delivered to customers at the same stage or to customers at the lower stage of the network.

3. Definitions and Abbreviations

1. EGR: The Electricity Governance Rules
2. DLF : Distribution Loss Factor or Reconciliation Loss factor
3. Embedded Generation: A generator which operates one or more generating units that are directly connected to a distribution network and injects energy into a distribution network
4. SCADA: Supervisory Control And Data Acquisition: SCADA systems are typically used to perform data collection and control at the supervisory level in a distribution network
5. LLF: Load Loss Factor: The LLF is the ratio between the instantaneous losses incurred at the peak load and the average instantaneous losses over two years
6. GXP : Grid Exit Point (Kaikohe and Kaitaia for Top Energy Limited)
7. ICC: Individually Calculated Customers: The customer for which EGR require site-specific loss factor to be calculated
8. Utilisation Factor (UF): Utilisation factor is the ratio of the maximum coincident KVA demand on the component to the rating of the component.
9. LV : Low Voltage
10. HV: High Voltage
11. TH : Total number of hours in two years
12. THH : Total number of half hourly recordings in two years

4. Network Energy Losses

Network Energy losses are categorised mainly in three different categories as following:

4.1 Reconciliation Losses

EGR require Reconciliation Losses to be calculated from the immediate past 24 months' energy injection and consumption information for an electrically connected network. These losses are the difference between energy purchased and sold in the Top Energy Network. Top Energy takes into account the energy injection from Transpower at both Gird Exit Points (GXPs) and the energy injection from Ngawha Geothermal Power Station at sub-transmission level when calculating losses on the network.

4.2 Technical Losses

There are two components of technical losses on a distribution network.

a. Load Losses: These losses depend on the electricity being supplied through the distribution network. These losses are proportional to the square of the current being supplied through the network equipment such as sub-transmission, distribution and, LV lines, zone substation and distribution transformers. These losses are also known as copper losses or I^2R losses.

b. No-load Losses: These losses are fixed and do not depend on the load. These losses arise from the standing or Iron losses of the Network transformers (Zone substation and Distribution).

Load Losses are calculated on the relevant part of the network under peak demand condition using DigSilent PowerFactory load flow package. The associated energy losses are calculated using Load Losses and appropriate Load Loss Factor[II] (LLF) as follows:

Load Energy Losses (kWh) = Load Losses at Peak Demand (kW) x TH (hrs) x LLF ***(i)***

Peak Losses are modelled in DigSilent PowerFactory using peak demand forecast for the year 2010. The LLF for zone substations is calculated using the previous two years SCADA data. Metering data is used to calculate LLF for site specific big 3 industrial customers. The peak load energy losses (kWh) is calculated by multiplying the load losses with total hours and associated LLF. These load losses includes sub-transmission (33kV), Zone substation transformers (33/11kV, 33/22kV) and distribution line (22kV, 11kV and 6.35kV) losses. The small spur lines in the distribution network are excluded in the model for simplicity, but 25% allowance is made for the part of the network which is not modelled explicitly.

The No-load Losses for zone substation transformers are obtained from manufacturer's data and test sheets to feed into DigSilent PowerFactory. The associated energy losses are calculated as follows:

No-Load Energy Losses (kWh) = No-Load Losses (kW) x TH (hrs) ***(ii)***

The LLF is not applied to No-load Losses as these losses are not dependent on the transformer loading. The No-load Losses are multiplied by total hours to calculate no-load energy losses in two-year period.

[II] Load Loss Factor is explained in detail in Section 5

The Load and No-load Losses for distribution transformers are obtained from the manufacturer's data sheets for different size transformers. Average losses are calculated for distribution transformers of different sizes, including SWER isolating transformers. The energy losses associated with No-load Losses for each type of distribution transformer are calculated as per Equation ii and they are added together in order to calculate total no-load energy losses.

The energy losses associated with Load Losses for each type of distribution transformer are calculated as Equation iii and added together in order to calculate total load energy losses:

Load Energy Losses (kWh) = Load Losses (kW) at Max. Rating x UF (%) ^2 X LLF x TH (hrs)
(iii)

The utilisation factor (UF) is explained in sub-section 6.6. The UF value used is determined by the kVA rating of distribution transformer.

