Network Loss Factor Methodology 2015-2016

Date: January 2015

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1. Introduction

The Electricity Industry Participation Code requires that Electricity Distributors calculate and publish a loss factor for each loss factor code in the registry. As these loss factors are used by the Reconciliation Manager in allocating volumes of energy at grid exit points to market participants, they are referred to in this report as reconciliation loss factors (RLFs).

This report presents the RLFs that should be applied to each customer's metered energy to recover upstream losses on Top Energy's Network (TEN) for the financial year 2015-2016. It also outlines the methodology, assumptions and data used for the calculation of the RLFs.

The methodology described in this report is based on the requirements set out in the Electricity Authority's "*Guidelines on the calculation and the use of loss factors for reconciliation purposes V2.1* [I] " issued on 1 November 2010. In February 2013 the Authority issued for consultation updated Guidelines, which have still to be finalised, and we have used these Guidelines where we have considered it appropriate.

Where half hourly metering data is not available, the peak demand data for the analysis was extracted from recent SCADA data. In order to calculate the Technical Losses at each stage of the Network, DigSilent Powerfactory was used. Top Energy's network model is detailed to the HV terminal of distribution transformers.

This Network Loss Factor Methodology is available from Top Energy's website at http://topenergy.co.nz/network/network-disclosures

2. Background

Reconciliation Losses are the difference between the total energy injected into the network and the total energy withdrawn from the network at the consumer connection points. These can be measured directly using metering data, and include both technical and non-technical losses.

Technical losses are a physical consequence of the transfer of electricity over the network. They occur over all parts of the network and vary with voltage, line length, conductor size and the amount of power being transferred. Technical losses form most of the total reconciliation losses and, while they cannot be measured directly, they can be estimated to a high level of accuracy through mathematical analysis and computer modelling of network performance.

The Guidelines require technical losses attributable to consumers connected to different parts of the network to be separately calculated. Technical losses arising from the supply of electricity to consumers directly connected at high voltage will be lower than the losses incurred in supplying electricity to consumers connected to the low voltage network and hence RLFs applied to high voltage metering points will be lower than those applied to low voltage meters. However, 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 and so some level of averaging is necessary. Typically this means that all consumers connected at a given voltage level are attributed the same level of technical losses.

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

Non-technical losses arise through metering errors, theft and errors in the back office processing of electricity accounts by retailers. There is no way they can be measured or directly estimated so they are normally derived by subtracting the estimated technical losses from the directly measured reconciliation losses.

An RLF is normally expressed as a multiplier and is used to estimate the total energy that needs to be injected into the network in order to produce the measured consumption at each ICP. The RLF is calculated as 1/(1-loss ratio) where the loss ratio equals the average proportion of losses over the network in the delivery of electricity from the point of injection to each metering point.

The Guidelines provide for site specific RLFs to be calculated for large loads and the Code requires a site specific RLF to be applied to generators rated above 10MW. Top Energy calculates site specific RLFs for the Ngawha generation plant and also for the Juken Nissho board mill near Kaitaia. Due to the low level of annual consumption of the AFFCO plant near Moerewa, the cumulative RLF corresponding to the location of the metering point on the network (RLF B), is applied to this customer.

The non-site specific loss ratios used to calculate the RLF's in this report are calculated for each voltage level. The RLFs representing the energy losses at each network voltage level are applied to the total energy delivered at that voltage level of the network, irrespective of whether the energy is delivered to consumers connected at that voltage or to consumers connected at a lower voltage.

3. Definitions and Abbreviations

1. EA: Electricity Authority

2. RLF : 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.

6. ICP: Installation Control Point: An ICP is a unique number that identifies an individual power connection.

7. GXP: Grid Exit Point

8. Utilisation Factor (UF): Utilisation factor is the ratio of the maximum non-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 one year (8760).

12. THH : Total number of half hourly recordings in one year.

4. Network Energy Losses

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

4.1 Reconciliation Losses

The Electricity Authority's "*Guidelines on the calculation and the use of loss factors for reconciliation purposes V2.1*" recommends Reconciliation Losses to be calculated from the immediate past 24 months' energy injection and consumption information for an electrically connected network. This requirement has not been carried over to the 2013 Draft Guidelines,. Hence for this analysis, Top Energy has used the used the measured Reconciliation Losses over the most recent 12 month period for which all required data is available, 1 September 2013 to 31 August 2014.

These losses are the difference between the energy delivered and the energy sold in the Top Energy Network. Top Energy takes into account the energy injection from Transpower at the Grid Exit Point (KOE) and the energy injection from Ngawha Geothermal Power Station at sub-transmission level when calculating losses on the network.

