Distribution Loss Factor Calculation Methodology Paper

February 2025

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1 Introduction

Distribution losses are electrical energy losses incurred in the conveyance of electricity over a distribution network. Distribution loss factors (‘DLFs’) are used to describe the average electrical energy losses for electricity transmitted on a distribution network between a distribution network connection and a transmission network connection point or virtual transmission node for the financial year in which they are to be applied. DLFs are used by the Australian Energy Market Operator (‘AEMO’) in the market settlement to adjust the electrical energy attributed to each retailer at each transmission network connection point. Consequently, market settlements are done based on an adjusted gross energy amount for each connection point. DLFs are also used by retailers directly for reconciliation with their purchasing against their customer billing processes.

DLFs must be determined in accordance with a methodology under the National Electricity Rules. If the Australian Energy Regulator (‘AER’) has determined a methodology, then that methodology must be applied. If the AER has not determined a methodology, then the relevant Distribution Network Service Provider (‘DNSP’) must determine a methodology.

The AER has not determined a distribution loss factor methodology, consequently each DNSP must develop, publish and maintain a methodology in accordance with clause 3.6.3(g) and (h) of the Rules.

This document set outs Ausgrid’s (AG) methodology for calculating DLFs. This methodology has been prepared in accordance with the requirements of the National Electricity Rules, in particular having regard to the principles contained in clause 3.6.3(h) of the Rules. This methodology is applied to both loads and generating units connected to the Ausgrid network.

This document is published on Ausgrid’s website at

https://www.ausgrid.com.au/Industry/Regulation/Network-prices.

1.1 Requirements of the National Electricity Rules

DLFs must be determined for all connection points either on a site-specific basis or collectively in relation to connection point classes

Clause 3.6.3(b)(2)(i) of the Rules requires that DLFs will be either site specific for certain types of connection points or for those which are not required to be site specific, based on voltage or connection point classes. Briefly, site specific DLFs will be determined in relation to:

- A connection point for an embedded generating unit with actual generation of more than 10MW, based on the most recent data available for a consecutive 12 month period at the time of determining the distribution loss factor. Where relevant data is not available for a consecutive 12 month period as a distribution network connection point is newly established or has been modified, a Network Service Provider may determine whether an embedded generating unit has generation of more than 10MW, based on its best projection of generation in the financial year in which the distribution loss factor is to apply, taking into account the terms of the relevant connection agreement;
- A connection point for an end-user with actual or forecast load of more than 40GWh or an electrical demand of more than 10MW, based on the most recent data available for a consecutive 12 month period at the time of determining the distribution loss factor. Where relevant data is not available for a consecutive 12 month period as a distribution network connection point is newly established or has been modified, a Network Service Provider may determine whether an end-user has load of more than

40GWh or forecast peak load of more than 10MW, based on its best projection of load in the financial year in which the distribution loss factor is to apply, taking into account the terms of the relevant connection agreement;.

- A connection point for a market network service provider; and
- A connection point between two or more distribution networks.

Also, Clause 3.6.3(b1) states the following:

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, the Distribution Network Service Provider must calculate a site specific distribution loss factor that, notwithstanding any other provision of the Rules to the contrary, for the purposes of the Rules is to apply in respect of that generating unit on the same basis as applies for a generating unit of more than 10MW or 40GWh per annum capacity as though the generating unit were a unit of more than 10MW or 40GWh per annum capacity.

Assignment of Connection Points

Clause 3.6.3(c), (d) (e) and (f) impose requirements in relation to the allocation of connection points to either a single transmission network connection point or to a virtual transmission node and to a class of distribution network connection points.

Principles to Apply to the Methodology

Clause 3.6.3(h) requires that the methodology must be developed having regard to the principles set out in sub clauses (1) - (6). The effect of these principles may be briefly summarised as:

(1) Seeking to ensure that the total amount of energy calculated in relation to a distribution network (as adjusted for losses by the relevant DLF) for a particular financial year is as close as reasonably practicable equal to the total metered or estimated energy flowing through all connections points in the distribution network and the total (actual) electrical energy losses incurred on the distribution network in the financial year;

(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 adjusted gross energy and DLFs i.e., by a reconciliation between the aggregate adjusted gross energy at all distribution customer connection points on AG Network’s distribution network in the previous financial year (applying the DLF’s set for that previous year) and the sum of the total metered energy at those points in that year plus the total (actual) losses incurred on that network in that year.

(3) For non-site specific connection points, determining the DLF by using a 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 class of distribution network connection points for the financial year in which the DLF is to apply;

(4) For site specific connection point, 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 in the financial year in which the DLF is to apply (See Attachment 2 for details).

(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;

(6) Treating flows in network elements that solely or principally provide market network services as invariant.

Ausgrid notes that these are principles to which regard must be had and are not prescriptive rules to be applied inflexibly. Ausgrid's proposed approach is consistent with the above principles, provides a fair and equitable result and is consistent with ensuring that the application of DLFs results in all energy losses being accounted for and recovered by affected parties in the market.