4.3 Low Voltage (LV) Network and Non-Technical Losses

EGR define the Non-technical Losses as the difference between Reconciliation Losses and Technical Losses for the entire network. These losses include unaccounted energy due to theft, meter inaccuracy and minor billing errors.

Due to the low level of LV network loading and modelling data, it is unpractical to calculate with utmost accuracy, the LV network's load losses using load flow studies. With such limitations, Top Energy attributes LV Network losses as part of the Non-technical Losses, while also considering a proportion of Non-technical Losses for theft, meter inaccuracy and minor billing errors. It is assumed that Non-technical Losses primarily occur at Low Voltage level. Therefore Non-technical Losses are only allocated to LV network customers. Such losses also include losses incurred on streetlight circuits.

LV and Non-technical Energy Losses = Reconciliation Losses – Total Upstream Losses ***(iv)***

5. Load Loss Factor

The LLF is the ratio between the average instantaneous losses over the immediate 24 months, and the instantaneous losses incurred at the peak load during the same period. It is proportional to the square of the load and expressed as:

$$LLF = \sum_{n=1}^{THH} \left(\frac{Load^2{}_n}{PeakLoad^2} \right) / THH \qquad \textbf{(v)}$$

Where: $Load_n$ = the 30-minute average load in the nth period
THH = the number of 30-minute load recordings in two years
Peak load = the highest 30-minute average load in two years

LLFs are calculated for each zone substation in Top Energy, as well as for GXPs and the 3 big industrial customers. These LLFs are calculated using the SCADA data for the last 24 months for all zone substation and GXP's, and metering data for the same period for the big 3 industrial customers.

6. DLF Calculation

This section presents the methodology used to calculate site-specific DLFs for any ICC and non-site specific DLFs for each stage of the network. Figure 1 represents the application of the DLFs at different network stages. This figure does not include the application of any site-specific ICC.

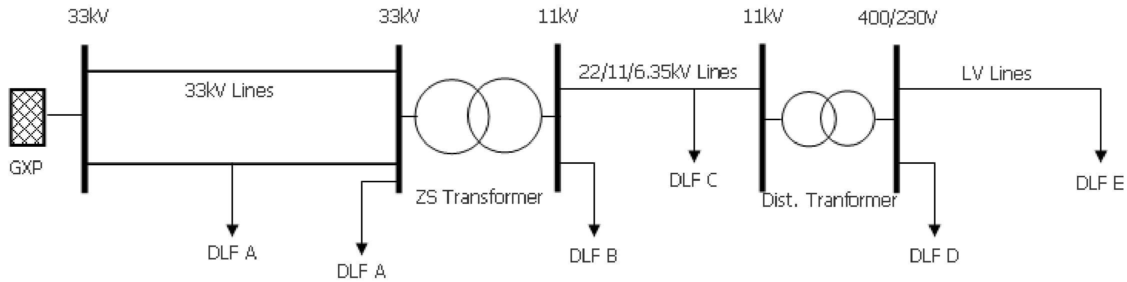

Figure 1: DLF Application at Different Network Stages

6.1 Reconciliation Loss Factor

Reconciliation Loss Factor is calculated using reconciliation losses

$$DLF\ R = 1 + \frac{\text{Reconciliation Losses (kWh)}}{\Sigma \text{ Energy Consumption (kWh) for Entire Network}} \qquad (vi)$$

6.2 Site Specific Loss Factor

EGR require site-specific loss factors to be calculated for a customer (Individually Calculated Customers ICC) with actual or forecast load of more than 40GWh per annum or an electrical demand of more than 10MW.

Energy Losses directly associated with an ICC are determined by the point of connection on the network (i.e. Sub-transmission level, Zone Substation level, etc). The losses are only calculated upstream of the point of connection. For example, if an ICC is connected to an 11kV zone substation bus, only losses in the sub-transmission lines and zone substation transformers will be considered.

