Forward-looking Transmission Loss Factors

Prepared by: AEMO Operations – System Commercial

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Approved for distribution and use by:

Approved by: Michael Gatt

Title: Executive General Manager Operations

Date: TBC

aemo.com.au

New South Wales | Queensland | South Australia | Victoria | Australian Capital Territory | Tasmania | Western Australia

Australian Energy Market Operator Ltd ABN 94 072 010 327

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Current version release details

Version	Effective date	Summary of changes
8.1	TBC	Changes to reflect the National Electricity Amendment (Integrating energy storage systems into the NEM) Rule 2021 and Rule 2023 No. 2, including to incorporate references to bidirectional units (BDUs).

Note: There is a full version history at the end of this document.

1. Introduction

1.1. Scope

This document specifies how AEMO calculates and applies inter-regional loss factor equations, intra-regional loss factors and average transmission loss factors using a forward looking loss factor (FLLF) methodology (the Methodology), and prepares load and generation data to calculate the applicable marginal loss factors (MLFs).

This Methodology is made under clauses 3.6.1(c), 3.6.2(d), (d1) and (g), and 3.6.2A(b) of the National Electricity Rules (NER), and has effect only for the purposes set out in clauses 3.6.1, 3.6.2 and 3.6.2A of the NER.

If there is any inconsistency between this Methodology and the NER, the NER will prevail to the extent of that inconsistency.

1.2. Definitions and interpretation

The words, phrases and abbreviations set out in the table below have the meanings given opposite them when used in this Methodology. Terms defined in the NER have the same meanings in this Methodology unless otherwise specified. NER-defined terms are intended to be identified by italicising them, but failure to italicise a defined term does not affect its meaning.

This Methodology is subject to the principles of interpretation set out in Schedule 2 of the National Electricity Law.

Term	Definition
AEMO	Australian Energy Market Operator Limited
AER	Australian Energy Regulator
AC	Alternating current
Connection point	In this methodology, refers only to a *transmission network connection point* unless otherwise specified
DC	Direct current
DNSP	*Distribution Network Service Provider*
EMS	Energy management system
Resource constrained	*Generating units* *and bidirectional units* are classified as either resource constrained or non-resource constrained, this definition impacts their prioritisation in the balancing of *supply* and demand.
ESOO	Electricity *statement of opportunities* – published annually by AEMO in August
FLLF	Forward looking loss factors
FLLF Study	Forward looking loss factor study performed to obtain MLF outcomes
Full Commercial Use Date	The anticipated commencement date of full commercial service.
MLF	*Marginal loss factors*
MNSPs	*Market Network Service Provider*
MT PASA	Medium Term *projected assessment of system adequacy*
NEB	Net energy balance
NEM	*National Electricity Market*

Term	Definition
NER	National Electricity Rules
Outlier	A year excluded from the five-year historical average when determining the generation energy cap. An outlier can be identified if the annual energy generated in a particular year is outside the range ±1.645σ (where σ is one standard deviation from the five-year historical average).
Pump Storage Schemes	A hydro *generating unit* or *bidirectional unit*, or group of hydro *generating units* or *bidirectional units*, that can operate both as a generator and a pump
Reference Year	The previous *financial year* (1 July – 30 June) in which historical data is to be used as an input to the loss factor calculation. (e.g. Target Year is 2015-16 and Reference Year is 2013-14)
RRN	*Regional reference node*
Sample Interval	A 30-minute period commencing on the hour or the half-hour
TNSP	*Transmission Network Service Provider*
Target Year	The *financial year* (1 July - 30 June) in which particular loss factors and loss equations determined under this Methodology are to be applied
VTN	*Virtual transmission node*.

2. Purpose

MLFs are used in the *National Electricity Market* (NEM) to adjust electricity prices to reflect the energy lost in transporting electricity across *networks*. *Intra-regional loss factors* and *inter-regional loss factor* equations apply for a *financial year* (1 July – 30 June).

2.1. MLFs and electrical losses

Electrical losses are a transport cost that need to be priced and factored into electrical energy prices. In the NEM, MLFs represent electrical losses between a *connection point* and a *regional reference node* (RRN). The factors are used to adjust electricity *spot prices* set at the RRN to reflect electrical losses between the RRN and a relevant *connection point*.

In a *power system* electrical losses are a function of the *load*, *network* and *generation* mix which is constantly changing. Another feature of electrical losses is that they increase quadratically to the electrical power transmitted (losses $\propto$ current^2). These variables mean that a single MLF for each *connection point* is necessarily an approximation.

2.2. Marginal losses

The NEM uses marginal costs as the basis for setting *spot prices* in line with the economic principle of marginal pricing. There are three components to a marginal price in the NEM: energy, losses and congestion.

The *spot price* for electrical energy is determined, or is set, by the incremental cost of additional *generation* (or demand reduction) for each *dispatch interval*. Consistent with this, the marginal loss is the incremental change in total losses for each incremental unit of electricity. The MLF of a *connection point* represents the marginal losses to deliver electricity to that *connection point* from the RRN.

3. Regulatory requirements

This Methodology applies to AEMO and any *Registered Participants* who are required to provide information and assistance to AEMO in the calculation of the MLFs and the preparation of *load* and *generation* data for those purposes.

Clauses 3.6.1 and 3.6.2 of the NER require AEMO to calculate, annually, *intra-regional loss factors* and *inter-regional loss factor* equations, respectively, for a *financial year*, and *publish* the results by April 1. Clause 3.6.2A requires AEMO to prepare *load* and *generation* data to calculate the MLFs. Clauses 3.6.1(c), 3.6.2(d), (d1) and (g) and 3.6.2A(b) of the NER require AEMO to detail the methodology to be used in these calculations.