4.2 Technical Losses

Technical losses represent the electricity that is consumed during the delivery to customers' installations. There are two components of technical losses on a distribution network.

a. Load Losses: These losses depend on the quantity of electricity being supplied through the network. At any given time, 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 constant and do not depend on load. These losses arise from the standing or iron losses of the network transformers (both zone substation and distribution transformers).

Losses at peak demand are calculated on the relevant part of the network using Top Energy's DigSilent PowerFactory load flow package. The associated total energy losses over a twelve month period were calculated applying an appropriate Load Loss Factor[II] (LLF) as follows:

$$\text{Load Energy Losses (kWh)} = \text{Load Losses at Peak Demand (kW)} \times \text{TH (hrs)} \times \text{LLF} \qquad \textbf{\textit{(i)}}$$

The LLFs for TE's Network and site specific industrial customers were calculated using 2012-13 actual metered data and there is no change for 2013-2014.

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

The No-load Losses for substation transformers were obtained from manufacturer's data and test sheets. The associated energy losses are calculated as follows:

$$\text{No-Load Energy Losses (kWh)} = \text{No-Load Losses (kW)} \times \text{TH (hrs)} \qquad \textit{(ii)}$$

The LLF was not applied to No-load Losses as these losses are not dependent on transformer loading and do not vary with time. The No-load Losses are multiplied by total hours to calculate the no-load energy losses over the one-year period.

The no load losses for distribution transformers were calculated in a similar manner to substation transformers by applying equation ii, using the no load losses supplied by the manufacturer. However, as distribution transformers are not modelled in DigSilent a different approach was used to calculate the distribution transformer load losses.

Manufacturers's data provides the load loss when a transformer is operating at its rated load. The actual distribution transformer peak load losses were assessed by applying a UF, and a LLF was then applied to convert this to annualised energy losses. The UF and LLF for distribution transformers, provided in Table 11 of the Draft 2013 Guidelines was used, as Top Energy does not have better data available.

Using this data the annualised load energy losses associated for each type of distribution transformer can be calculated using Equation iii:

$$\text{Load Energy Losses (kWh)} = \text{Load Losses (kW) at Max. Rating} \times (\text{UF (\%)}^2) \times \text{LLF} \times \text{TH (hrs)} \qquad \textit{(iii)}$$

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

Non-technical Losses are 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 nature of the of LV network, its low level of loading and the extensive modelling data that would be required, it is impractical to calculate the LV network's load losses using load flow studies with a high level of accuracy. With such limitations, Top Energy does not separately calculate LV network losses but includes them in its derivation of Non-technical losses (which are derived by subtracting high voltage and distribution transformer technical losses from the total measured reconciliation losses). The approach is valid if it is assumed that Non-technical Losses primarily occur at LV level. This applies to the Top Energy network, where only three large consumers are metered at 11kV or above. Hence Non-technical Losses are only allocated to LV network consumers.

$$\text{LV and Non-technical Energy Losses} = \text{Reconciliation Losses} - \text{Total Upstream Technical Losses} \qquad \textit{(iv)}$$

Top Energy has analysed this approach and compared it with the approach recommended in the draft Guidelines issued for consultation by the Electricity Authority in February 2013 and is satisfied that the use of the approach recommended in the draft Guidelines would not have a material impact on the RLFs applied to any ICP.

5. Load Loss Factor

The LLF is the ratio between the average instantaneous losses over a 12 month period, 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:

$$LLF = \sum_{n=1}^{THH} \left(\frac{Load_n^2}{PeakLoad^2}\right)/THH$$

(v)

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

A single network LLF has been applied to all parts of the network excluding distribution transformers, except that a separate LLF was calculated for JNL as a site specific industrial customer. The network LLF was calculated using the metered data for the past 12 months for power injected at the Kaikohe grid exit point from both the grid and Ngawha power station. The LLF applied to JNL was calculated using JNL's half hourly metering data. Separate LLFs were applied to distribution transformers as described in section 6.6.

A sensitivity test has been undertaken to assess the impact of applying different load factors across a feasible range and found that most material relative impact on calculated RLFs was under 0.7% and most were under 0.25%. Top Energy is therefore satisfied that the assumption of a single load factor across the whole network (excluding distribution transformers) does not have a material impact on the calculated RLFs.

6. RLF Calculation

Figure 1 represents the application of the RLFs at different network stages. This figure does not include the application of any site-specific ICP.