1.2 Ausgrid's General Approach in Deriving Non-site specific DLFs

STEP 1 Reconciliation of previous financial year

The starting point for the calculation of DLFs for the following year is firstly carrying out a reconciliation of prior years' losses as contemplated by principle (2) above. This involves calculating the actual losses that occurred in each year, which is a matter of subtracting energy exiting the distribution network from the energy entering the distribution network. Having determined the actual losses, this is compared to what the losses had been projected to be at the time of setting the DLFs for that year.

Appendix A - Section 1.1 Diagram 1 and the associated text gives the timing of tasks related to the setting of DLFs for the specified period.

STEP 2 Estimation of Losses for the year in which the DLFs are to apply

Clause 3.6.3 (h) (5) anticipates the use of the most recently available consecutive 12 month load and generation data to determine losses for the following year, with some adjustment where necessary. Clause 3.6.3 (h) (2) contemplates reconciliation of the previous financial year, which may not be the most recent 12 month period.

Ausgrid therefore estimates losses on the most recent data available and adjusts this data to reflect factors such as anticipated seasonal load variability (consistent with principle 3.6.3 (h) (5) as well as to account for any differences demonstrated by the previous financial year's reconciliation.

STEP 3 Determining the volume weighted average electrical energy loss for connection points

Having established a headline or *top down* figure for total losses, those losses then must be apportioned to various asset classes in the network on a volume weighted average basis. This step, known as a *bottom up* allocation, is described in more detail in Section 2 but in summary, an engineering calculation is done to determine the anticipated losses for each asset category. Once this allocation takes place, any remaining proportion of losses is allocated to unread meters and accrual. This accrual is allocated by default to the LV network since this is the only part of the electrical network left where losses have not been technically assessed. Losses on the LV network cannot be determined with precision because of its massive nature and diversity in load and configuration.

As anticipated by clause 3.6.3 (b) (2), distribution losses for non-site specific connection points are considered in customer categories, related to the functional part of the network where those categories relate to. The various categories are estimated using the approaches shown in Figure 1[1].

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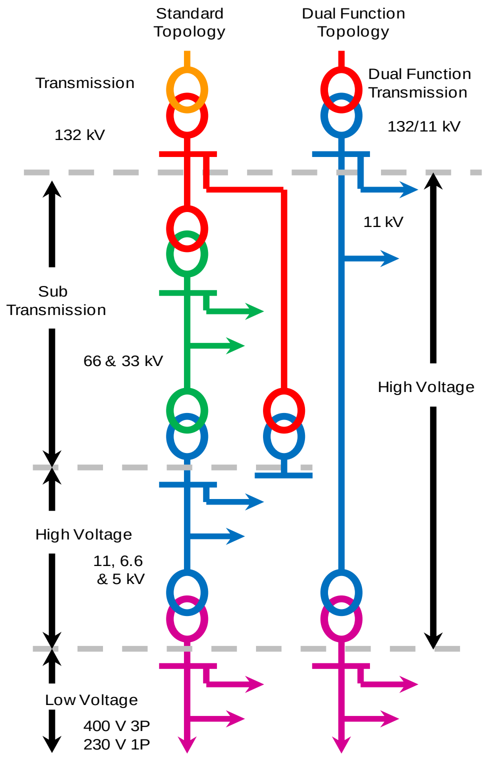
[1] ***Series*** (or copper) losses occur in the network connection between generator(s) and load(s) due to the resistance to electrical flow and vary with the power supplied to the load. Series losses tend to follow a "square law", in that the series loss in a simple network is proportional to the square of the current supplied to the load. ***Shunt*** (or iron) losses are a "leakage" of energy (mainly associated with the connection of transformers and other equipment to the network) and occur regardless of the flow of power to the load.

In this analysis, the effect of transmission losses (in both the TransGrid and Ausgrid transmission networks) has been excluded[2]. On 1 February 2000, the boundary of the transmission network changed in NSW, to include Ausgrid's transmission assets (previously these assets had been treated as distribution). Both distribution and transmission loss factors have been altered accordingly. The present revision of losses for 2024/25 reflects the change in the transmission boundary that occurred on 1 February 2000.

Figure 1 - Loss Factor Estimation



	Standard Topology		Dual Function Topology	
Loss Element	**Series Loss**	**Shunt Loss**	**Series Loss**	**Shunt Loss**
Radial 132 kV network	Load Flow using PSS/E	negligible	N/A	N/A
132/11 kV Sub Trans Substations		Transformer & substation shunt losses		
132/66 & 132/33 kV Substations		Transformer & substation shunt losses		
ST Network		negligible		
Zone substations		Transformer & substation shunt losses		
HV Network	Load flow studies at peak load & loss load factor	negligible	Load flow studies at peak load & loss load factor	negligible
Distribution substations	Transformer count & loss load factor	Transformer & substation shunt losses	Transformer count & loss load factor	Transformer & substation shunt losses
LV Network	Balance	negligible	Balance	negligible
Meters and load control	negligible	Device count & shunt loss	negligible	Device count & shunt loss
Non technical losses	N/A	Residual losses	N/A	Residual losses

The next step is to allocate a portion of each asset class's losses to customer classes. For example, a certain amount of losses relates to 33kV feeders. Some of those losses are caused by domestic customers load further below in the network. The allocation of asset losses to customer class is carried out based on a pro rata energy allocation as well as considering each customer class peak, shoulder and off peak energy mix and their average power factor. Having carried out this allocation, the calculation of DLFs at this point is then a simple case of taking the losses allocated to a customer class and dividing by the total energy for that customer class and adding one.