There are extensive requirements to be met in developing the Methodology, all of which are reflected in this document.

4. Principles

Consistent with the NER requirements detailed in clauses 3.6.1, 3.6.2 and 3.6.2A, AEMO has established the following principles to develop this Methodology:

- Best approximation to full nodal pricing in line with *market* design principles.
- Loss factors to be forward looking.
- Complete year of historical data rather than a representative sample.
- Minimal extrapolation to modify data from the Reference Year.
- Loss factors to be based on marginal losses at each *connection point*.

5. Forward-looking Loss Factor Methodology

An overview of this Methodology is illustrated below, and a timeline is set out in Appendix A. Data requirements are listed in Appendix C.

Network data

- Prepare a network model that best represents the power system in the Target Year

Load forecast data

- Prepare load forecasts for existing and new connection points for the Target Year

Controllable network element flow data

- Prepare flow data used for existing controllable Market Network Service Provider (MNSP) network elements and controllable regulated network elements
- Estimate flow data for new controllable MNSP network elements and controllable regulated network elements

Generation data

- Prepare Reference Year data for existing *generation units* and *bidirectional units*
- Estimate generation profiles for new *generating units* and *bidirectional units*
- Determine maximum capacities of exising and new *generating units* and *bidirectional units*

Suppy and demand balance

- Determine the Interconnector limits
- Restore supply-demand balance by applying minimal extrapolation to *generating units* and *bidirectional units*

Intra-regional loss factors

- Calculate loss factors at each connection point for each Sample Interval
- Calculate volume weighted marginal loss factors

Inter-regional loss factor equations

- Determine inter-regional loss factor equations

Publication and updates

- Publish intra-regional loss factors and inter-regional loss factor equations by 1 April

5.1. Network data

A model of the *power system* for the Target Year is required to simulate *load* flows. This section describes how the network model is constructed.

5.1.1. Identify future augmentations

AEMO consults with *Transmission Network Service Providers* (TNSPs) to identify committed transmission augmentations expected to be commissioned during the Target Year. The TNSPs check that identified augmentations satisfy the commitment criteria set out in the AEMO Electricity Statement of Opportunities (ESOO). TNSPs then supply AEMO with sufficient network data for the identified augmentations to be represented in the network model.

5.1.2. Prepare a base case load flow

AEMO takes a single snapshot of the NEM transmission network from the AEMO Energy Management System (EMS). AEMO then modifies the snapshot to:

- Include all known *connection points* (existing and planned).
- Represent anticipated system normal operation.

- Include committed network augmentations.
- Maintain a voltage profile that represents high load conditions.
- AEMO may include a number of voltage control buses to improve the stability of the *load* flow solution. AEMO limits the use of voltage control buses to minimise variation to historical reactive flow outcomes.

5.2. Load forecast data

Load flow simulation studies require load forecasts for the Target Year. AEMO, or the relevant TNSP, forecasts *load* at each *connection point* based on data from the Reference Year.

5.2.1. Forecasting connection point load

AEMO, or the TNSP, produces *connection point load* forecasts for each *load connection point* by 15 January each year. If the TNSP produces the forecast, then AEMO provides to the TNSPs, by 15 October, relevant historical *connection point load* data for the Reference Year.

The *connection point load* forecasts are:

- Based on Reference Year *connection point* data (retaining the same weekends and public holidays).
- Consistent with the latest annual *regional load* forecasts prepared by AEMO or the TNSP.
- Based on 50% probability of exceedance and medium economic growth conditions.
- To include any known new *loads*.
- To include existing and committed generation that is embedded in the distribution network.
- An estimate of the active and reactive power at each *connection point* for each Sample Interval.

5.2.2. AEMO due diligence

Where a TNSP provides the *connection point* forecasts, AEMO reviews the forecasts to ensure that:

- The aggregated *connection point* annual energies (accounting for estimated transmission losses) match the latest ESOO.
- The aggregated maximum demand matches the latest ESOO (accounting for estimated transmission losses and *generating unit* and *bidirectional unit* auxiliaries).
- The differences between the Reference Year and forecast data for selected *connection points* are acceptable.

AEMO and TNSPs consult to resolve any apparent discrepancies in the *connection point* data.

5.3. Controllable network element flow data

Controllable network elements (DC links) include both controllable *Market Network Service Providers* (MNSPs) and controllable regulated network elements. Flows on DC links form an input to load flow simulation studies unless they operate in parallel to other regulated network elements (AC circuits).

5.3.1. Controllable Network Elements with historical flow data

Flows on DC links that operate in parallel with AC circuits are not inputs to *load* flow simulation studies. Such flows are determined by *load* flow simulation studies and are described in section 5.5.3 (Parallel AC and DC links).Controllable Network Elements with historical flow data

AEMO assumes that flows in MNSP DC links are unchanged from Reference Year flows. If flows in MNSP DC links are likely to change in response to modified *generation* profiles, in accordance with section 5.5.7 or 5.9, then AEMO adjusts Reference Year flows on MNSP DC links to reflect the change in *generation* profiles.

5.3.3.5.3.2. New Controllable Network Elements

For new or recently commissioned DC links where there is no Reference Year flow, AEMO assumes a value of zero (less than 1 MW) for each Sample Interval.

5.4. Generation data

Load flow simulation studies require a base set of *generation* data as an input. For existing *generating units and bidirectional units*, AEMO uses *generation* data from the Reference Year. For new *generating units and bidirectional units*, AEMO estimates *generation* using different methods depending on the technology type. These methods are described in detail in this section.