When an asset is shared between non-site specific load and an ICC, or between more than one ICC, all the losses need to be allocated fairly based on peak demands. For example, considering a large customer with 10 MW peak demand connected to a Zone Substation with a 14 MW peak demand. If load flow studies show total losses in the upstream Network due to the large customer, and all other connected load is 360kW, then the losses attributable to the large customer are:

360 kW x 10 MW /14MW = 257 kW

Site-specific DLFs are calculated for the big 3 industrial customers (IND) on the Network. Load Losses for these customers are calculated using load flow analysis based on the customer's forecast peak demand and network load data. The model includes the network connection and the interconnection assets used ton transfer the energy between the customer point of connection, the GXP, and/or Ngawha Generations. The No-load Losses for the zone substation transformers are added to the Load Losses in order to obtain the total losses. The total losses are allocated to an ICC and converted into energy losses per annum using a specific LLF for the corresponding ICC. DLF for an ICC is calculated as follows:

$$\text{DLF for ICC} = 1 + \frac{\Sigma \text{ Losses (kWh) attributable to an ICC}}{\Sigma \text{ Energy Consumption (kWh) for an ICC}} \qquad (vii)$$

The losses and energy allocated to all ICCs are then removed from the total network losses and total network energy consumption. The remaining losses and energy are used to calculate DLFs for each stage of the network as follows:

$$\text{DLF} = 1 + \frac{\Sigma \text{ Losses (kWh) for each stage of Network – associated ICC losses}}{\Sigma \text{ Energy Consumption (kWh) for all section downstream including that section – associated ICC consumption}} \qquad (viii)$$

The following sections explain the methodology used to estimate energy losses for each hierarchical stage of the Top Energy Network.

6.3 Sub-transmission Network (33kV line) Losses

Specific load flow studies for the northern and southern 33kV networks are implemented to calculate the Load Losses in 33kV lines at peak demand. The forecast peak demand for each 33/11kV substation is used.

The LLFs are calculated at both GXPs using respective 30-minute averaged zone substation SCADA data, and applied to the Load Losses of the 33kV lines supplied from each GXP, thus calculating associated energy losses as per Equation i.

6.4 Zone Substation Losses

Zone substation models are developed, and load flow studies are carried out using the forecast peak demand for each 11kV distribution feeder to obtain the Load Losses at peak demand.

The LLFs are calculated for each zone substation using 30-minute averaged feeder SCADA data. LLF for zone substations are then averaged individually, and thus applied to zone substation Load Losses to calculate associated energy losses.

The No-load Losses for all zone substation transformers are obtained from manufacturer's data sheets. Energy losses associated with No-load Losses of the zone substation transformers are calculated as per Equation ii.

The total zone substation losses are then added to upstream losses (sub-transmission line losses) to calculate the DLF at zone substation level.

6.5 HV Network (22/11/6.35 kV Line) Losses

Top Energy's HV Network is modelled using GIS data. Backbone models for each individual feeder are developed, starting from the 11kV bus at respective zone substation. The models also include 2 wire and SWER lines with isolating transformers. All spur lines with length less than 500m are not included in the model for simplicity. All distribution transformers and spurs mentioned above are modelled as lump loads on HV feeder. Load flow studies are implemented on all feeders using corresponding forecast peak demand to obtain the Load Losses.

LLFs for each zone substation, as per Equation v, are applied to HV feeders supplied from respective zone substation to obtain associated energy losses on each feeder as mentioned in sub-section 4.2. Energy losses for all distribution feeders in the Network are aggregated in order to calculate the DLF for the entire HV Network.

6.6 Distribution Transformer Losses

The Load and No-load Losses incurred in distribution transformers are obtained from Manufacturer's data sheets. Average losses are calculated for transformers including SWER isolating transformers categorized by type and size. The average utilization factor for the entire Top Energy Network is used to calculate Load Losses as follows:

$$\textit{Load Losses} = \Sigma\,(\textit{Losses at Rated MVA}) \times (UF)^2$$

The number of transformers of each size is obtained from Top Energy's GIS database as disclosed in Top Energy's Asset Management Plan.

On average, the utilization factor for Top Energy's distribution transformers is approximately 30% for transformers up to 300kVA, and approximately 40% for transformers above 300kVA. This information is obtained from randomly selected transformer load logging data on the entire network. As Top Energy does not have maximum demand indicators on its distribution transformers, this selective load logging data are considered to be the most reliable data available.

LLFs for the northern and southern network zone substations are averaged to obtain one value for the entire Top Energy Network. The energy losses for the Load and No-load Losses are calculated as shown in sub-section 4.2.

The DLF calculation for distribution transformers will be carried out periodically in order to reflect potential changes in network topology or loading.