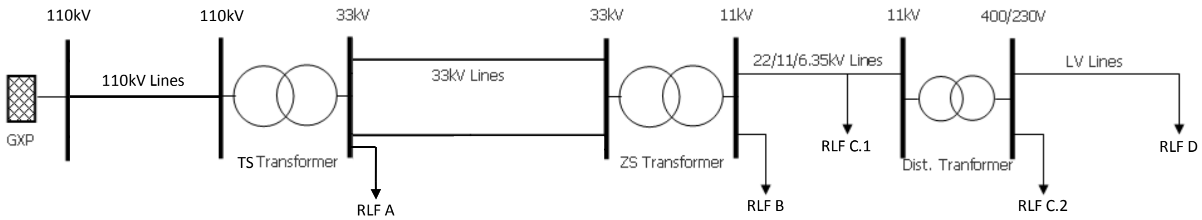

Figure 1: RLF Application at Different Network Stages

6.1 Reconciliation Loss Factor

The Reconciliation Loss Factor for the entire network is calculated using Equation vi

$$\text{RLF R} = 1/\left(1-\left(\frac{\text{Reconciliation Losses (kWh)}}{\Sigma \text{ Energy Injected (kWh) for Entire Network}}\right)\right)$$

(vi)

Where Reconciliation Loses are the measured losses on the network over a twelve month period and the total energy injected is the metered injection over the same period.

As indicated in Figure 1, loss factors can be calculated in a similar way for different network segments where the losses are the calculated losses for that segment and the energy injected refers to the energy injected into a particular segment. Calculation of the losses for each network segment is discussed further below. The energy injected is equal to the energy injected into the entire network, less calculated upstream losses, less energy supplied to customers directly connected at an upstream voltage.

The cumulative RLF at any network voltage level is the product of all upstream RLFs.

6.2 Transmission (110kV)

With effect from 01 April 2012, Top Energy gained ownership of the 110kV assets at the Kaikohe and Kaitaia GXPs inclusive of the 110kV KOE-KTA transmission circuit. The 110kV losses are now included in the loss factor calculations, which means that RLFs across the network are higher than those applied prior to 1 April 2012.

Transmission losses are allocated equally across all consumers including those in the southern area. Kaikohe transmission substation losses need special consideration because of the impact of Ngawha Power station, and its high load factor. When Ngawha is operating, under most load conditions its output is fed directly into the Kaikohe 33kV network, bypassing the Kaikohe 110kV transformers. Hence the load through the Kaikohe transformers is relatively low. For this analysis load losses for the Kaikohe 110/33 kV transformers are assumed to be zero but the non-load losses are included.

Load flows are performed for the individual 2012 peaks of Kaikohe and Kaitaia to determine the load losses of the Kaitaia substation and the KOE-KTA 110kV line. The network LLF, calculated as described in Section 5 was used, and the energy losses were calculated as per Equation i.

6.3 Sub-transmission Network (33kV line) Losses

Specific load flow studies for the northern and southern 33kV networks were implemented to calculate the Load Losses in 33kV lines at peak demand. The actual 2012 peak demand for each 33/11kV substation was used.

The TE network LLF described in section 5 is applied to the Load Losses of the 33kV lines supplied from each transmission substation, thus calculating associated energy losses as per Equation i. In calculating the sub-transmission RLF an adjustment was made to remove the losses attributed to JNL in the calculation of JNL's site specific loss factor.

6.4 Zone Substation Losses

Zone substation models are developed, and load flow studies were carried out using the 2012 peak demand for each 11kV distribution feeder to obtain the Load Losses at peak demand.

The TE network LLF described in section 5 is 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.

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 have been developed, starting from the 11kV bus at the 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. These distribution transformers and spurs are modelled as lump loads on the HV feeder backbone. Load flow studies were implemented on all feeders using corresponding 2012 peak demand to obtain the Load Losses.

The TE network LLF as per section 5, was applied to HV feeders supplied from respective zone substations to obtain associated energy losses on each feeder as mentioned in sub-section 4.2. Energy losses for all distribution feeders in the Network were aggregated in order to calculate a single RLF for the entire HV Network.

6.6 Distribution Transformer Losses

The rated Load and No-load Losses incurred in distribution transformers were obtained from Manufacturers' data sheets. Average losses are calculated for transformers including SWER isolating transformers categorized by type and size.

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

The Utilisation factors (UF) and LLFs used to calculate transformer load losses are based on the factors recommended in Table 11 of the draft *Guidelines on the calculation and use of loss factors* issued for consultation by the EA in February 2013. The energy losses for the Load and No-load Losses are calculated using formula iii.

6.7 Low Voltage Network Losses

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

6.8 Embedded Generator Losses

The Electricity Industry Participation Code requires the calculation of a site-specific RLF 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 RLF for Ngawha Generation.