5.4.1. New generating units and bidirectional units

AEMO calculates loss factors for existing *generating units, bidirectional units* and committed *generating units and bidirectional units* with a full commercial use date that results in a forecast commissioning date within the Target Year., Aas published in the latest ESOO and updated with new *generation* information published on the AEMO website[1] up to the 31 January prior to the Target Year.

5.4.2. New generating unit and bidirectional unit forecast – general principles

All *generating units and bidirectional units* incorporated into the FLLF study that were not commercially operational for some or all of the Reference Year will require either a partial or complete profile to be incorporated into the FLLF study for any period where Reference Year historical data is insufficient.

Where the Full Commercial Use Date occurred within the Reference Year, only Sample Intervals prior to the identified Full Commercial Use Date will be estimated with historical *generation* data used for the remainder.

[1] The Generation Information Page on AEMO's website. AEMO periodically updates this page.

A *generation* profile should reflect the expected impact on flows at the wholesale boundary/boundaries (point of *connection* to the shared *transmission network*). This includes consideration of the impact of auxiliary load, *connection asset* losses and *distribution* losses where applicable.

5.4.3. Estimation method for new wind and solar generation

For a new wind or solar *generating unit* or ~~where aggregated~~ potentially for *bidirectional units* where aggregated, AEMO will produce *forecast generation* outcomes for Sample Intervals in the Reference Year prior to the Full Commercial Use Date using Reference Year weather data and assumptions described in paragraphs (a) or (b) below.

AEMO will submit estimated *generation* profiles to the relevant proponents for review, and will incorporate revisions advised by the proponent, where that advice aligns with the requirements within Appendix B and is provided by the applicable date in Appendix A.

For both wind and solar *generation*, default commissioning profiles will be applied for the estimated commissioning period prior to the expected Full Commercial Use Date. Commissioning profiles may be revised from this default based on proponent feedback where that feedback is verifiable.

When estimating profiles for both wind and solar *generation* AEMO may implement a scaling factor based on the economic behaviour of wind and solar generation within the reference year. This scaling will be performed on a regional basis and is to be based on observed levels of economic curtailment. Where scaling to represent economic curtailment is applied, AEMO will detail both the method and factors implemented within the final report.

(a) Wind

- To estimate forecast generation outcomes for wind *generating units* or potentially for *bidirectional units* where aggregated~~where aggregated potentially *bidirectional units*~~, AEMO will use locational Reference Year wind speed measurements. For *generating units* or potentially for *bidirectional units* where aggregated, ~~where aggregated potentially *bidirectional units*~~ whose Full Commercial Use Date occurred in the Reference Year prior to the time of estimation, a power curve is applied that is derived from historical measurements of both wind speed and output. For other new *generating units* potentially for *bidirectional units* where aggregated~~or where aggregated potentially *bidirectional units*~~, a power curve is applied that is generic and dependent on the capacity of the turbines.

(b) Solar

- To estimate forecast generation outcomes for solar *generating units* or potentially for *bidirectional units* where aggregated~~where aggregated potentially *bidirectional units*~~, AEMO will use locational reference year solar irradiance data measurements. The solar irradiance is then utilised as an input to the System Advisor Model[2] (SAM). Within SAM additional considerations are made for wind speed and air temperatures to ascertain the appropriate level of thermal de-rating.

[2] Further information on the System Advisor Model can be found at https://sam.nrel.gov/

5.4.4. Estimation method for new thermal, hydro and storage generating units and bidirectional units

AEMO consults with proponents of new thermal, hydro and storage *generating units* and *bidirectional units* to determine an anticipated *generation/load* profile reflective of their expected operation within the Target Year as per Appendix B.

5.4.5. New technologies and fuel types

For new *generating units* and *bidirectional units* that utilise a new technology or fuel type, AEMO assesses the *generation* profile in accordance with Appendix B to ensure that the information supplied by the proponent is credible.

5.4.6. Retired generating units and bidirectional units

Generating units and *bidirectional units* that retire in the Target Year are identified in the latest ESOO or AEMO website.[3] The forecast generation output of retiring plant is set to zero from the retirement date specified in the latest ESOO.

AEMO consults with the *Generator* for the retiring *generating unit* or *bidirectional unit* if the information in the latest ESOO or on AEMO's website[4] is insufficient to provide an exact retirement date.

5.4.7. Generating unit and bidirectional unit capacities

AEMO sets the ~~maximum~~ capacity of each *generating unit* or *bidirectional unit* to the value published in the latest ESOO.[4] AEMO uses separate values for summer and winter, where summer is defined as 1 December to 31 March. For summer capacities, the summer typical capacity[5] is utilised, with the exception of Tasmania where the summer capacity will be utilised.

AEMO then estimates sent-out capacity because *load* flow simulation studies require sent-out *generation* data. AEMO estimates the sent out capacity of *generating units* and *bidirectional units*, for both summer and winter, by subtracting an estimate of auxiliary *load* from the maximum capacity. AEMO estimates the auxiliary *load* from the difference between SCADA *generating unit* or *bidirectional unit* terminal output, as obtained from the AEMO EMS, and the sent-out value for the same Sample Interval. Where the auxiliary *loads* are separately measured or negligible, AEMO will not correct the Reference Year *generation* data.

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[3] As per the Generating unit expected closure year publication. Further information can be found at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information.

[4] As per the Generation information page publication. Further information can be found at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information.

[5] The summer typical capacity is a secondary summer capacity value published within the generation information page which is intended to be reflective of typical summer conditions, where summer capacity is indicative of more extreme summer conditions.