6.7 Low Voltage Network Losses

The DLF at LV Network level is calculated using energy losses obtained as per sub-section 4.3.

6.8 Embedded Generator Losses

EGR require calculating site-specific DLF for an embedded generating unit with actual generation of more than 10MW. Ngawha Geothermal Power Station, with 25MW total generating capacity is connected to the Top Energy network with a 10km 33kV line at Sub-transmission level. This section defines the methodology used to calculate DLF for Ngawha Generation.

The methodology considers all generation units as a single group and calculates their combined impact on overall network energy losses, using the Marginal Approach. The overall reduction or increase in energy losses caused by a group of embedded generators is then allocated to each generator based on generating capacity of individual generator. The DLF for embedded generators is then calculated as follows:

$$DLF = 1 + \frac{\Sigma\,\textit{Energy Loss Reduction/ Increase}}{\Sigma\,\textit{Energy Generated}} \qquad \text{(ix)}$$

To analyse the total impact on energy losses due to Ngawha Geothermal Power Station, a load flow study is conducted with and without generators connected to the Top Energy Network. Network losses are calculated for both cases respectively, with the difference in the total network losses of these two cases calculated and converted into energy losses per annum, using the LLF calculated for Ngawha Geothermal Power Station. The difference in energy losses are not allocated to each generator. The total energy generated is obtained from the metering data at the power station. The DLF for Ngawha is calculated using Equation ix.

It has been noticed that, the Ngawha generation neither increases nor decreases the losses on the Top Energy Network. As a result, DLF for Ngawha Generation is 1.000. However, the Top Energy customers still benefit from the Ngawha Generation, as they do not have to pay for the losses which otherwise would have incurred on Transpower network in the absence of Ngawha generation.

7. Compliance Requirement

Once DLFs are calculated and applied to appropriate voltage level, the distributor shall submit to the Commission their proposed loss factors for the next financial year, prior to 1 March of each year regardless of whether or not there is any change from the previous financial year. Moreover, a report detailing loss factor calculation methodology and the detailed DLF / Reconciliation Losses for each voltage level shall be prepared for the submission to the Commission as per the requirement specified in the Commission's Guideline [1]. Such report must be submitted prior to 1 March of each year as well.

8. Network Loss Factor Summary

This section summaries the loss calculation methodology and the DLF for each stage of the network. Table 1 below is the summary of the method applied to calculate losses

Loss Type	Losses Applied to	Load Losses	No-Load Losses
Reconciliation Losses	Entire Network	Total Network Injection - Total Network Consumption	
Technical Losses	Sub-Transmission Network (33kV Lines)	Using DigSilent PowerFactory Simulation	N/A
	Zone Substation		Using Manufacturer's Data sheet and Test sheets
	HV Network (22/11/6.35kV Lines)		N/A
	Distribution Transformers	Using Transformer count, % Utilisation Factor, Manufacturer's Data sheets and transformer Test sheets	Using Manufacturer's Data sheet and Test sheets
Non-Technical Losses	LV Network	Reconciliation Losses – Total Upstream losses.	

Table 1: Loss Calculation for Each Stage of the Network

Loss Type	Loss Factor Code	Applied to Customer Connected to	Individual DLF-Consumption	Cumulative DLF-Consumption	DLF-Generation
Reconciliation Losses	GLV	Entire Network (Reconciliation)	N/A	1.097	1.000
Technical Losses	DLF A	Sub-Transmission Network (33kV Lines)	1.028	1.028	1.000
	DLF B	Zone Substation	1.004	1.031	1.000
	DLF C	HV Network (22/11/6.35kV Lines)	1.015	1.046	1.000
	DLF D	Distribution Transformers	1.019	1.065	1.000
Non-Technical Losses	DLF E	LV Network (Non-Technical + LV)	1.032	1.097	1.000
Site-Specific Customers	IND 1	Site-Specific Customers	N/A	1.016	1.000
	IND 2	Site-Specific Customers	N/A	1.035	1.000
	IND 3	Site-Specific Customers	N/A	1.081	1.000
	GEN1	Site-Specific Customers-Embedded Generators	N/A	1.097	1.000

Table 2: DLF for Each Stage of the Network and Site-Specific Customers – Financial Year 2009/10