1.3 Energy entering the Distribution network

Energy entering Ausgrid's Distribution network is determined from the Wholesale Metering Points ('WMP'), as these are used for both market settlements and transmission network pricing. The WMPs only measure energy entering Ausgrid's Distribution network. There are also supplies to Ausgrid from:

- Endeavour (at Camellia 33kV, Carlingford 66kV and Guildford 33kV);
- Macquarie Generation (Liddell 33kV); and
- Embedded generators (at 132, 33 and 11kV).

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[2] In its glossary, the National Electricity Rules defines transmission assets to include those assets of 66kV or higher voltage, which operate in parallel with and support the main transmission network. Ausgrid owns and operates 132kV transmission assets in the Sydney and Newcastle areas.

The total energy entering the distribution network as determined for the DLF calculation in the specified financial year is given in **Section 1.2 of Appendix A**.

1.4 Energy exiting the Distribution network

Calculating energy exiting the network or ‘sold’, though conceptually simple, is quite labour intensive, requiring the measurement and aggregation of over 1.8 million connection points on the Ausgrid network. It requires tracking each connection point, ensuring a meter is installed and is in good working order, that it is read regularly, that the reading is billed and invoiced correctly. All of this is also required for customer billing and therefore determining the volume exiting the network is done through the use of billing invoices of all 1.8 million network customers. Because of the lagging nature of meter reading being spread out over a three month cycle, determining exit volumes requires at least a five month delay from the end of the financial year. This guarantees that a reliable ‘sales’ volume has been calculated.

1.5 Proposed Approach to Loss Estimation for Financial Year 2025/26

As indicated in Section 1.2 above, Step 2 of Ausgrid’s methodology involves an estimation of the losses for the year in which the DLF’s are to apply.

The top down forecast DLF value for the specified financial year is shown in **Appendix A Section A.1.3**.

2 Breakdown of Technical Losses

Having established a *top down* figure for total losses in the entire distribution network, losses must now be allocated across the different voltage levels at which each of the customer classes connect to the network, known as a *bottom up* allocation. Due to the increased connection of large scale embedded generating units existing in the distribution, subtransmission and transmission systems on the Ausgrid network, electricity is now starting to flow in a bi-directional fashion within the Ausgrid network. The calculation of losses across voltage levels necessarily requires an assessment of the total losses at each voltage level. Once this is established, an apportionment of that loss volume must be made, not only to customers connected at that voltage, but also customer connected below but who have had their energy delivered through that voltage. This section sets out Ausgrid's methodology to carry this out.

2.1 Calculation of Site Specific Loss Factors

Ausgrid calculates site specific loss factors using the Incremental Transmission Loss Allocation method. This involves the allocation of losses to specific load or generation points within the system according to the effect on total losses of an incremental change in load or generation. The Incremental Transmission Loss Allocation method utilises load-flow analysis in PSS/E and a correlated load model to represent the loads across an annual duration. See attachment 2 and 3 for details.

2.2 Calculation of Loss Load Factors

Loss Load Factors provide for a simple translation of series losses over full load duration, when calculating losses. For HV feeders Loss Load Factors ('LLFs') are modelled in Sincal to determine the full load losses which are summed together at the zone level. The distribution substation LLFs are calculated using the distribution substation load cycle. See attachment 2 for more details.

2.3 Sub-transmission network series losses

A correlated load model[3] was used to derive the series losses for each sub-transmission asset and the average series losses for loads of greater than 10 MW. Each 66 and 33 kV location represents a major customer connected to the sub-transmission network, whilst 11 kV locations can be large customers but are mostly zone substations, where the downstream load of both high voltage and low voltage customers is aggregated. The correlated load model accounts for diversity and seasonal variations in load to determine the subtransmission network series losses. See attachment 3 for details.

2.4 Sub-transmission network shunt losses

Estimates of the average shunt losses in 132, 66 and 33 kV transformers are combined with the number of in-service transformers to determine the annual energy losses. An estimate is also made of the energy consumed by Zone substation auxiliaries, including transformer fans and pumps. These calculations are updated for each year's DLF analysis.

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[3] The annual load data from major customer and zone substation load points are used to form the correlated load model. This utilises k-means clustering to determine the magnitude of the load for n load levels and the expected percentage of time across the annual duration.

2.5 High voltage network series losses

Series losses were analysed for all distribution feeders at each zone substation using load flow techniques at peak load and then multiplying the full load losses by the zone specific LLF.

2.6 Distribution substation series losses

A stock take of available records of distribution transformer design rating information was carried out, which gave the nameplate rating of series losses and iron losses. This information was then used to calculate rated series and iron losses for each transformer.