Reductions in capacity

AEMO will consider using a reduced generating capacity if the capacity of a *generating unit* or *bidirectional unit* is forecast to be reduced. AEMO will consult with the *Generator* to determine the reason for the forecast capacity reduction. If the capacity has been restored from a reduced capacity in the prior year(s), then AEMO in consultation with the *Generator* will backfill the Reference Year profile of the *generating unit* or *bidirectional unit* to represent the restored capacity.

5.5. Supply-demand balance

AEMO uses the minimal extrapolation principle to balance supply and demand. AEMO uses *generation* data from the Reference Year and then extrapolates this data to balance supply and demand. This follows updating of the network model, scaling the *connection point loads*, and including any committed new *generating units* and *bidirectional units*.

The availability of a *generating unit* or *bidirectional unit* is used to denote the level to which it can be operated. An availability of zero means the *generating unit* or *bidirectional unit* is unavailable for operation. A *generating unit* or *bidirectional unit* is considered available in a period if its availability in the equivalent Reference Year period was greater than zero.

AEMO obtains the availability status of each *generating unit* or *bidirectional unit* for each Sample Interval from *market* data. The availability of a *generating unit* or *bidirectional unit* is a factor that is considered in the adjustment of the supply-demand balance for those periods when it is necessary to increase the level of *generation*. This is discussed in section 5.5.2.

5.5.1. Excess generation

There will be an excess of *generation* for each Sample Interval where the forecast *connection point loads* have grown by less than the initial forecast of the output of the new *generating units* or *bidirectional units*.[6] For these Sample Intervals, AEMO reduces the net *generation* by scaling the output of all the non-resource constrained *generating units* or *bidirectional units* in proportion to their Reference Year output.

For new non-resource constrained *generating units* or *bidirectional units*, AEMO scales the initial estimate of the output in the same manner as the Reference Year output of the existing *generating units* or *bidirectional units*.

For resource constrained *generating units* or *bidirectional units*, AEMO reduces the net *generation* by scaling the output of all resource constrained *generating units* or *bidirectional units* only when output of all non-resource constrained *generating units* or *bidirectional units* is equal to zero for a given Sample Interval.

AEMO will review outcomes where excess *generation* is observed, large thermal *generating unit* reductions will be reviewed against minimum stable *generation* limits and adjustments made where deemed necessary in consultation with generators.

[6] Network augmentations also affect the supply/demand balance by altering the network losses.

5.5.2. Insufficient generation

There will be a deficit of *generation* for each Sample Interval where the *connection point loads* have grown by more than the initial estimate of the output of the new *generating units* or *bidirectional units*. For these Sample Intervals, AEMO increases the net *generation* in the following order of priority:

1. The spare capacity of non-resource constrained *generating units* or *bidirectional units* that are currently running (ON) is used in proportion to the spare capacity of each *generating unit* or *bidirectional unit*.
2. The capacity of the non-resource constrained *generating units* or *bidirectional units* that were not running (OFF) but available is used in proportion to the capacity of each *generating unit* or *bidirectional unit*.
3. Dispatchable Pump Storage Schemes are reduced in proportion to their Reference Year *load*.
4. The capacity of the non-resource constrained *generating units* or *bidirectional units* that were not running (OFF) and are unavailable is used in proportion to the capacity of each *generating unit* or *bidirectional unit*.
5. The spare capacity of hydro *generating units* or *bidirectional units* is used in proportion to the spare capacity of each *generating unit* or *bidirectional unit*.
6. Dummy *generating units* (created in the *load* flow simulation due to a *generation* shortfall created) are used, being applied at the RRN.[7]

The extrapolated generation energy is subject to the following:

$$Gen_{forecast} < Gen_{hist} \times (1 + Gen_{change\,\%} + Percent\_demand\_change + Percent\_buffer)$$

where:

$Gen_{forecast}$ = Extrapolated generation energy (GWh)

Gen_hist = five-year historical average (GWh) ignoring outliers in years t-2 to t-5

$Gen\_\text{change\_\%}$ = Generation change in the Target Year as a % total NEM generation (%)

$Percent\_demand\_\text{change}$ = Percentage change in NEM demand in the Target Year compared to Reference Year (%)

$Percent\_buffer$ = Factor to account for variations from the five-year average and/or conditions where insufficient generation exists

AEMO will not substitute prior years when excluding outliers from the historical average. i.e:

- If no outliers, use a five-year historical average.
- If one outlier, use four-year historical average.
- If two outliers, use three-year historical average.

[7] Using a dummy generating unit at the RRN is equivalent to *load* shedding.

5.5.3. Parallel AC and DC links

For *inter-regional flows* where a regulated DC link is in parallel to other AC circuits, AEMO apportions flow between the DC and AC elements- by application of a derived relationship based from observations of Reference Year flows on both the DC and AC elements.

The relationship will include a ratio and offset and be based on the linear regression of the observed Reference Year flows on both DC and AC circuits under system normal conditions.

AEMO treats new regulated DC links in parallel with other AC circuits in proportion to the maximum capabilities of the DC and AC circuits. AEMO uses different ratios where the capabilities are not the same in each direction.

5.5.4. Interconnector limits

AEMO implements representative *interconnector* limits for summer and winter, and peak and off peak periods for the Target Year consistent with the limits described in the latest ESOO. AEMO consults with TNSPs when developing these representative limits.

AEMO may need to adjust *generation* to maintain *inter-regional flows* within the respective transfer capabilities. This requirement could arise through the interaction of *interconnector* limits and *load* growth and new *generation*.

5.5.5. Switchable connection points

A *generating unit* or *bidirectional unit* or *load* may be physically switchable between two (or more) *connection points*. An example is Yallourn Unit 1 which can either be connected to the Victorian 500 kV or 220 kV networks. For these types of connections, AEMO allocates the *load* or *generating unit* or *bidirectional unit* metering data to the appropriate *connection point*. AEMO then calculates separate loss factors for each *connection point* and volume weights these loss factors to give a single MLF.

