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Distribution Loss Factor Calculation Methodology

Version Number 1.1

February 2020

Overview

TasNetworks must develop, publish and maintain a methodology for calculating distribution loss factors in accordance with National Electricity Rules clauses 3.6.3(g) and (h).

Tasmanian Networks Pty Ltd (ACN 167 357 299)

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1. Introduction and Purpose

Distribution losses are electrical energy (active energy) losses incurred in conveying electricity over a distribution network. Distribution loss factors (**DLFs**) are used to describe the average electrical energy lost in conveying electricity from a transmission network connection point (or virtual transmission node) to a distribution customer connection.

The Australian Energy Market Operator (**AEMO**) uses DLFs in market settlements to calculate the electrical energy attributed to each retailer at each transmission network connection point. DLFs are calculated and applied on a financial year basis. Metered energy is grossed up by the DLF to reflect the energy supplied at transmission connection points to meet customer consumption. To reflect this, retailers apply DLFs to metered customer consumption in the billing processes.

The National Electricity Rules (**the Rules**) require that every year each Distribution Network Service Provider (**DNSP**) must determine the DLFs to apply in the next financial year and that they must be determined in accordance with a methodology under the Rules. If the Australian Energy Regulator (**AER**) has determined a methodology, then that methodology must be applied.

As the AER has not determined a methodology then TasNetworks must develop, publish and maintain a methodology in accordance with clause 3.6.3(g) and (h) of the Rules.

This document set outs TasNetworks' methodology for calculating DLFs. This methodology has been prepared in accordance with the requirements of the Rules, in particular having regard to the principles contained in clause 3.6.3(h) of the Rules.

This document is published on TasNetworks' website at www.tasnetworks.com.au/Planning-our-network and made available upon request to interested persons.

The methodology is drawn from that developed in July 2004[1] by Aurora Energy, the then Tasmanian local distribution network service provider (**DNSP**), and approved by the Office of the Tasmanian Economic Regulator.[2][3]

The methodology has been updated in February 2020.

2. Scope

Power system losses are the differences in the amount of electricity that is delivered into electricity networks and that delivered to customers to meet their demands. Distribution losses are those incurred in the distribution network.

There are two measures of electricity pertinent to losses; being electrical energy and electrical power.

- Electrical energy is the amount of electricity delivered or consumed over a period of time and is typically measured in kilowatt-hours (**kWh**) and megawatt-hours (**MWh**).
- Electrical power is the rate at which electrical energy is delivered or consumed and is typically measured in kilowatts (**kW**) and megawatts (**MW**).

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[1] Aurora Energy, Distribution Loss Factor Calculation Methodology, July 2004, BES (Aust) Pty Ltd

[2] Office of the Tasmanian Economic Regulator, Approval of Distribution Loss Factors for Electricity Consumers for 2005-06

[3] Office of the Tasmanian Economic Regulator, Distribution Loss Factor Calculations – Treatment of Non-Technical Losses March 2006

Electrical energy losses associated with a distribution system can be classified as:

- Technical Losses comprising:

  Series losses associated with the flow of electricity through electricity circuits. Series losses are proportional to the square of the electricity flowing and to the resistance of the electricity circuits.

  Shunt losses are "leakage" of electrical energy associated with "charging up" or "excitation" of the network and occur regardless of the amount of electrical power flowing through the network. Whilst there are a number of sources of shunt losses they are mainly associated with transformers.

- Non-technical losses due to metering data errors, unbilled customers, information system deficiencies, modelling assumptions and theft.

3. Requirements of the National Electricity Rules

Rules' clause 3.6.3 provides for the determination of DLFs; in particular, clause 3.6.3(i) requires:

> Each year the DNSP must determine the distribution loss factors to apply in the next financial year in accordance with 3.6.3(g) and provide these to AEMO for publication by 1 April. Before providing the distribution loss factors to AEMO for publication, the DNSP must obtain the approval of the AER for the distribution loss factors it has determined for the next financial year.

Clause 3.6.3(b)(2) requires that DLFs will be either site specific for certain types of connection points or not site specific.

Site specific DLFs are calculated individually according to the actual network and connection point characteristics and will be determined in relation to:

- an embedded generating unit with actual generation of more than 10MW,
- an end-user with actual or forecast load of more than 40GWh or an electrical demand of more than 10MW,
- a market network service provider, and
- between two or more distribution networks.

Clause 3.6.3(b1) requires the calculation of a site specific DLF where a Generator, or a Small Generation Aggregator, meets the reasonable cost of the DNSP in performing the necessary calculation in respect of a generating unit of up to 10MW or 40GWh per annum capacity.

For distribution connection points that are not site specific, the DLF should be based on network average DLFs based on voltage or connection point classes.[4]

Clauses 3.6.3(c), (d) (e) and (f) require the assignment of distribution connection points to either a single transmission network connection point or to a virtual transmission node and also to a class of distribution network connection points. In addition, the assignment must be consistent with the geographic boundaries of the pricing zones for use in distribution service pricing, and the voltage levels incorporated within those pricing zones.

Rules, Clause 3.6.3(h) requires that the methodology must be developed having regard to principles; summarised as:

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[4] NER clause 3.6.3(b)(2)(ii) DLFs will be derived using the **volume weighted average of the average electrical energy loss** between the transmission network connection point or virtual transmission node to which it is assigned and each distribution network connection point in the relevant voltage class.