In most cases, distribution substations are equipped with manual reset maximum demand indicators (MDIs) and these readings are recorded periodically within Ausgrid's asset management systems. Peak series loss of each transformer can then be determined by scaling the rated series loss with the square ratio of the MDI and the rated current. Individual transformer copper loss was calculated by applying the loss load factor to the peak series loss. Rated iron losses do not change with loading, so were applied directly.

For transformers without calculated losses, due to a lack of either nameplate information or an MDI record, a scaling was applied. Transformers were grouped into different rating classes with similar loss to rating ratios. Losses were scaled up by applying the loss to rating ratio to each group of the rating class.

The peak losses in distribution substations were converted to an annual energy loss using an annual system loss load factor (as discussed earlier in Section 2.2).

These distribution substation series losses are updated for each year's DLF analysis.

2.7 Meters and load control device shunt losses

Meter losses are calculated based on nameplate information per meter type multiplied by number of NMIs forecasted for the year for which the DLF is being calculated is multiplied by average number of meters per NMI. Note that the meter potential coil (or power supply) connection is on the input side of the meter and therefore its losses are not recorded in the meter consumption.

2.8 Low voltage network losses including non-technical losses

Once all technical losses were determined upstream from the methodology outlined above, residual losses were allocated to the LV network, including non-technical losses. Non-technical losses include fraud but also can arise from metering, data and information system deficiencies. A consistent flow of reports from staff and the public giving rise to investigation. Ausgrid uses approximately 150 compact recording instruments (theft monitors). These are installed in the street to check the meter readings at premises under investigation. All non-technical losses are assumed to take place on the low voltage network and therefore are attributed to this class of customer.

3 Summary of Losses

Table 1 in Appendix A Section 2 provides a summary of the forecast for the specified financial year of the energy entering Ausgrid's distribution network, the losses on Ausgrid's distribution network and the energy exiting Ausgrid's distribution network for the different distribution asset classes.

4 Tariff Class Averaging

Between the tariff groups of low voltage customers, there is a significant variation in consumption patterns and power factors. To manage this, loss factors are assigned to tariff groups rather than to just voltage levels where a number of tariffs exist. Thus the domestic customer classes (including controlled load) are averaged, as are the LV and HV business customers. The averages apply across the whole of Ausgrid's network.

4.1 Time Variation of Losses

Losses for the tariff customer classes are estimated for peak, shoulder and off peak periods[4], taking into account the square law relationship of series losses. The loss factors for peak, shoulder and off peak are then used in conjunction with the tariff group energy consumption patterns to develop overall loss percentages.

4.2 Accounting for Power Factor

This issue arises predominantly in relation to streetlight loads, which have a markedly different power factor (around 0.40) compared with the remaining load (around 0.95 average). The contribution of individual loads to the total series loss has therefore been adjusted by taking into account the angle between the load and the average. This results in a "scaling factor" which increases the streetlight distribution loss factor[5].

4.3 Geographic variation of Loss Factors

The variability of loss factors at the sub-transmission network level was estimated in 2002 from TPRICE analysis and is repeated below. Distribution losses in the network are characterised by high values at a few (mainly geographically remote) locations. The following table includes the likely range of distribution losses to LV connected customers.

Table 3: Geographic variation of loss factors

Voltage level	Lower bound	Average	Upper bound
Sub-transmission	1.00	1.009	1.1
High Voltage	1.00	1.013	1.4
Low Voltage	1.02	1.055	1.5

It should be noted that a very few large customers are connected at the sub-transmission level.

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[4] The peak and off peak periods are now defined as follows:

Residential customers:

Peak is from 3 pm to 9 pm on all days during 1 November to 31 March (inclusive) – the 'summer months' and from 3 pm to 9 pm on all days during 1 June to 31 August (inclusive) – the 'winter months'.

Off peak is at all other times that are not Peak.

Business customers:

Peak is from 3 pm to 9 pm on working weekdays during 1 November to 31 March (inclusive) – the 'summer months' and from 3 pm to 9 pm on working weekdays during 1 June to 31 August (inclusive) – the 'winter months'.

Off peak is at all other times that are not Peak.

[5] The power factor and consumption pattern adjustments are made, with a typical power factor of 0.4 for street lights being assumed. A scaling factor was calculated as the MVA contribution by each LV class to the overall MVA of LV loads. This approach is described in Attachment 1.

Attachment 1 – Accounting for Load Power Factor

This section describes how the power factor of components of the LV load supplied by the network should be taken into account in determining their loss factor. Some components of the load, such as streetlights, have a much lower power factor than other loads.

The situation may be understood with reference to the P-Q diagram below. Line OZ represents the LV load on the network. The load comprises MVA load components a, b, and c with power angles of α, β and χ respectively. The MW load components are a’, b’ and c’.