AEMO assumes that for Sample Intervals where the *generating unit* or *bidirectional unit* is ON, the *connection point* is unchanged from the state in the Reference Year *generating unit* or *bidirectional unit* data. Further, when the *generating unit* or *bidirectional unit* or *load* is OFF but is required to be used, then AEMO assume that the *connection point* state has not changed since the last known state. This is in accordance with the principle of minimum extrapolation.

The operator of a switchable *load* or *generating unit* or *bidirectional unit* may consider that in the Target Year, the switching pattern of their *generating unit* or *bidirectional unit* will differ significantly from the Reference Year switching pattern. Where the operator expects that the *generating unit* or *bidirectional unit* switching will differ by more than five days in aggregate, then the associated TNSP consults with the operator of the *generating unit* or *bidirectional unit*, to prepare an appropriate switching profile for the Target Year.

5.5.6. Intra-regional limits

AEMO incorporates *intra-regional* limits where they are anticipated to have a material impact under system normal conditions within the Target Year. *Intra-regional* limit implementation follows the principles of minimal extrapolation, where relevant *generation* will be scaled in proportion to their Reference Year output or forecast output. Where a *generating unit* or bidirectional unit has been impacted by the consideration of an *intra-regional* limit, AEMO will notify the relevant proponent.

AEMO will detail the *intra-regional* limits considered in the FLLF study in the final report.

5.5.7. Abnormal generation patterns

This clause applies when a *Generator* or AEMO believes that a Reference Year *generation* profile will not reflect the Target Year *generation* profile.

A *Generator* may, on its own initiative or at AEMO's request, provide an adjusted *generation* profile to AEMO by 15 November. AEMO then reviews the adjusted *generation* profile, and considers whether to use the adjusted *generation* profile in lieu of the Reference Year *generation* profile.

AEMO will use the most recent MT PASA data, as of 1 January, as a trigger for initiating discussions with participants with the potential to use an adjusted *generation* profile for the loss factor calculation.

AEMO may only decide to accept an adjusted *generation* profile if it is satisfied that:

- The Reference Year *generation* profile is clearly unrepresentative of the expected *generation* profile for the Target Year.
- The adjusted *generation* profile is independently verifiable and based on physical circumstances only. Some examples are:
  - Drought conditions.
  - Low storage levels or rainfall variability for hydroelectric *generating units* or *bidirectional units*.
  - Outages of greater than 30 continuous days.
  - Failure in the supply chain impacting on fuel availability.
- The adjusted *generation* profile is not market-related and does not arise as a result of the financial position of the *Generator*.
- The adjusted *generation* profile is not claimed to be confidential, as AEMO will *publish* it along with its reasoning for using an adjusted *generation* profile as part of the report accompanying the publication of the MLFs.

AEMO may seek an independent review of any adjusted *generation* profile submitted by a *Generator*.

If AEMO accepts an adjusted *generation* profile, this information is *published* on 1 April. The information is aggregated quarterly on a regional or sub-regional level.

AEMO historically reviews how adjusted *generation* profiles compared with actual *generation* profiles. AEMO *publishes* a summary of the review, with *generation* profiles aggregated quarterly on a regional or sub-regional level.

AEMO calculates, and *publishes* in October each year, indicative extrapolated *generation* data for scheduled *generating units* or *bidirectional units* along with key inputs and modelling assumptions to assist *Generators* to identify grossly incorrect Reference Year generation data. The calculation will be approximate and will:

- Only reflect information known at the time.
- Only include existing and major new *connection points*.
- Only include an approximate load forecast.
- Be based on the previous year's network model and will not include new augmentations.

5.6. Intra-regional static loss factors

AEMO uses TPRICE[8] or an equivalent software application to calculate loss factors. The calculation algorithm can be summarised as:

- A *load* flow is solved for each Sample Interval using the supplied *generation* and *load* data.
- The MLFs for the *load* flow swing bus[9] are calculated for each *connection point* and Sample Interval from a Jacobian matrix.
- The MLFs for the associated RRN are calculated for each Sample Interval as the ratio of the *connection point* loss factor to the associated RRN loss factor.
- For each *connection point*, the *marginal loss factors* (with respect to the RRN) for each Sample Interval are volume weighted by *connection point* MLFs (with respect to the RRN) to give the static MLF.

5.6.1. Dual MLFs

AEMO calculates dual MLFs for *transmission network connection points* where a single MLF for the *transmission network connection point* does not satisfactorily represent transmission network losses for active energy *generation* and consumption. AEMO applies to duals MLFs to:

- *Transmission network connection points* classified as Pump/Battery/other Energy Storage Schemes.
- Other *transmission network connection points* where the net energy balance (NEB) is less than 50%.
- Other *transmission network connection points* where the net energy balance (NEB) is between 50% and 90% and the difference between the individual export/consumption MLFs is >=0.1.
- Other *transmission network connection points* where the net energy balance (NEB) is between 50% and 90% and the MLF is less than 0.9 or greater than 1.1.

The NEB threshold test is as follows:

Determine the percentage NEB by expressing the net energy at a *transmission network connection point* as a percentage of the total energy generated or consumed at a *transmission network connection point*, whichever is greater.

[8] The TPRICE application calculates the loss factor for each *connection point* and RRN referred to the *load* flow swing bus defined in the network model. The loss factor of *connection point* A referred to *connection point* B is defined as the ratio of their respective loss factors with respect to the swing bus.