1. the aggregate of all of the adjusted gross energy amounts for a distribution network should equal, as closely as is reasonably practicable, the sum of:
    - the aggregate of electrical energy flowing at all connection points in the distribution network; and
    - the total "actual" electrical energy losses incurred on the distribution network;

2. being able to demonstrate the extent to which the objective in (1) has been achieved through a reconciliation based on the previous financial year's actual results;

3. for non-site specific connection points, determining the DLF by using a volume weighted average of the average electrical energy loss[5] between the transmission network connection point or virtual transmission node to which it is assigned and each distribution network connection point in the relevant class of distribution network connection points;

4. for site specific connection points, determining the DLF by reference to the average electrical energy loss between the distribution network connection point and the transmission network connection point to which it is assigned;

5. using the most recent actual load and generation data available for a consecutive 12 month period to determine the average electrical energy losses referred to in (3) and (4), adjusted if necessary to take into account projected load and or generation growth in the financial year in which the distribution loss factors are to apply; and

6. treating flows in network elements that solely or principally provide market network services as invariant. It is noted that this principle is not relevant to Tasmania.

Rules' clause 3.6.3 (g) requires that DLFs must be determined for all connection points either:

- individually, for all connection points assigned to a single transmission network connection point or
- collectively, for all connection points assigned to a transmission network connection point or a virtual transmission node and a particular distribution network connection point class.

This methodology is consistent with these non-prescriptive principles and aims to provide a fair and equitable result consistent with ensuring that the application of DLFs results in all energy losses being accounted for and recovered from the relevant distribution customers.

4. Method Overview

TasNetworks has grouped transmission connection points into seven regions for DLF calculation as shown in Figure 1. This is done as it is not possible to measure the distribution losses incurred by individual customers; hence, distribution loss factors are calculated as regional averages applied at various hierarchal network levels on the distribution network.

TasNetworks has chosen to adopt the seven upper-level regions due to the nature of assets in each area, combined with the need to aggregate customers to determine system specific DLFs. Using these seven

[5] Note: The Rules' definition of "average electrical energy loss" includes the words "volume weighted average" so this Rules' clause appears to be incorrectly worded.

upper-level regions allows for the right balance between accuracy and simplicity while complying with the requirements of the Rules.

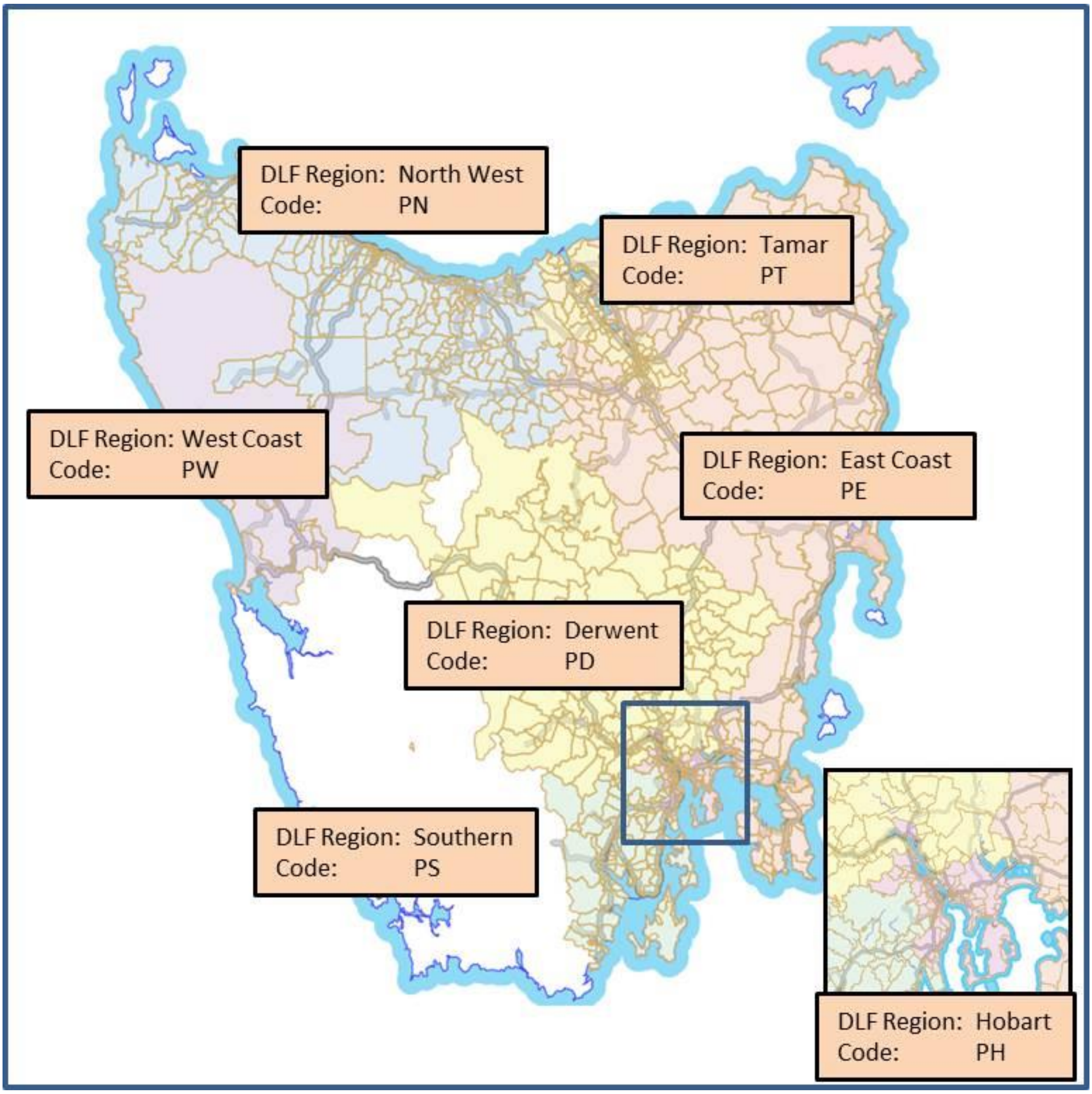


Figure 1 Tasmanian DLF Regions

The various network levels are classified as:

- Sub-transmission being either 44kV or 33kV distribution lines that either emanate from transmission connection points or interconnect between zone substations;
- Zone substation direct connection at either 22 kV or 11 kV;
- High voltage distribution feeder being either a 22 kV or 11 kV distribution line that emanates either from a transmission connection point or a zone substation;
- Distribution substation direct connection at 400 V; and

- Low voltage distribution being 400 V distribution lines that provide reticulation to customer premises.

