Distribution Loss Factor Calculation Methodology Paper

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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 on the basis of 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 document is published on Ausgrid’s website at www.energy.com.au/network_prices and made available upon request to interested persons.

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) 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. (For generators with actual generation of less than 10MW a site specific DLF can be calculated if the generator agrees to meet the reasonable costs of the DNSP calculating the DLF);
- A connection point for an end-user with actual or forecast load of more than 40GWh or an electrical demand of more than 10 MW.
- A connection point for a market network service provider; and
- A connection point between two or more distribution networks.

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 ie, by a reconciliation between the aggregate adjusted gross energy at all 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.

(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 simply 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. The following diagram demonstrates the timing of tasks related to the settling of DLFs:

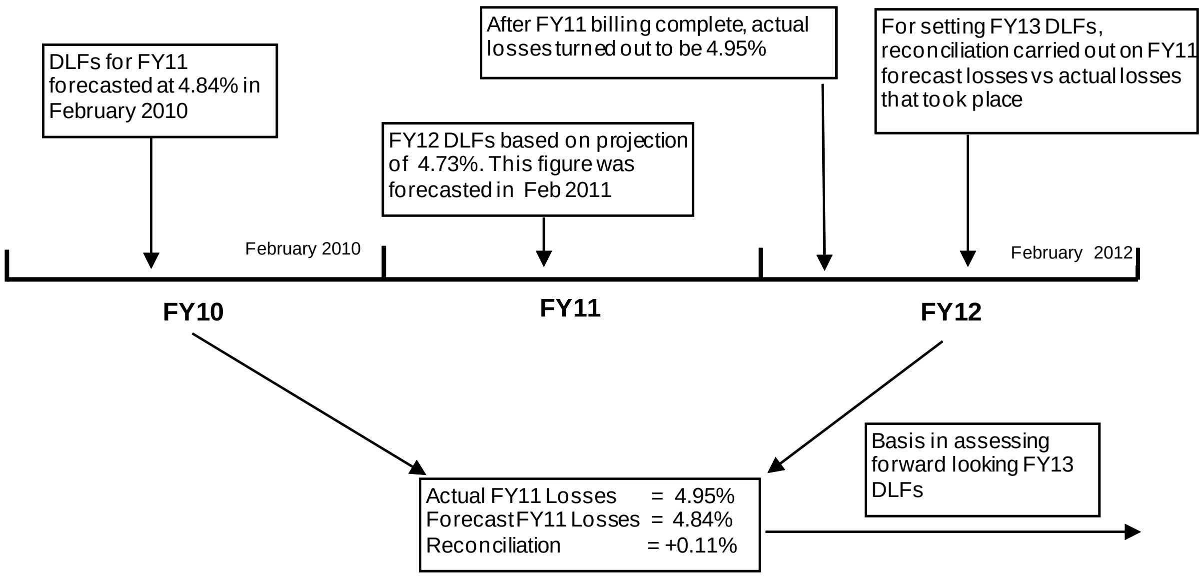


Diagram 1: Timing for DLF Calculation and Subsequent Reconciliation

From diagram 1 above, it can be seen that the setting of 2010/11 DLFs must be set before the beginning of that year. So DLFs are forecast for the following year, and this calculation is usually completed around February each year. For 2010/11, DLFs were forecast to be 4.84%.

Assessing how this forecast compares with what really took place can only be carried out two years later in February 2012, when billing for 2010/11 is complete and stable. At this point in time, losses can be determined by comparing energy entering the distribution network and energy leaving the distribution network. Reconciliation for 2010/11 shows losses ended up being 4.95%. This reconciliation process is then used in the estimation of losses for subsequent years.

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.

EnergyAustralia 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 any precision because of its massive nature and diversity in load and configuration.

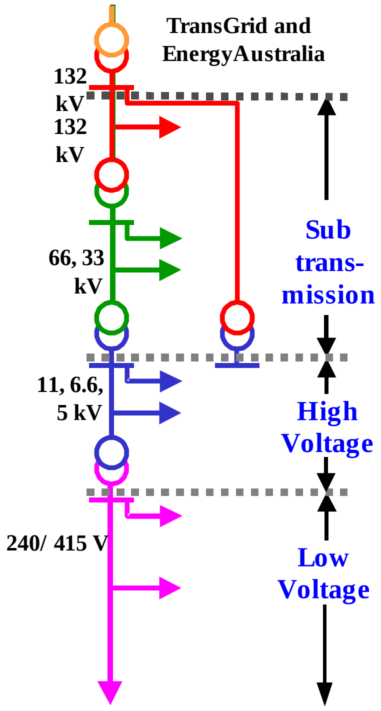
As anticipated by clause 3.6.3 (b) (2), distribution losses for non-site specific connection points are considered in customer categories, related to the functional part of the network where those categories relate to. The various categories are estimated using the approaches shown in Figure 1 on the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

In this analysis, the effect of transmission losses (in both the TransGrid and Ausgrid 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 2012/13 reflects the change in the transmission boundary that occurred on 1 February 2000.

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.