[9] The selection of swing bus does not directly affect the *marginal loss factors* with respect to the assigned *regional reference node*. There is a small effect on the flows in the network flows from changing the swing bus and this has a small indirect effect on the loss factors.

$$\text{NEB} = \frac{\text{Absolute(Sum of energy generated and consumed)}}{\text{Maximum(Absolute(energy generated), Absolute(energy consumed))}}$$

Where

$\text{Absolute}(x)$ *is the absolute value of x; and*

$\text{Maximum}(x, y)$ *is the maximum value of x and y.*

Refer to Appendix D for a worked example.

5.6.2. Virtual transmission nodes (VTN)

AEMO calculates *intra-regional loss factors* which are averaged over an adjacent group of *transmission network connection points* collectively defined as a VTN. Refer to Appendix E for the calculation methodology.

5.7. Inter-regional loss factor equations

5.7.1. Regression procedure

AEMO determines *inter-regional marginal loss factor* equations by using linear regression analysis. The procedure is as follows:

- The *marginal loss factors* for each of the RRNs, defined with respect to the swing bus, are extracted from the output of the TPRICE run used to calculate the *intra-regional loss factors*.
- For each pair of adjacent RRNs:
  - The *inter-regional marginal loss factors* are calculated for each Sample Interval as the ratio of *marginal loss factors* of the associated RRNs.
  - The *inter-regional loss factor* equations are estimated by regressing the *inter-regional marginal loss factors* against the associated *interconnector* flow and selected regional demands.

  The *regional* demands are included in the *inter-regional loss factor* equations if they significantly improve the fit of the regression equation.

Where the fit of an *inter-regional loss factor* regression is poor, then AEMO considers using additional variables in the regression analysis, including:

- The output of specific *generating units* or *bidirectional units* that affect the *inter-regional losses* (for example losses on QNI would be affected by *generation* at Millmerran).
- Transfers on other *interconnectors*.

Including these variables would require alterations to the AEMO market systems.

5.7.2. Loop flows

At present the regional model of the NEM is linear because *interconnectors* between regions do not form loops. Loop flows may be introduced in the future if additional *interconnectors* are built between *regions* that are not currently interconnected or if the region model is modified.

If loops are introduced into the NEM regional model, then the FLLF methodology may need to be revised.

5.7.3. Modelled generating unit, bidirectional unit and load data

Where the range of *interconnector* flows is less than approximately 75% of the technically available range of the *interconnector* flows or where the regression fit is poor, the resulting *inter-regional* loss factor equation will be unrepresentative.

For these scenarios the *load*, ~~and~~ *generating unit* and *bidirectional unit* data are scaled in a power simulation tool to produce a set of randomly distributed flows covering the technically available range of the *interconnector* flows. The regression analysis is repeated using the modelled data obtained from these flows. The modelled *generating unit*, *bidirectional unit* and *load* data would not be used for *calculating intra-regional loss factors*.

5.8. Publication

AEMO *publishes* the *intra-regional loss factors* and *inter-regional loss factor* equations by 1 April prior to the Target Year. The *intra-regional loss factor* report will be revised on a quarterly basis to reflect intra-year revisions.

AEMO endeavours to *publish* a preliminary report in November the year prior to the application of the loss factors for information purposes only, and a draft report of *intra-regional loss factors* by 1 March.

5.9. Unexpected and unusual system conditions

In developing this methodology, AEMO used best endeavours to cover all expected operating and system conditions that could arise when producing the *load*, *generating unit*, *bidirectional unit* and *network* dataset that represents the Target Year.

In practice, unexpected operating or system conditions can arise that are not covered in this Methodology. If this arises, then AEMO will make a judgement based on the principles listed in the NER and in section 5. All such judgements that AEMO is required to make while developing the MLFs will be identified in the *published* report listing the loss factors.

5.10. New connection points or interconnectors

AEMO *publishes* MLFs and *inter-regional loss factor* equations by 1 April prior to each Target Year. If AEMO is notified after 1 April of new *connection points* or new *interconnectors* that require MLFs or *inter-regional loss factor* equations, then AEMO follows the procedure specified in this section.

5.10.1. Network

The *network* representation used to calculate the MLFs for the new *connection point* is based on the *network* used to perform the most recent annual MLF calculation.

The *network* representation is modified to incorporate the new *connection point*. This may include addition of new or changed *transmission elements* or modifications to existing *connection points*.

5.10.2. Generation, bidirectional unit and lLoad data

The *connection point load*, and *generating unit* and *bidirectional units* data used to calculate the MLFs for the new *connection point* is based on the *connection point* data used to perform the most recent annual MLF calculation.

If the new *connection point* is a *load*, the relevant TNSP supplies AEMO with the *load* data for each Sample Interval following the commissioning of the *connection point*. If the new *connection point* is a *generating unit* or *bidirectional unit*, AEMO determines an estimate of the output for the new *generating unit* or *bidirectional unit* using the procedure set out in section 5.4 in consultation with the proponent.

5.10.3. Methodology

The procedure in section 5.5 is applied to restore the supply-demand balance by making adjustments to the output of *generating units* or *bidirectional units*. This would be the same procedure used by AEMO to perform the most recent annual MLF calculation. *The intra-regional loss factor* for the new *connection point* would be calculated using the procedure in section 5.6.

When AEMO calculates the MLF for a new *connection point*, MLF values for existing *connection points* in the vicinity may also be affected. However, when a new *connection point* is established after the MLFs have been *published*, AEMO will not revise the *published* MLFs for the existing *connection points*.