4.1. Top Down & Bottom Up Processes

There are three processes in establishing the DLFs being:

- Top Down loss calculation,
- Bottom Up regional network level loss calculation, and
- Loss factor and DLF calculation for each network level.

Top Down Process

The top down process establishes by each DLF region the difference between:

- the total energy delivered by the transmission system and embedded generation into the distribution system and
- the total energy consumed by distribution customers.

The differences are calculated from metered quantities at the transmission connection points (each transmission node identifier (**TNI**)) and at distribution customer connection points (from each national metering identifier (**NMI**) related to each TNI). The input from embedded generation is also included.

The difference between the metered energy flowing into the distribution network and the energy consumed by distribution customers is referred to as “top down losses”.

Under Rules’ principles 1 & 2 of clause 3.6.3(h) the top down losses are those that should either equal or be reconciled with respective aggregates of adjusted gross energy amounts.

Bottom Up Process

The top down process establishes the total quantity of distribution losses but cannot identify losses at the different network levels. The bottom up process models the entire distribution system to calculate the technical losses at the different network levels. These calculated technical losses in combination with the top down sales are the basis of calculation of the DLFs across the different network levels.

The bottom up process is based on modelling all:

- sub-transmission lines,
- zone substations,
- high voltage distribution lines, and
- distribution transformers.

Low voltage reticulation is modelled using a set of representative low voltage distribution lines that reflect typical network topologies, customer characteristics and customer connection location profiles.

The models include assumptions about customer individual and aggregate load factors, load loss factors, and maximum demands as outlined in Appendix A.

A comparison between top down losses derived from metering data and the calculated bottom up losses provides a mechanism to check for discrepancies and opportunities to improve the metering information and refine the bottom up modelling. In this comparison it is expected that the top down losses will be greater than the bottom up losses due to non-technical losses that include energy loss due to theft, meter errors, unbilled customers and the treatment of un-metered supply. This is discussed further in the section on Low Voltage Losses in Appendix A.

The detailed methodology used in applying Rules' principle 3.6.3(h)(3) requiring that volume weighted average of the average electrical energy loss[5] is used to determine DLFs is based on these top down and bottom up processes and is described in Appendix A.

DLF Calculation

From the results of the Top Down and Bottom Up processes the regional and network level DLFs are calculated using the following process:

- sales and embedded generation data is aggregated for each DLF network level for each DLF region,
- DLF network level losses for each DLF region are obtained from the Bottom Up modelling,
- from these DLF level sales and embedded generation data and DLF level losses each DLF level loss factor is calculated,
- the DLFs for each DLF level are one plus the sum of that levels loss factor and all downstream lower network level loss factors.

Details of the applicable formulae are provided in Appendix A.

Adjusted Gross Energy Reconciliation

Rules, Clause 3.6.3(h)(2) requires a reconciliation for the previous financial year between the aggregate of the adjusted gross energy amounts and the sum of distribution customer metered consumption and electrical energy losses.

This reconciliation is included as part of the Top Down process by application of the DLFs to distribution customer metered energy and comparison with metered energy entering the distribution system.

5. Distributed Embedded Generation

It is assumed that distributed embedded generation has the opposite impact on average annual distribution losses as does customer demands; that is, embedded generation tends to reduce losses in regions of low embedded generation and tends to increase losses in regions of excess embedded generation. On this basis the same regional network level DLFs are applied to embedded generation metered energy as those applied to customer metered energy. The intention of this is that most embedded generators will reduce distribution losses and should receive a credit for reducing the losses.

Embedded generation that is covered under Rules' clauses 3.6.3(b)(2)(i) and 3.6.3(b1) requiring site specific DLFs is discussed in section 7, Site Specific Embedded Generation.

The following relates to regional cases where a common DLF is applied to distribution customers and embedded generation; in particular, where there is either:

- minimal embedded generation compared with customer consumption or
- minimal customer consumption when compared with embedded generation.

The regional DLF that is applied to both the customer demand and the embedded generation should be developed having regard to the principle of reconciling consumption, generation, losses and inflows to the distribution network. To achieve this balance the appropriate weighting factor is "customer consumption less embedded generation". This gives a network level loss factor formulation as below:

$$LF = \frac{Losses}{Customer\ Consumption - Embedded\ Generation}$$

The resultant generic loss factor formulation is:

$$DLF = 1 + LF$$

Depending on the relative magnitudes of customer consumption and embedded generation the DLF can be either greater than unity or less than unity. This would be reflective of whether incremental embedded generation decreases losses or increases losses.

Where the outturn DLF is not realistic; that is, the DLF is not close to unity because consumption and generation are relatively close then a different approach is required. Under these circumstances the losses are allocated based on energy consumption plus generation. The network level loss factor would then be calculated from:

$$LF = \frac{Losses}{Customer\ Consumption + Embedded\ Generation}$$

The resultant generic loss factor formulations for customers and embedded generation would be given by:

$$DLF_{customers} = 1 + LF$$

$$DLF_{embedded\ generation} = 1 - LF$$

In specific situations; for example, a single distribution feeder, where embedded generation and customer consumption are not significantly different and clauses 3.6.3(b)(2)(i) and 3.6.3(b1) do not apply; then under Rules' clause 3.6.3(d)(2) the embedded generation could be assigned to a class called large embedded generation. The large embedded generation class DLF would be determined in the same way as for site specific DLFs under clauses 3.6.3(b)(2)(i) and 3.6.3(b1). The customers would be treated on a regional average basis.