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

Figure 1 - Loss Factor Estimation



Loss Element	Series Loss	Shunt Loss
Transmission (parallel 132 kV)	TPRICE simulation	transformer substation and typical shunt loss
Radial 132 kV network		negligible
132/ 66 & 132/ 33 substations		transformer substation and typical shunt loss
ST networks		negligible
Zone substations		transformer substation and typical shunt loss
HV network	Loadflow studies at peak load and loss load factors	negligible
Distribution substations	transformer count, load and loss load factors	transformer and typical shunt loss
LV Network	Loadflow on a sample LV networks	negligible
Meters and load control	negligible	device count typical shunt loss
Non technical losses	N/ A	residual calculated purchases less sales

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:

- Integral (at Carlingford 66 kV and Guildford 33 kV);
- Delta Electricity (Vales Point 33 kV);
- Macquarie Generation (Liddell 33 kV); and
- Embedded generators (at 132, 33 and 11 kV).

The total energy entering the distribution network in 2010/11 was 28,990 GWh.

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 1.6 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 1.6 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 2012/13

As indicated in Section 1.2 above, Step 2 of EnergyAustralia'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 12 month period, being 4.95%

b. Figure in a.) 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 2012/13, is forecast to be 4.81%.

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. Since electricity generally flows from higher voltages to lower voltages in a distribution system, 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 cost allocation software TPrice. TPrice is used in the NEM for the allocation of transmission costs and the calculation of Transmission Loss Factors by AEMO.

Ausgrid uploads the full topology of the network down to the 11kV busbar of each zone substation and then also down to each customer of greater than 10MW usage, into TPrice. This covers line impedances, connections, transformer impedances and standard operating conditions. Each customers load profile from metering data is uploaded, and each zone substation has a deemed load profile applied and uploaded in to TPrice as well. TPrice then runs a loadflow for each hour of the year. Any loadflow must calculate losses as part of its calculation of energy flows, since a loadflow cannot converge to a solution without all power flows balancing.

TPrice then collates the results and calculates the total losses attributable to each large customer. It does this by allocating upstream shared losses on a total energy basis. For example, consider a substation that a large customer connected but with other load connected as well. Consider that TPrice has determined electrical losses on the substation of 100MWh over the year and substation saw 20,000MWh of load pass through it during the year. The large customer connected downstream used 500MWh, and then the losses through the zone substation attributed to the large customer are:

100MWh x 500/20,000 = 2.5MWh

This method is applied to all upstream assets such that the large customer receives a portion of losses all the way along the supply chain. It should be noted that the above calculation is carried out separately for peak, shoulder and off peak energy. This is because losses during peak more congested periods are markedly higher, since series losses are proportional to the square of the current.

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 using peak loads. This is very handy since all planning scenarios are carried out for peak loads. Loss Load Factors ('LLFs') are calculated based on load duration curves using the Method of Intercept (MOI), which are computed from half-hour average demands over a full year. The load duration curve is squared and then averaged to obtain the LLF. The LLFs are then applied to the losses calculated at peak demands to determine the actual losses. To minimize extremity effects from a single year, an average LLF is used. This average is based on an average across a number of years[3], as shown in Table 1 below:

Table 1: Loss Load Factors for EnergyAustralia

Year	Loss Load Factor % LLF
1999/00	36.7%
2000/01	43.2%
2001/02	39.9%
2002/03	38.5%
2003/04	38.8%
2004/05	36.9%
2005/06	37.8%
2006/07	38.1%
2007/08	33.5%
AVERAGE	**38.16%**

The loss load factor of 0.382 has therefore been used in calculating series losses for 2012/13.

[3] Due to time constraints the LLF for 2008/09 has not been calculated, therefore the average LFF inherent in the DLFs this year is the same as that used last year.

2.3 Subtransmission network series losses

TPRICE analysis[4] is used to derive the series losses for each subtransmission asset and the average series losses for loads of greater than 10 MW[5]. Each 66 and 33 kV location represents a major customer connected to the subtransmission 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. To calculate the projected energy losses for 2012/13, load forecast from Sub-transmission Planning is used. This analysis is updated periodically to account for any major changes in network topology and usage patterns.

2.4 Subtransmission 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. The calculation is revised periodically to adjust for any material changes in asset mix and loading.

2.5 High voltage network series losses

Series losses for 180 (of 220) zone substations across the EnergyAustralia network were analysed using load flow techniques at peak loads. Peak losses were converted to an annual energy loss using the updated system loss load factor of 0.382 (refer to Section 2.2 above). The remaining 50 substations were assumed to have the same average losses as those analysed.

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 were 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 of 0.382 (as discussed earlier in Section 2.2).

This analysis is recalculated periodically for any material changes in asset mix, topology and loading.

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 2012/13 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.

[4] Load flow analysis, using 8760 hourly records for the latest year. Hourly loads mostly estimated from average load profiles at zone substations, scaled to match the load profiles at transmission exit points. Those loads greater than 10 MW were taken directly from metering records.

[5] TPRICE calculates marginal loss factors directly, as the weighted average of the marginal loss at each load, for each hour of simulation. Average loss factors for each hour are calculated by apportioning the series losses in each element of the network using the pricing allocation. In this simulation, the energy method of pricing allocation has been used.