5.11. Intra-year Revisions

AEMO may be required to perform intra-year revisions to MLF outcomes where AEMO identifies a modification that in AEMO's reasonable opinion results in a material change in capacity of an existing *connection point* as per clause 3.6.2(i)(2) of the NER. For these purposes:

(a) AEMO considers an expected annual change in capacity is material if it is equal to or greater than 10% of the assumed *load* or *generation* flows at the time the annual MLFs for the Target Year were calculated; and

(b) a change in capacity at a *transmission network connection point* can be associated with a new or modified *connection* in a *distribution network*..

This section describes the process AEMO will use to revise an MLF for the purposes of clause 3.6.2(i)(2) of the NER.

5.11.1. Network

The *network* representation used to calculate the MLFs for the modified *connection point* is based on the *network* used to perform the most recent annual MLF calculation.

The *network* representation is adjusted only as required to reflect the subject modification.. This may include addition of new or changed *transmission elements* where applicable.

5.11.2. Generation and Load data

The *connection point load*, and *generating unit* or *bidirectional unit* data used to calculate the MLFs for the new *connection point* is based on the *connection point* data used to perform the most recent annual MLF calculation, adjusted only as required to reflect the subject modification.

If the modification relates to a *load connection point*, the relevant TNSP supplies AEMO with the *load* data for each Sample Interval following the commissioning of the *connection point*. If the modification relates to a *generating unit* or *bidirectional unit*[10], AEMO determines an estimate of the output for the relevant *generating unit* or *bidirectional unit* using the procedure set out in section 5.4 in consultation with the proponent.

5.11.3. Methodology

The procedure in section 5.5 is applied to restore the supply-demand balance by making adjustments to the output of *generating units* or *bidirectional units*. This would be the same procedure used by AEMO to perform the most recent annual MLF calculation. *The intra-regional loss factor* for the modified *connection point* would be calculated using the procedure in section 5.6.

When AEMO calculates a revised MLF for a modified *connection point*, MLF values for existing *connection points* in the vicinity may also be affected. However, AEMO will only make an intra-year revision of the *published* MLF for the *connection point* which was modified.

[10] This may be a modification to *transmission-connected generating units* or *bidirectional units*, or new or modified *distribution-connected generating units* or *bidirectional units* that materially change the capacity of an associated existing *transmission network connection point*.

Appendix A. Timeline

Date	Action	Section
August	AEMO commences work for Target Year commencing on the following 1 July	
August to December	AEMO publishes historical comparison FLLF study for the previous financial year	
October	AEMO publishes *generation* forecast results and modelling assumptions paper	5.5.7
15 November	Deadline for Generators to inform AEMO of abnormal generation conditions in the Target Year	5.5.7
November	AEMO publishes preliminary report	
1 January	Deadline for latest MT PASA results to use as trigger for initiating discussions with participants regarding use of adjusted generation profiles	5.5.7
31 January	Deadline for updates on AEMO website (Generation page) to be included.	5.4.1
1 March	AEMO publishes draft report of intra-regional loss factors on website	
1 April	AEMO publishes intra-regional loss factors and inter-regional loss equations on website	5.8
1 April to end of Target Year	AEMO calculates and publishes, as required MLFs for newly registered connection points, and inter-regional loss factor equations for new interconnectors	5.11
1 July	Intra-regional loss factors and inter-regional loss equations effective in market systems	2

Appendix B. New generating units and bidirectional units

This appendix describes the guidelines for proponents of a new *generating unit* or *bidirectional unit* who are required to provide AEMO with information necessary to determine the forecast *generation* data, or wish to provide additional or updated information. This information is provided for the purposes of clause 3.6.2A of the NER.

The process for wind and solar generation is:

- Alterations from the estimated *generation* profile prepared by AEMO under section 5.4 are valid only if AEMO receives credible advice from the proponent detailing:
  - Commissioning activities.
  - Planned outages.
  - Considerations relating to capacity factor.
  - Consideration of auxiliary load.
  - Consideration of losses within unregulated transmission/distribution/connection assets located between the generating unit's or *bidirectional unit's* connection point and the wholesale connection point/s.
  - Consideration of additional limitations anticipated to impact output for all or part of the Target Year.

The process for thermal, hydro and storage *generating units* or *bidirectional units* is:

- As the proponent provides the generation/load profile, supporting evidence will be required from the proponent detailing:
  - Commissioning activities.
  - Operational behaviour.
  - Planned outages.
  - Energy limits.
  - Consideration of auxiliary load.
  - Consideration of losses within unregulated *transmission/distribution/connection* assets located between the *generating unit's* or *bidirectional unit's* *connection point* and the wholesale connection point/s.
  - Consideration of additional limitations anticipated to impact output for all or part of the Target Year.

AEMO may seek an independent review of any information provided by a proponent in relation to information provided to support the forecast *generation* data of new *generating units* or *bidirectional units*.

Appendix C. Data required by AEMO

The following table summarises the data necessary for AEMO to implement the forward-looking loss factor methodology. The table includes a description and the source of each item of data.