6. Site Specific Customer Connection Points

Rule' clause 3.6.3(2)(i) requires site specific DLFs to be calculated for qualified distribution network users and hence it is necessary to allocate network losses between qualified end users and other customers. Site specific DLFs are calculated using Rules' principle 3.6.3(h)(4) that requires the application of average electrical energy loss.

To achieve this, the methodology has to be adjusted as follows:

- the losses on each segment of the network due to all listed specific customers is aggregated and subtracted from the total calculated network losses on each segment of the network.
- all site specific customer sales in each segment of the network is aggregated and subtracted from the total network sales on each segment of the network.
- the balances in the network losses and sales is then used to determine the volume weighted average DLFs for general users.

Details of the calculation of site specific DLFs are described in Appendix A.

7. Site Specific Embedded Generation

The following discussion relates to distribution lines where an embedded generator has generation that can either exceed or be less than the customer demands on that distribution line and the following Rules' clauses apply:

3.6.3(b)(2)(i) a site specific distribution loss factor derived in accordance with the methodology

(A) a connection point for an embedded generating unit with actual generation of more than 10MW,

3.6.3(b1) Where a Generator, or a Small Generation Aggregator, meets the reasonable cost of the Distribution Network Service Provider in performing the necessary calculation in respect of a generating unit of up to 10MW or 40GWh per annum capacity,

It is assumed that the majority of customers on the distribution line would not be required to be site specific; hence their DLF would be based on network average DLFs based on voltage or connection point class. In determining site specific DLFs for embedded generators regard must be given to the following principle:

> 3.6.3(h)(4): The distribution loss factor for a distribution network connection point described in clause 3.6.3(b)(2)(i) [site specific] is determined using the average electrical energy loss between the distribution network connection point and the transmission network connection point to which it is assigned.

In line with principle 3.6.3(h)(1) the combination of the DLF applicable to the customers and that applied to the embedded generation should result in accounting for the total annual losses across the DLF region.

A challenge arises when the generation output volume varies between being less than to exceeding the customer power demand on the distribution line to which the embedded generator is connected. In such circumstances, the exchange of energy at the transmission network connection point varies between net import into to export from the distribution network.

Under these circumstances the impact of the embedded generation can vary between reducing losses to increasing losses. Depending on the magnitudes, durations and coincidence of the customer demands and embedded generator generation the annual DLF applicable to the embedded generator can be either

- greater than unity, that is the embedded generator actually reduces annual losses, or
- less than unity, that is the embedded generator actual increases annual losses.

Embedded generator specific DLFs are determined following the steps below:

- based on either historical records or other relevant information select an appropriate number of embedded generation and customer consumption scenarios representative of patterns throughout a year,
- for each scenario, model the interactions between the embedded generation, customer consumptions and resultant losses,
- estimate network losses based on the modelling the distribution network between the generator's connection point and the transmission network connection point for each modelled operating period of the generator,
- Calculate the annual overall DLF utilising a volume weighting factor based on the average electrical energy loss for each modelled operating period of the generator.

In distribution lines where there are both site specific embedded generators and site specific customers along with customers that are not be required to be site specific then the same modelling approach would apply but potentially requiring significantly more scenarios to be examined.

8. Definitions

Term	Definition
Active Energy (MWh)	As in the Rules
Active power (MW) (in this paper referred to as "power" or "demand")	As in the Rules
Adjusted Gross Energy	As in the Rules – basically metered energy adjusted for DLF
AL-n	Annual losses in Customer Category n
Apparent power (MVA)	As in the Rules
average electrical energy loss (Rules Chapter 10)	The volume-weighted average of the electrical energy losses incurred in each trading interval over all trading intervals in a defined period of time
Distribution Customer	As in the Rules
Distribution line	As in the Rules
Distribution Loss Factor (DLF)	As in the Rules
Distribution Losses	As in the Rules
Distribution losses	As in the Rules
Distribution network	As in the Rules
Distribution network user	A Distribution Customer or an Embedded Generator (as in the Rules)
Distribution system	As in the Rules
Embedded generation	As in the Rules
High Voltage	System voltage greater than 1 kV (as in the Rules)
Load Factor	Ratio of average demand over maximum demand
Loss Factor (LF)	Ratio of losses at a particular network level over sales at that level
Load Loss Factor (LLF)	Ratio of average power loss over power loss at maximum demand
Loop Maximum Demand (LMD)	The highest value of electrical demand determined in an electrical loop, over the defined time period
Low Voltage	System voltages less than or equal to 1 kV
Maximum Demand (MD)	As in the Rules
National Metering Identifier (NMI)	As described in Rules clause 7.3.1(d)
Reactive power (MVAr)	As in the Rules
RMS	The Root Mean Square (RMS) is the square root of the arithmetic mean of the squares of a set of numbers
SL-n	Sales in Customer Category n
Supply	The delivery of electricity (as in the Rules)
Transmission Node Identity (TNI)	Code identifying the relevant transmission node
Transmission system	As in the Rules

9. Authorisations

Action	Name	Date	Signature
Prepared by	Mike Green (MG)	May 2016	
Reviewed by	Paul Connor (PC)	May 2016	
Reviewed by	David Strong (DS)	May 2016	
Authorised by	Kirstan Wilding (KW)	May 2016	
Revised By	David Strong (DS)	February 2020	
Approved By	Stephen Jarvis (SJ)	February 2020	

10. Document Control

Date	Version	Description	Author	Approved by
May 2016	0.1	Draft for review	MG	KW
June 2016	1.0	Final for Issue	MG	KW
February 2020	1.1	Revised method for calculating line losses using load flows at RMS load in place of maximum demand. Use of MW and MVAR in place of amps for line loads where available.	DS	SJ

Appendix A

Top Down Losses

Top down losses are calculated as the sum of the boundary energy at transmission connection points plus embedded generation minus distribution customer sales. The top down losses calculation uses revenue metering data comprising metering:

- Types 1 to 4 - interval metering,
- Type 5 – not applicable to Tasmania,
- Type 6 - accumulation metering covering basic meters and PAYG, and
- Type 7 – un-metered supply.