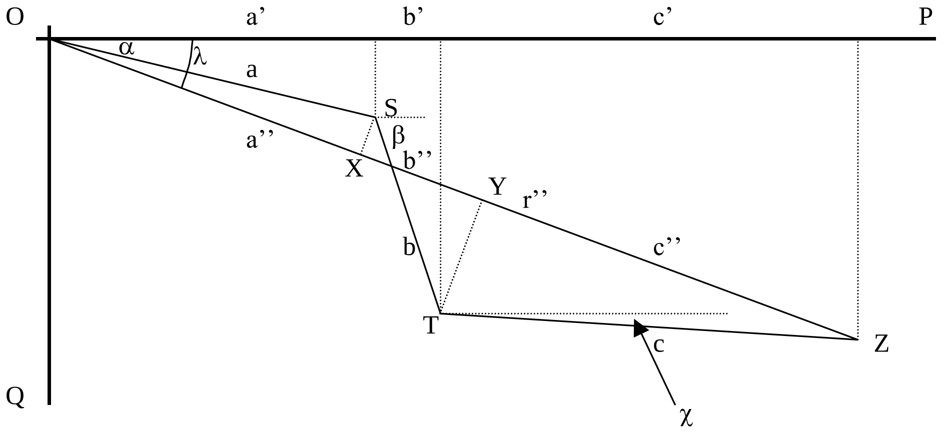


Figure 1: Vector diagram indicating load power factor

Line OZ is the total MVA load and is the vector sum OSTZ of load components a, b and c. It has a value of r” and power angle λ.

Now, the series losses in the network are driven by the total MVA load. The relative contributions to the total loss by the three loads in this example are OX, XY and YZ.

The MVA contribution of each component of load depends upon the cosine of difference between its angle and the angle of the total load. If the angles of the total MVA load is :

$$r'' = a'' + b'' + c''$$

$$= a^*\cos(\lambda - \alpha) + b^*\cos(\lambda - \beta) + c^*\cos(\lambda - \chi)$$

$$= a'^*\cos(\lambda - \alpha)/\cos(\alpha) + b'^*\cos(\lambda - \beta)/\cos(\beta) + c'^*\cos(\lambda - \chi)/\cos(\chi)$$

The above equation is used to determine the contribution to the total MVA load by each component.

By way of example, consider there are just two load components, with a’ being 19,000 MWh with power factor 0.95 (20,000 MVAh at angle 18.19°) and b’ 135 MWh with power factor 0.40 (337.5 MVAh at angle 66.42°). The total load r” is the vector sum of these quantities, 20,226.4 MVAh at angle 18.91°.

The contributions to the total MVAh load r” are as follows:

$$a'' = 19{,}000^*\cos(18.91^\circ - 18.19^\circ)/\cos(18.19^\circ) = 19{,}998.45$$

$$b'' = 135^*\cos(66.42^\circ - 18.19^\circ)/\cos(66.42^\circ) = 227.95$$

These contributions expressed as a multiple of the MWh load are as follows:

a”/a = 19,998.45/19,000 = 1.05

b”/b = 227.95/135 = 1.69

In the calculation of distribution loss factors, these ratios are used as scaling factors to apportion the contribution to series component of losses.

Attachment 2 - Methodology for sub-transmission network loss calculations

Introduction

This attachment outlines the methodology and assumptions for calculating the series loss component of Ausgrid's sub-transmission network (zone substation 11kV busbars and above) which are not classified as Dual Function Transmission assets by Ausgrid in accordance with the National Electricity Rules.

Methodology

The methodology for calculating network losses is the Incremental Transmission Loss Allocation method. The Incremental Transmission Loss Allocation method was first used to optimise the dispatch of generators to reduce transmission losses. The optimisation process was completed by assigning an Incremental Transmission Loss to each generator as given by.

$$ITL_i = \frac{\partial P_{loss}}{\partial P_i}$$

Further, the process can be easily extended to loss allocation to a load point of generating unit by assigning a bus its losses according to its effect on the total losses of the system. Thus, the loss due to bus k_i is given by.

$$L_k = S_k \frac{\partial P_{loss}}{\partial S_k}$$

Where, L_k are the system losses due to bus k. S_k is apparent power of bus k and P_{loss} is the total system losses.

The Incremental Transmission Loss Allocation algorithm performs a first order sensitivity analysis on the network to expand the system losses, where each term in the linear expansion then defines the fraction of losses attributable to the corresponding bus. It has been mathematically derived that the calculated total losses at each load/generation point in the system is approximately twice the amount of losses i.e.

$$\kappa_0 = \sum_{k=1}^{n} L_k \cong 2L$$

The final step is to normalise L_k to allocate a portion of the total losses to bus k thus providing the loss allocation.

$$L'_k = \frac{L}{\kappa_0} L_k$$

The implementation of this method involves determining the partial differential equations through perturbing the load/generation level of a certain bus and redetermining the system losses through load flow simulations. The partial differentiation then becomes the change in losses divided by the change in load due to the perturbation as shown below.

$$L_k = Size\ of\ load/generation \times \frac{change\ in\ losses}{change\ in\ load/generation}$$

$$L_k = S_{k\ actual} \times \frac{P_{loss\ k\ perturbed} - P_{loss\ actual}}{S_{k\ perturbed} - S_{k\ actual}}$$

Incremental Transmission Loss Allocation Procedure

The practical implementation of the Transmission Loss Allocation method requires a two key inputs,

(1) Network connectivity and impedance model in PSSe. The connectivity model is assumed to be in the system normal state.