3 Summary of Losses

Table 2 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 2: Energy Balance for Network, based on 2012/13 Volumes for Reference Purposes

NETWORK ASSETS		ENERGY "PURCHASED"					LOSS IN MWh			ENERGY DELIVERED
		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	13,003,913.2	4,335,430.4	-	942,092.0	18,281,435.6	28,895.0		28,895.0	267,611.9
132/66 kV substations	132/66 kV Tx	-	-	-	-	-	28,781.3	2,927.1	31,708.4	23,888.8
66 kV transmission		-	-	-	-	-	-		-	-
66 kV substation		-	-	-	-	-	-		-	-
66 kV system	66 kV network	-	-	710,631.9	-	710,631.9	13,888.2		13,888.2	297,303.1
132/33 kV substations	132&66/33 kV Tx	-	-	-	-	-	21,187.8	32,565.5	53,753.3	487,130.2
66/33 kV substations	132&66/33 kV Tx	-	-	-	-	-	587.8	532.7	1,120.5	-
33 kV transmission		-	-	-	-	-	-		-	556,318.5
33 kV substation		-	-	-	-	-	-		-	-
33 kV system	33 kV network	-	5,350,462.9	-	591,277.3	5,941,740.2	182,964.0		182,964.0	689,887.2
ST System		-	-	-	-	-	-		-	1,065,882.0
132/11 kV substations	Zone substations	-	-	-	-	-	18,865.2	13,560.3	32,425.5	-
66/11 kV substations	Zone substations	-	-	-	-	-	5,299.3	5,342.8	10,642.1	-
33/11 kV substations	Zone substations	-	-	-	-	-	38,318.2	36,313.0	74,631.1	179,019.8
HV substation		-	-	-	-	-	-		-	125,027.7
HV system	HV network	-	2,466,639.4	-	34,433.3	2,501,072.7	373,034.5		373,034.5	1,401,789.5
Distribution substations	Distribution Subs	-	-	-	-	-	225,609.8	181,480.9	407,090.8	-
LV substation		-	-	-	-	-	-		-	-
LV system	LV Network	-	-	-	55,283.7	55,283.7	36,537.6		36,537.6	21,073,362.6
Meters and load control	Meters	-	-	-	-	-	-	76,251.8	76,251.8	-
Network Assets										
Total for Distribution Network		**13,003,913.2**	**12,152,532.7**	**710,631.9**	**1,623,086.4**	**27,490,164.1**	**973,968.7**	**348,974.1**	**1,322,942.9**	**26,167,221.3**

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 classes 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 territory.

4.1 Time Variation of Losses

Losses for the tariff customer classes are estimated for peak, shoulder and off peak periods[6], 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[7].

4.3 Geographic variation of Loss Factors

The variability of loss factors at the subtransmission 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
Subtransmission	1.0	1.009	1.1
High Voltage	1.0	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 subtransmission level.

6 The peak, shoulder and off peak periods are now defined as follows:

- ***Peak*** is from 2.00 p.m. - 8.00 p.m. on working weekdays;
- ***Shoulder*** is from 7.00 a.m. - 2.00 p.m. and 8.00 p.m. - 10.00 p.m. on working weekdays for business customers and includes the period from 7.00 a.m. - 10.00 p.m. for residential customers; and
- ***Off peak*** is at all other times.

7 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'.

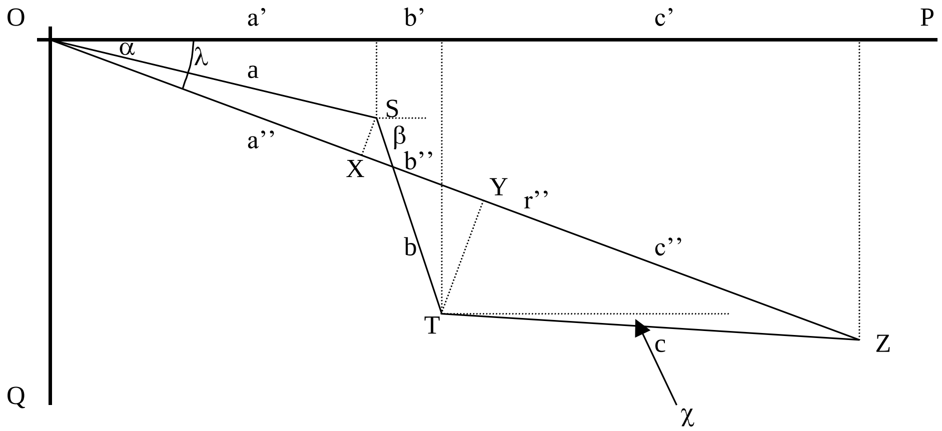


Figure 1: Vector diagram indicating load power factor

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(λ - α) + b*cos(λ - β) + c*cos(λ - χ)

= a'*cos(λ - α)/cos(α) + b'*cos(λ - β)/cos(β) + c'*cos(λ - χ)/cos(χ)

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° – 18.19°)/cos(18.19°) = 19,998.45

b" = 135*cos(66.42° – 18.19°)/cos(66.42°) = 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.