Basic meters are only read monthly or quarterly. An accrual process is required to calculate sales and generation for customers with basic metering. An accrual process is also required for PAYG metering data.

Un-metered supply metering data is created from an engineering calculation and is estimated for the twelve month period as determined in accordance with the metrology procedure.

All of the metering data used in the top down process is obtained from metering data provided by relevant Metering Data Providers and stored in TasNetworks' IT systems.

The top down process has two key roles:

- the identification of locations with discrepancies in energy data and possible sources of metering errors and
- in conjunction with the bottom up process the calculation of non-technical losses and reviewing for reasonableness.

Bottom Up Losses

Introduction

The 'Bottom Up' losses are based on modelling all network segments and are used to establish the losses for various classes of customers; that is, those connected to the network at different voltage levels.

The distribution network consists of a large number of loads, sources, various types and sizes of conductors and transformers. An "average" approach is to be adopted with the following assumptions made during the calculation:

- load currents maintain a constant ratio to the total feeder current
- voltages at every source bus remain constant in magnitude
- power factor remains constant.

Series (Copper) Losses and Shunt (Iron) Losses are the main components to be included in the overall bottom up losses calculation.

Series Losses vary and change with the square of current or power demand.

Shunt losses are associated with transformation and are largely fixed since they are related to voltage magnitudes that are largely constant.

Based on these assumptions, the annual distribution energy losses can be calculated from the maximum demand losses. This is done by the introduction of the Load Loss Factor (**LLF**) that is calculated by:

$$LLF = \frac{Actual\ Energy\ Loss\ (MWh)\ during\ a\ period}{Maximum\ Demand\ Loss\ (MW)\ \times number\ of\ hours\ in\ the\ period}$$

LLF can be estimated from demand information:

$$LLF = \left(\frac{\sum Interval\ Values}{Annual\ Maximum\ Interval\ Value \times Number\ of\ Intervals}\right)^2$$

Additionally the term Load Factor is defined as:

$$Load\ Factor = \frac{Average\ Demand\ (MW)}{Maximum\ Demand\ (MW}$$

If interval values are not available it is possible to establish a relationship between peak demand on a system and the average technical losses through consideration of load factors and load loss factors. Empirical formulas giving the relationship between the Load Loss Factor (LLF) and the Load Factor are:

$$LLF = k \times Load\ Factor + (1 - k) \times Load\ Factor^2$$

Where k is a constant, typically 0.3 for sub-transmission systems and 0.2 for high voltage feeders and distribution substations. Sample sections of the network can be analysed to produce an estimate of the applicable k factor.

The accuracy of the ‘Bottom Up’ calculation is judged based on comparison with the ‘Top Down’ measurement through acceptance of the level of non-technical losses.

The maximum load on a feeder can be impacted by one off events. The average load is a much more stable value. The value of k in the calculation of LLF is an empirical value that can vary between feeders.

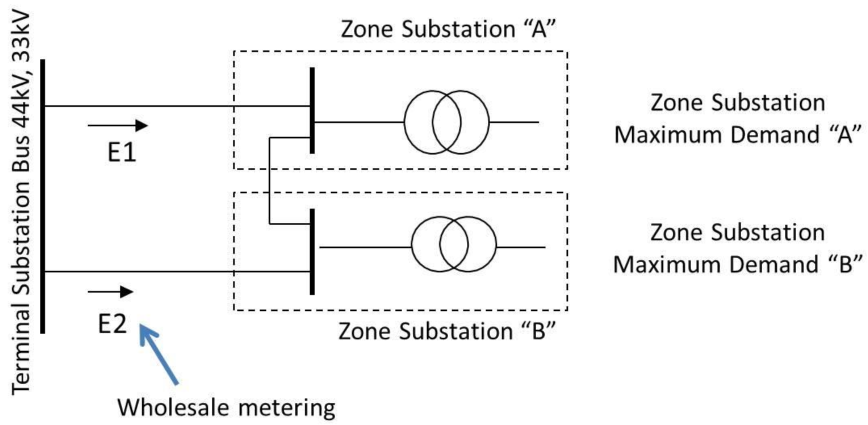
An alternative method for calculating line losses has been proposed by Leith Elder of the University of Wollongong that does not require assuming a value for k.

The revised method is to calculate the RMS value of the load and then calculate the losses at RMS load.

The calculation of losses at the RMS value of load should be used in place of a Load Loss Factor for calculating load losses where interval data is available to allow the calculation of the RMS value of load.

Amps does not have a sign so does not provide a direction of power flow. There are now some substations where flow can be from the feeder into the substations. Feeder MW and MVAR have a sign indicating direction and should be used for the calculation where available.