(2) Correlated Load Model. The correlated load model uses k-means clustering algorithm to approximate the magnitude of a load / generation point for n load levels and a probability of the load level occurring. The k-means clustering algorithm takes 15min sampled load / generation data from metering or SCADA at the required load / generation points to create the correlated load model. See attachment 3 for details.

Network losses are thus calculated using load-flow analysis in PSSe. The Incremental Transmission Loss Allocation method iterates across each load level in the correlated load model and calculated the following.

- The overall series losses from the subtransmission system (11kV busbars and subtransmission connected major customers) to the transmission connection points.
- The partial differential equations are solved at each load / generation point through perturbing the load / generation and normalising the system loss to allocate a portion of the system loss to the load / generation point.

The annual energy losses at each load level is calculated by linearised integration (“under the curve”) of the calculated MW losses. The annual energy losses are compiled by the addition of the probability weighted losses calculated at each load level.

The series losses are allocated to each load / generation point and also further allocated to a particular category, eg 132kV lines, 132kV substations, 33kV lines, 33kV substations etc.

The Incremental Transmission Loss Allocation method is automated using python scripts which create the correlated load model, calculates the series losses and allocates a portion of the series losses to each load / generation point in the category breakdown as listed above.

The Distribution Loss Factor (DLF) is finally calculated for ICT load / generation points.

$$DLF = 1 + \frac{P_{loss}}{P_{load/generation}}$$

The DLF is generally a number greater than one for ICT load points. As energy flow occurs between the transmission connection point or embedded generation to the point of connection, losses will be incurred across the system impedance.

The DLF for generating units can be greater or less than one. The interpretation of DLF for values greater of less than one for generating units is as follows.

- DLF > 1. The generating unit will reduce overall system losses.
- DLF < 1. The generating unit will incur system losses.

This is dependent on a number of factors which can influence losses allocated to a generating unit. These factors are the network connection point, generating unit maximum generation and system impedance between the generating unit transmission connection point and network load.

Attachment 3 – Correlated Load Model

To accurately depict the load and generation variance and correlation over an annual duration, a correlated load and generation model is used. The k-means clustering algorithm is used to generate correlated load and generation magnitudes for active power (MW) at each load and generation point for a finite number of load levels. This uses 15min sampled load / generation data of MW and MVAr from metering or SCADA at the required load / generation points. The MW datasets are set as the observations for the k-means clustering algorithm.

The k-means clustering algorithm uses an iterative refinement technique. The steps to implement the k-means clustering algorithm on is as follows.

(1) Select an initial set of k-means cluster mean c_i

(2) Find the Euclidean distance of each point in the dataset with the identified k-means cluster means. The Euclidean distance between two points ($p = (p_1, p_2)$ and $q = (q_1, q_2)$) in space is.

$$d(p,q) = \sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2}$$

(3) Assign each observation to the cluster c_i with the nearest mean where dist is the Euclidean distance

$$\arg\min_{c_i \in C} dist(c_i, x)^2$$

(4) Calculate the new cluster mean from the clustered points where S_i is the set of all points assigned to cluster c_i

$$c_i = \frac{1}{|S_i|} \sum_{x_i \in S_i} x_i$$

(5) Repeat steps (2), (3) and (4) until no changes are observed in the cluster means between iterations.

The k-means clustering process above will provide correlated MW magnitudes at each load and generation point and the probability of the load level occurring.

The reactive power component of the loads is derived from the average of reactive power component of the load points mapped to each k-means cluster.

For generating units, the reactive power component is determined by the operating mode of the system.

Attachment 4 – Virtual Transmission Nodes

As per 3.6.2 (b) (3) of the National Electricity Rules, Ausgrid seeks approval for the use of the following Virtual Transmission Nodes.

Below is a list of the current, future additions and future removal of virtual transmission nodes expected from 1 July 2025.

Current List

TNI	Substation	VTNI
NALX	Alexandria 33	NEV3
NBFN	Beaconsfield North 132	NEV3
NBFS	Beaconsfield South 132	NEV3
NBG1	Bunnerong 132	NEV3
NBG3	Bunnerong 33	NEV3
NBHL	Brandy Hill 11	NEV2
NBMP	Belmore Park 11	NEV3
NBM1	Belmore Park 132	NEV3
NCBS	Campbell Street 11	NEV3
NCS1	Campbell Street 132	NEV3
NCHM	Charmhaven 11	NEV2
NCTB	Canterbury 33	NEV3
NCR1	Cronulla 132	NEV3
NGF3	Gosford 66	NEV2
NGSF	Gosford 33	NEV2
NGSQ	Green Square 11	NEV3
NGB1	Gwawley Bay 132	NEV3
NGWF	West Gosford 11	NEV2
NHBB	Homebush Bay 11	NEV3
NHVN	Hurstville North 11	NEV3
NHYM	Haymarket 132	NEV3
NKN1	Kurnell 132	NEV3
NKNL	Kurnell South 11	NEV3
NKOG	Kogarah 11	NEV3
NLCV	Lane Cove 132	NEV3
NLD3	Liddell 33	NEV1
NMBK	Meadowbank 11	NEV3
NMKV	Marrickville 11	NEV3
NMPK	Mason Park 132	NEV3
NMRK	Muswellbrook 132	NEV1