Data	Description	Source
Existing Load Connection Points		
Connection point load	MW & MVAr by Sample Interval	AEMO or relevant TNSP (AEMO will estimate the data if it is not supplied)
New Load Connection Points		
Estimated commissioning date	Date of commercial operation	Latest ESOO, confirmed with proponent
Connection point load	MW & MVAr by Sample Interval	AEMO or relevant TNSP
Existing generating units and bidirectional units		
Generator terminal capacity for summer and winter	Summer typical and winter MW values	Latest ESOO
Auxiliary requirements for summer and winter	Summer and winter MW values	AEMO estimate with consultation with the Generator
Historical generation profile	MW by Sample Interval	AEMO settlements data
Availability status by *sample interval*	Status by Sample Interval	AEMO market systems
New generating units and bidirectional units		
Estimated commercial use date	Full commercial use date	Latest ESOO, confirmed with the owner
Nameplate rating	MW	Latest ESOO, confirmed with the owner
Longitude, latitude, elevation	˚/'/m	Publicly available information
Global horizontal irradiance (GHI), direct normal irradiance	W/m^2	Weather data provider
Wind Speed	km/h	Weather data provider
Temperature	˚C	Weather data provider
Commissioning Details	Commissioning hold points and timeline	AEMO estimate with further consultation with the Generator
Forecast generation profile	MW by Sample Interval	Proponent in consultation with AEMO
Existing MNSP		
Historical energy transfer profile	MW by Sample Interval	AEMO settlements data
New MNSP		
Estimated commissioning date	Date of commercial operation	Latest ESOO, confirmed with proponent
Interconnector Capability		
Capacity in each direction	Summer/Winter MW Capacities	Latest ESOO, in consultation with the TNSPs
Existing transmission network		
Network data and configuration	Load flow, representative of system normal	EMS and operating procedures
Transmission network augmentations		
List of network augmentations	List of augmentations	Latest ESOO, in consultation with the TNSPs
Estimated commissioning date	Date of commercial operation	Latest ESOO, in consultation with the relevant TNSP
Network element impedances	Network element impedances	Relevant TNSPs

Appendix D. NEB calculation example

Consider a transmission network connection point that includes two generators and two loads.

Interval	Gen 1 (GWh)	Gen 2 (GWh)	Load 1 (GWh)	Load 2 (GWh)	Flow on transmission network connection point (GWh)		
					Net	Generation	Load
Period 1	12	2	0	-10	4	4	
Period 2	13	5	-2	-20	-4		-4
Period 3	11	8	0	-10	9	9	
Period 4	10	8	-1	-30	-13		-13
Period 5	9	6	0	-25	-10		-10
Period 6	21	8	-2	-10	17	17	
Period 7	15	2	-1	-15	1	1	
Period 8	13	0	-2	-25	-14		-14
Period 9	3	8	0	-30	-19		-19
Period 10	23	8	-1	-10	20	20	
Total	130	55	-9	-185	-9	51	-60

Net energy at transmission network connection point = 9 GWh

Net generation at transmission network connection point = 51 GWh

Net load at transmission network connection point = -60 GWh

$$\text{NEB} = \frac{\text{Absolute}(\text{Sum of energy generated and consumed})}{\text{Maximum}(\text{Absolute}(\text{energy generated}), \text{Absolute}(\text{energy consumed}))}$$

$$\text{NEB} = \frac{\text{Absolute}(9)}{\text{Maximum}(\text{Absolute}(51), \text{Absolute}(-60))}$$

$$\text{NEB} = 15\%$$

Appendix E. Method for calculating average transmission loss factors for VTNs

Each *Distribution Network Service Provider* (DNSP) must provide to AEMO by 1 March:

- A description of the DNSP's proposed VTNs, including an unambiguous specification of which *transmission network connection points* constitute the VTN; and
- Written approval from the AER for each proposed VTN as required by clause 3.6.2(b)(3) of the NER.

AEMO calculates the average loss factor for each VTN using the annual energy for the respective *transmission network connection points* as weightings for the *marginal loss factors* for the *transmission network connection points* that constitute the VTN.

The average *transmission loss factor* for a VTN proposed by the DNSP and approved by the AER (VTN_V) is calculated according to:

$$MLF_V = \frac{\sum(MLF_n \times P_n)}{\sum P_n}$$

where

MLF_V is the *marginal loss factor* that applies for the Target Year to VTN V;

MLF_n is the *intra-regional loss factor* that applies for the Target Year to *transmission connection point* n; and

P_n is the annual energy for each *transmission connection point* n that was used to calculate the MLF_n for the Target Year.

The *connection point* data used by AEMO to calculate the P_n values used as weights is the same connection point data used to calculate MLF_n.

AEMO determines and *publishes* the *intra-regional loss factors* for each VTN requested by the DNSP in by 1 April. These VTN loss factors are to apply for the next financial year.

AEMO applies the *intra-regional loss factors* for each VTN from 1 July.

Version release history

Version	Effective date	By	Summary of changes
8.1	TBC	SC	Changes to reflect the National Electricity Amendment (Integrating energy storage systems into the NEM) Rule 2021 and Rule 2023 No. 2, including to incorporate references to bidirectional units (BDUs).
8.0	18 Dec 2020	SC	Clarification and addition of definitions (including for 5 minute settlement), methodology amendments including: • Base case load flow • Inclusion and estimation of committed generation • Scaling for excess and insufficient generation • Parallel AC and DC links • Intra-regional limits • Dual MLFs • Intra-year modification of MLFs
7.0	8 Feb 2017	SP&C	Amended following 2016 Rules Consultation
6.1	21 Nov 2014	SP&C	Add approval signature. Fix minor typographical errors.
6.0	30 Oct 2014	SP&C	Amended following 2014 Rules Consultation
5.0	18 Sept 2014	SP&C	Updates to Methodology to include changes resulting from the Draft Determination of the 2014 Rules Consultation.
4.0	29 June 2011	ESOPP	Updates to methodology for calculating dual marginal loss factors for a transmission network connection point.
3.0	1 April 2010	ESOPP	Methodology for Calculating Forward-Looking Loss Factors: Final Methodology updated to include changes resulting from the more recent Rules Consultation completed on 27 February 2009.
2.0	12 Aug 2003	Planning	Methodology for Calculating Forward-Looking Loss Factors: Final Methodology updated.
1.0	7 May 2003	Planning	Methodology for Calculating Forward-Looking Loss Factors: Final Methodology developed after extensive consultation was conducted during 2002 and 2003.