Sub-transmission Line Losses



The standard methodology to calculate the loss component for the sub-transmission loop / lines is detailed as below:

- Set up full network model for all sub-transmission lines in each loop
- Obtain loop maximum demand (MD)
- Run load flow to determine power losses (LMD) at loop maximum demand
- Determine Load Factor for the sub-transmission loop
- Calculate the Load Loss Factor (LLF) using metered data or using the formula

$$Load\ Loss\ Factor\ (LLF) = 0.3 \times Load\ Factor + 0.7 \times Load\ Factor^2$$

(Factor 0.3 may be replaced with calibrated factor if available)

- Calculate the annual losses (a_{L-1}) on the sub-transmission loop

$$\mathrm{a}_{\mathrm{L}-1} = LMD \times LLF \times 8760$$

Where 8760 = 24 hours X 365 days

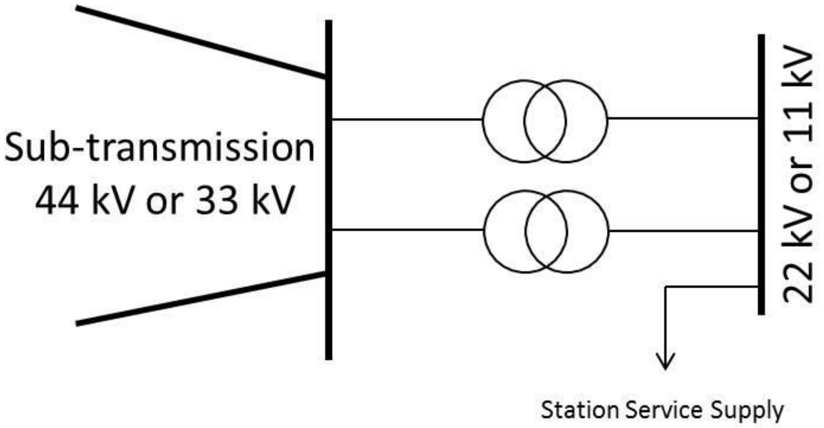
Total DLF regional losses for all sub-transmission lines are calculated by summing the annual losses for each individual sub-transmission line in the DLF region, giving A_{L-1}.

The calculation of losses at the RMS value of load should be used in place of a Load Loss Factor for calculating sub-transmission line losses where interval data is available to allow the calculation of the RMS value of load.

Feeder MW and MVAR should be used for the calculation where available.

An alternative method for calculation of sub-transmission line losses is the use of metering data where available. If there is interval metering data available at each end of the line the losses can be calculated as the difference between the energy into the line and the energy out of the line at the remote end.

Zone Substation Losses



The standard methodology to calculate the loss component for the Zone Substation is:

- Obtain zone substation maximum demand MD (MW)
- Determine losses at MD (LC_{MD} in MW) using transformer design information
- Determine Load Factor for Zone Substation Transformers
- Calculate the Load Loss Factor (LLF) using metered data or using the formula

$$Load\ Loss\ Factor\ (LLF) = 0.3 \times Load\ Factor + 0.7 \times Load\ Factor^2$$

(Factor 0.3 may be replaced with calibrated factor if available)

- Calculate Annual Series Losses (LC) for the transformer

$$LC = LC_{MD} \times LLF\ (MW)$$

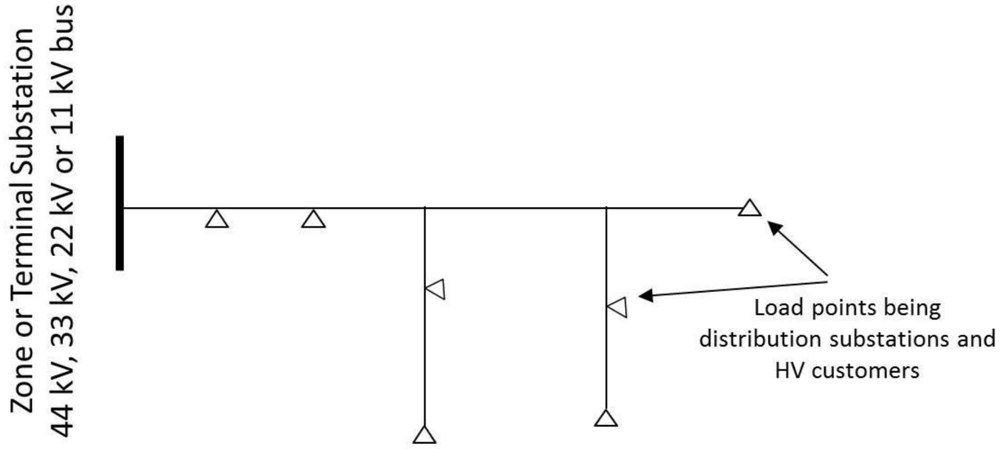
- Add fixed Shunt Losses (LI in MW) using transformer no-load loss design information
- Add Station Service Supply (LSS) losses (if not metered)
- Calculate Total Annual Losses (a_{L-2}) for the Zone Substation Transformer

$$a_{L-2} = (LC + LI + LSS) \times 8760$$

Where 8760 = 24 hours X 365 days

Total DLF regional losses for all zone substations are calculated by summing the annual losses for each individual zone substation in the DLF region, giving A_{L-2}.