NPHT	Peakhurst 33	NEV3
NPH1	Potts Hill 132	NEV3
NPHL	Potts Hill 11	NEV3
NMQP	Macquarie Park 11	NEV3
NMQS	Macquarie Park 33	NEV3
NMU3	Munmorah STS 33	NEV2
NMUN	Lake Munmorah 132	NEV2
NNEW	Newcastle 132	NEV2
NOR1	Ourimbah 132	NEV2
NOR6	Ourimbah 66	NEV2
NORB	Ourimbah 33	NEV2
NRKD	Rockdale 11	NEV3
NRWR	Rookwood Road 132	NEV3
NRSB	Rose Bay 11	NEV3
NSE2	Sydney East 132	NEV3
NSMB	Somersby 11	NEV2
NSN1	Sydney North 132	NEV3
NSPT	St Peters 11	NEV3
NSFS	Strathfield South 11	NEV3
NSW1	Sydney West 132	NEV3
NSYS	Sydney South 132	NEV3
NTG3	Tuggerah 132	NEV2
NTME	Tomago 132	NEV2
NTPR	Top Ryde 11	NEV3
NVP1	Vales Pt 132	NEV2
NWR1	Waratah 132	NEV2
NWAV	Waverley 11	NEV3
NWYG	Wyong 11	NEV2

Future additions list

TNI	Substation	VTNI
NKGF	Kingsford 11	NEV3
NMAR	Maroubra 11	NEV3

Appendix A

A.1 Annual DLF Data Summary

A.1.1 Ausgrid's General Approach in Deriving Non-site specific DLFs

Diagram 1 Reconciliation of previous financial year

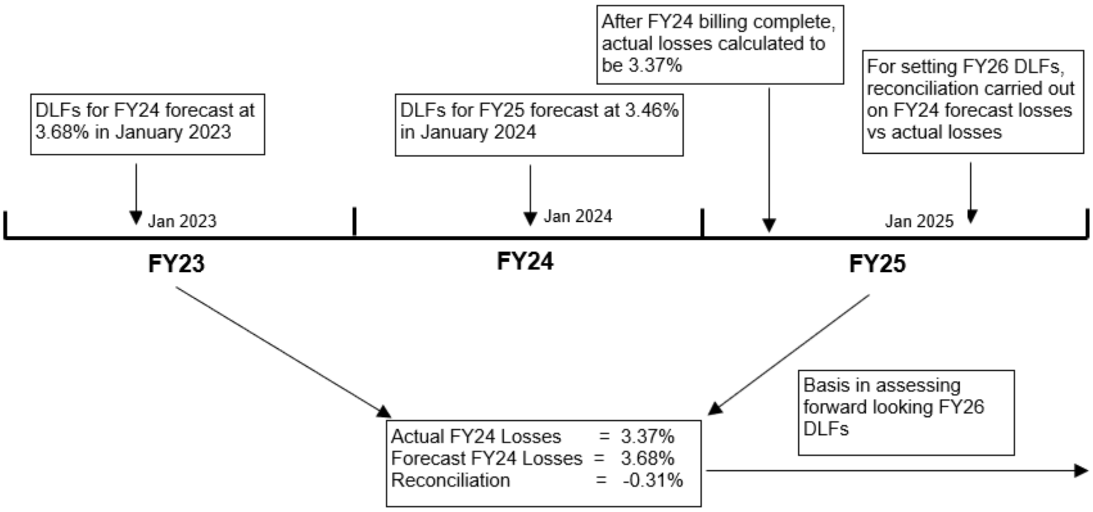


Diagram 1: Timing for DLF Calculation and Subsequent Reconciliation

As shown in Diagram 1 above, the setting of FY26 DLFs must be carried out before the start of the applicable financial year. Since DLFs are prepared as a forecast for the subsequent year this calculation is typically completed as early as January each year. For FY25, the total DLF was forecast in January 2024 to be 3.46%.

Determining how the forecast compares to actuals is carried out two years later in January 2026, when billing for FY25 is complete and stable. At this point in time, actual losses can be determined by comparing energy entering the distribution network and energy leaving the distribution network. The reconciliation for FY24 shows that actual losses were 3.37%. We have used this result as the basis to estimate losses for subsequent years.

A.1.2 Energy entering the Distribution network

The total energy entering the distribution network as determined for the DLF calculation in FY24 was calculated as 24,987.121 GWh.