To analyse the total impact on energy losses due to Ngawha Geothermal Power Station, a load flow study was conducted with and without generators connected to the Top Energy Network. The difference in network peak load losses with and without Ngawha operating was found to be only 8kW or less than 0.5%. In practical terms this is because when Ngawha is generating the losses incurred in delivering the generated energy to Kaikohe are offset by a reduction in load losses on the Kaikohe 110/33kV transformers.

As a result, the RLF for Ngawha Generation is assessed as 1.000. Top Energy consumers also benefit from the Ngawha Generation, as they do not have to pay for the losses which otherwise would have incurred on the Transpower network if Ngawha was not operating.

7. Site Specific Loads

A site specific loss factor has been calculated for the JNL mill near Kaitaia because of the relative size of the load and its high LLF. This has been determined as follows:

RLF_A was the same for JNL as for all other consumers, consistent with Top Energy's decision to allocate transmission losses across all consumers on the basis of total consumption.

Using load flow analysis, technical losses on the sub-transmission network at peak load were determined for each network segment used to supply power to the mill. These are the 33kV lines between Kaitaia and the mill and the JNL zone substation transformers. The peak losses on each segment attributable to the mill have been estimated by pro-rating these losses on the basis of the ratio of mill load to the total load on the segment. Annualised losses at each network level attributable to the mill are calculated using the mill's actual LLF.

No load losses on the JNL zone substation transformers have also been attributed to the mill by pro-rating annual no-load losses on each transformer by the ratio of the peak load attributable to the mill and the peak transformer load.

The sub-transmission RLF for the mill was then calculated using the equation i. This was multiplied by RFL_A to obtain the site specific RLF for JNL; this ensured the transmission losses are included.

The sub-transmission losses attributable to the mill are subtracted from the calculated technical losses of each sub-transmission network segment before calculating the sub-transmission network loss factor in order to avoid double counting.

8. Compliance Requirement

Once RLFs are calculated and applied to appropriate voltage level, the distributor must submit to the Electricity Authority its 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 RLF / Reconciliation Losses for each voltage level shall be prepared for the submission to the Electricity Authority as per the requirement specified in the Electricity Authority's Guideline [I].

9. Network Loss Factor Summary

This section summaries the loss calculation methodology and the RLF 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	Transmission (110kV)	Using DigSilent PowerFactory Simulation	Using Manufacturer's Data sheet and Test sheets
	Sub-Transmission Network (33kV Lines)		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, Appendix C of Draft Guidelines 2013	Using Manufacturer's Data sheet and Test sheets
LV and Non-Technical Losses	LV Network	Reconciliation Losses – Total Upstream technical losses.	

Table 1: Loss Calculation for Each Stage of the Network

Loss Type	Loss Factor Code	Applied to Customer Connected to	Individual RLF	Cumulative RLF
Reconciliation Losses	RLF R	Entire Network (Reconciliation)	N/A	1.1134
Technical Losses	RLF A	Transmission Network (110kV)	1.0169	1.0169
	RLF B	Sub-Transmission Network (33kV Lines, Zone Substation)	1.0289	1.0464
	RLF C.1	HV Network (22/11/6.35kV Lines)	1.0262	1.0737
	RLF C.2	Distribution Transformers	1.0175	1.0925
Non-Technical Losses	RLF D	LV Network (Non-Technical + LV)	1.0361	**1.1320**
Site-Specific Customers	RLF I1 (JNL)	JNL	**1.0273**	N/A
	RLF I2 (AFFCO)	AFFCO –Cumulative RLF B	**1.0464**	N/A
	RLF G1 (NGA)	Ngawha Generation	1	1.0000

Table 2: RLF for Each Stage of the Network and Site-Specific Customers – Financial Year 2015/16

Table 3: Summary of overall losses on the TOPE Network (23 (d)

	ACTUAL 24 Month to Aug14	CURRENT 12 mths to Aug 14	Less IND 12 mths to Aug14	NETWORK 12 mths to Aug 14	BUDGET 12 mths to Aug 15
Total Energy Injected into Network	716,864,895	358,457,254	62,533,265	295,923,989	354,372,112
Total Energy Sold to Customers	644,145,388	322,300,645	60,701,040	261,599,605	318,627,561
				-	
Total Losses (kWh)	72,719,507	36,156,609	1,832,225	34,324,384	35,744,552
Loss percentage	10.14%	10.09%	2.93%	11.60%	10.09%
TLF for Entire Network (Reconciliation) Including ICC	**1.1129**	**1.1122**	**1.0302**	**1.1312**	**1.1122**

The above Distributor loss factor report is provided as per guideline (23) accompanied by the requested soft copy distributors report data (24).

Date of Response:

Signed By:

Mr David Worsfold
General Manager Network
Top Energy Ltd