High Voltage Distribution Line Losses



The standard methodology to calculate the loss component for the High Voltage Distribution Network is:

- Determine the feeder current (Im) at Maximum Demand (MD)
- Carry out load flow for feeder at Maximum Demand current and establish power loss (L_{MD}).
- Determine Load Factor of the HV feeder
- Calculate the Load Loss Factor (LLF) either using metered data or using the formula

$$Load\ Loss\ Factor\ (LLF) = 0.2 \times Load\ Factor + 0.8 \times Load\ Factor^2$$

(Factor 0.2 may be replaced with calibrated factor if available)

- Calculate the Annual Losses (a_{L-3}) for the feeders off the zone substation:

$$\mathrm{a}_{\mathrm{L-3}} = L_{MD} \times LLF \times 8760$$

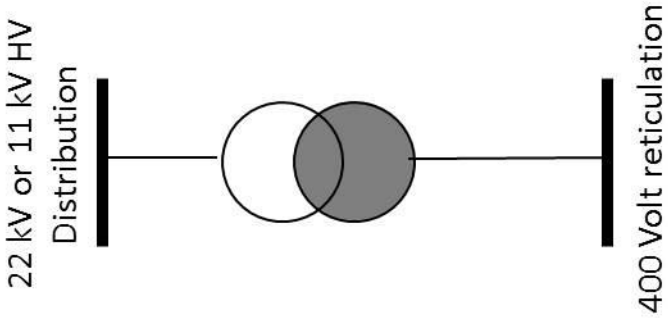
Where 8760 = 24 hours X 365 days

Total DLF regional losses for all high voltage distribution feeders are calculated by summing the annual losses for each individual high voltage distribution feeders in the DLF region, giving A_{L-3}.

The calculation of losses at the RMS value of load should be used in place of a Load Loss Factor for calculating HV feeder losses where interval data is available to allow the calculation of the RMS value of load.

Feeder MW and MVAR should be used for the calculation where available.

Distribution Substation Losses



The standard methodology to calculate the loss component for the Distribution Transformers is detailed as below.

- Determine average MD of transformers
- Determine typical Series Losses (LC_R) of the transformer at its nameplate rating
- Calculate Series Losses (LC_{MD}) for the transformer at MD

$$LC_{MD} = LC_R \times \left(\frac{MD}{Name\ Plate\ Rating}\right)^2$$

- Estimate the Load Factor of the transformer
- Calculate the Load Loss Factor (LLF) either using metering data or using the formula

$$Load\ Loss\ Factor\ (LLF) = 0.2 \times Load\ Factor + 0.8 \times Load\ Factor^2$$

(Factor 0.2 may be replaced with calibrated factor if available)

- Calculate Annual Series Losses (LC) for the transformer

$$LC = LC_{MD} \times LLF\ (MW)$$

- Add fixed Shunt Losses (LI) for the Transformer
- Calculate Total Annual Losses ($a_{L\text{-}4}$) of the Transformer

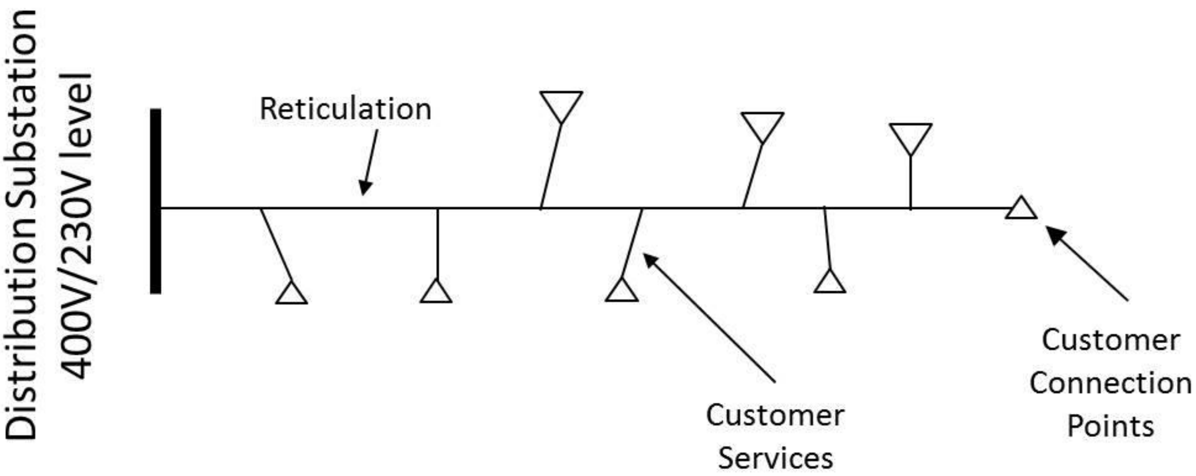
$$a_{L-4} = (LC + LI) \times 8760$$

Where 8760 = 24 hours X 365 days

Total Losses for all distribution transformers can then be calculated by summing the annual losses for each individual transformer or type of transformer.

Total DLF regional losses for all distribution substations are calculated by summing the annual losses for each individual distribution substations in the DLF region, giving $A_{L\text{-}4}$.

Low Voltage Losses



The standard methodology to calculate the loss component for the Low Voltage reticulation is:

- Establish a representative Low Voltage reticulation configuration including number of customers
- Determine Maximum Demand to apply to representative Low Voltage reticulation
- Carry out load flow for reticulation at Maximum Demand and establish power loss (L_{MD}).
- Determine reticulation Load Factor
- Calculate the Load Loss Factor (LLF) either using metered data or using the formula

$$Load\ Loss\ Factor\ (LLF) = 0.2 \times Load\ Factor + 0.8 \times Load\ Factor^2$$

(Factor 0.2 may be replaced with calibrated factor if available)

- Calculate the Annual Losses (a_{L-5}) for the representative Low Voltage reticulation:

$$a_{L-5} = L_{MD} \times LLF \times 8760$$

Where 8760 = 24 hours X 365 days

Total DLF regional technical losses for all low voltage reticulation are calculated by scaling up the calculated representative low voltage reticulation annual losses by the total annual sales at the low voltage level.

The non-technical losses determined by the difference between the regional aggregate Top Down losses and Bottom Up technical losses are allocated to Low Voltage giving A_{L-5}.