A.1.3 Proposed Approach to Loss Estimation for Financial Year 2025/26

Ausgrid's methodology involves an estimation of the losses for the year in which the DLF's are to apply. The estimation is calculated as follows:

a. Estimated losses based on most recent actual load and generation data available for a consecutive 24 month period, being 3.33%.
b. The value in a. above is adjusted to take into account forecast load variability, other instability in data due to timing of available data for sales.

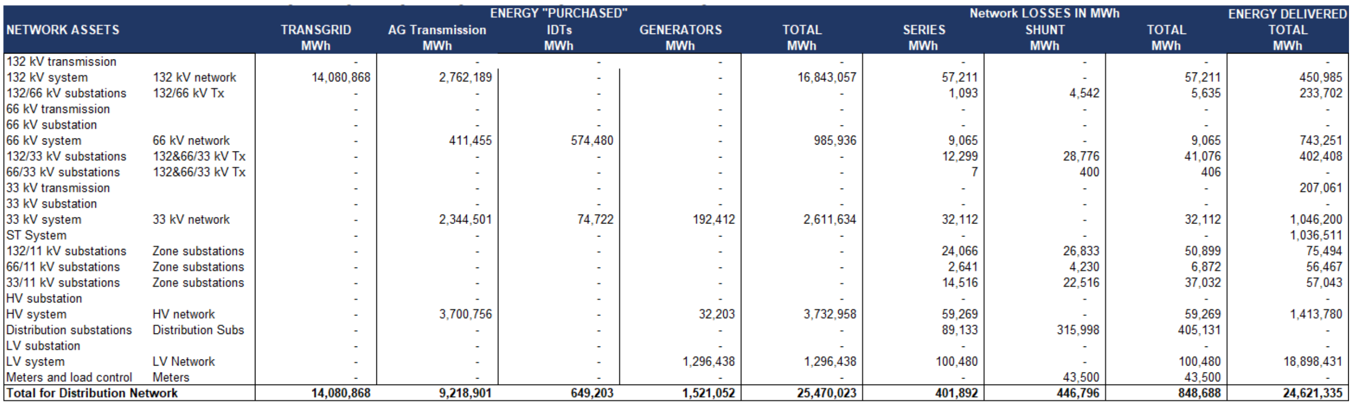
Such adjustment is based on the historical loss reconciliations from previous years.

Estimated losses (the *top down* figure) for the financial year FY26, is forecast to be 3.33%.

A.2 Summary of Losses

The Table below provides a summary of the energy entering Ausgrid's distribution network, the losses on Ausgrid's distribution network and the energy exiting Ausgrid's distribution network for the different asset classes.

Table 1: Energy Balance for Ausgrid Distribution Network, based on forecast FY26 Volumes for Reference Purposes



		ENERGY "PURCHASED"					Network LOSSES IN MWh			ENERGY DELIVERED
NETWORK ASSETS		TRANSGRID MWh	AG Transmission MWh	IDTs MWh	GENERATORS MWh	TOTAL MWh	SERIES MWh	SHUNT MWh	TOTAL MWh	TOTAL MWh
132 kV transmission		-	-	-	-	-	-	-	-	-
132 kV system	132 kV network	14,080,868	2,762,189	-	-	16,843,057	57,211	-	57,211	450,985
132/66 kV substations	132/66 kV Tx	-	-	-	-	-	1,093	4,542	5,635	233,702
66 kV transmission		-	-	-	-	-	-	-	-	-
66 kV substation		-	-	-	-	-	-	-	-	-
66 kV system	66 kV network	-	411,455	574,480	-	985,936	9,065	-	9,065	743,251
132/33 kV substations	132&66/33 kV Tx	-	-	-	-	-	12,299	28,776	41,076	402,408
66/33 kV substations	132&66/33 kV Tx	-	-	-	-	-	7	400	406	-
33 kV transmission		-	-	-	-	-	-	-	-	207,061
33 kV substation		-	-	-	-	-	-	-	-	-
33 kV system	33 kV network	-	2,344,501	74,722	192,412	2,611,634	32,112	-	32,112	1,046,200
ST System		-	-	-	-	-	-	-	-	1,036,511
132/11 kV substations	Zone substations	-	-	-	-	-	24,066	26,833	50,899	75,494
66/11 kV substations	Zone substations	-	-	-	-	-	2,641	4,230	6,872	56,467
33/11 kV substations	Zone substations	-	-	-	-	-	14,516	22,516	37,032	57,043
HV substation		-	-	-	-	-	-	-	-	-
HV system	HV network	-	3,700,756	-	32,203	3,732,958	59,269	-	59,269	1,413,780
Distribution substations	Distribution Subs	-	-	-	-	-	89,133	315,998	405,131	-
LV substation		-	-	-	-	-	-	-	-	-
LV system	LV Network	-	-	-	1,296,438	1,296,438	100,480	-	100,480	18,898,431
Meters and load control	Meters	-	-	-	-	-	-	43,500	43,500	-
Total for Distribution Network		**14,080,868**	**9,218,901**	**649,203**	**1,521,052**	**25,470,023**	**401,892**	**446,796**	**848,688**	**24,621,335**