DLF Calculation

Introduction

The methodology for calculating DLFs determines an average loss level for five different network segments based on modelling of the segments. A DLF is calculated for each network segment and customers are allocated the appropriate DLF for the network segment to which their electrical installation is connected. The DLF categories relating to the five network segments are:

- $DLF_{Subtx\text{-}Line}$ is the distribution loss factor to be applied to a second tier customer or market customer connected to a sub-transmission line (at 44kV or 33kV).
- $DLF_{Zone\ Sub}$ is the distribution loss factor to be applied to a second tier customer or market customer connected to the lower voltage side of a zone substation
- $DLF_{HV\text{-}Fdr}$ is the distribution loss factor to be applied to a second tier customer or market customer connected to a distribution line from a zone substation at voltages of 22kV, 11 kV or 6.6kV.
- $DLF_{Dist\text{-}Sub}$ is the distribution loss factor to be applied to a second tier customer or market customer connected to the lower voltage terminals of a distribution transformer (at 400/230V).
- $DLF_{LV\text{-}Lines}$ is the distribution loss factor to be applied to a second tier customer or market customer connected to a low voltage line at 230/400V.

Firstly the Loss Factor (**LF**) is calculated for each DLF network level expressed as:

$$LF = \frac{Calculated\ Annual\ Losses\ (MWh) in\ the\ Category}{Annual\ Net\ Sales\ in\ Category\ (MWh) + Annual\ Net\ Sales\ Downstream\ of\ Category (MWh)}$$

Where the "Net Sales" is defined as:

> Energy consumed by all distribution customers within the DLF region at the network level minus energy exported by embedded generation into that network level.

Secondly, the network level DLFs are calculated by aggregating the downstream lower network level loss factors up to and including the subject level, expressed as:

$$DLF_{L-n} = 1 + \sum LF_{L-n}$$

Forward Looking DLFs

In accordance with principle (5) of Rules' clause 3.6.3(h) in calculating the DLFs the most recent actual load and generation data available for a consecutive 12 month period must be used. These may be adjusted to take into account projected load and / or generation growth in the financial year in which the DLFs are to apply.

Consideration of future trends in network losses would include changes in load patterns including embedded generation penetration, power factor and network configuration and expansion. In particular equipment utilisation changes, asset replacements, development of new sub-transmission, zone substations, and HV distribution all are taken into account when determining the DLFs.

The use of forecast changes in sales increases complexity and reduces transparency and has minimal impact on the outturn DLFs. For the purpose of the DLF calculation the historical load data is used.

DLF Calculation and Application Rules

DLFs are calculated by apportioning losses at the various customer connection categories according to the sales achieved for that category and downstream lower network levels.

The table below shows the formulas to be used to calculate the DLFs and the factors to be applied to the customer.

Customer Connection Point	Calculated Annual Losses in Category	Annual Net Sales	Loss Factor Formulas of calculating DLFs for each Category	Total Amount to be applied to Customer
Sub-Transmission (44kV, 33kV)	A_{L-1}	NS_{-1}	$LF_{\text{Subtx-Line}} = \frac{A_{L-1}}{(NS_{-1} + NS_{-2} + NS_{-3} + NS_{-4} + NS_{-5})}$	Subtx-Line
Zone Substation	A_{L-2}	NS_{-2}	$LF_{\text{Zone}} = \frac{A_{L-2}}{(NS_{-2} + NS_{-3} + NS_{-4} + NS_{-5})}$	Subtx-Line + Zone-Sub
HV Feeder	A_{L-3}	NS_{-3}	$LF_{\text{HV Fdr}} = \frac{A_{L-3}}{(NS_{-3} + NS_{-4} + NS_{-5})}$	Subtx-Line + Zone-Sub + HV-Fdr
Distribution Substation	A_{L-4}	NS_{-4}	$LF_{\text{Dist Sub}} = \frac{A_{L-4}}{(NS_{-4} + NS_{-5})}$	Subtx-Line + Zone-Sub + HV-Fdr + Dist-Sub
LV Network (400/230V)	A_{L-5}	NS_{-5}	$LF_{\text{LV lines}} = \frac{A_{L-5}}{NS_{-5}}$	Subtx-Line + Zone-Sub + HV-Fdr + Dist-Sub + LV-Lines + non-technical

Site Specific Connection Points

This section describes the methodology used in determining the “site specific” distribution loss factors for the qualified customers under NER clause 3.6.3(2)(i).

At present most of the qualified site specific customers are connected to network configurations given below:

- Customers connected directly to sub transmission network off terminal stations
- Customers connected to shared sub transmission network
- customers connected to dedicated high voltage feeder
- Customers connected to shared high voltage feeder

The main steps are as follows:

1. Model the distribution network from the transmission connection point to the customer’s distribution connection point.
2. Evaluate the total peak demand power losses using a power system modelling package and actual maximum demands recorded in the last financial year.
3. Allocate the total peak demand power losses to site-specific customers and the rest of the network customers on the network under consideration. This can be done using “customer energy” or “customer demand” as the principle driver for allocation.
4. Determine the site-specific customer and rest of network annual load factor.
5. Calculate load loss factor (LLF) employing empirical formulae.
6. Calculate annual losses using the allocated peak demand losses and LLF:

$$Site\ Specific\ Annual\ Losses\ (MWh) = Allocated\ Peak\ Demand\ Loss\ (MW) \times LLF \times 8760\ (hours)$$

7. Determine annual energy consumption. For site-specific DLF calculation this is obtained from last financial year’s billing data.
8. Calculate customer specific DLF using the formula:

$$Customer\ Specific\ DLF = 1 + \frac{energy\ losses\ (MWh)}{energy\ consumption\ (MWh)}$$

Where a customer is supplied on a dedicated feeder and there is metering at the substation the losses can be calculated as the difference between the feeder metering at the substation and the customer revenue metering.