Jemena Electricity Networks (Vic) Ltd

2016-20 Electricity Distribution Price Review Regulatory Proposal

Attachment 7-12

Nuttall Consulting - Independent analysis of augmentation expenditure

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30 April 2015

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Regulation and business strategy

AER augex model

Calibration report

A report to JEN

Confidential final

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Table of contents

Executive summary

Nuttall consulting has been engaged by Jemena Electricity Networks (JEN) to prepare a forecast of the augmentation needs of its network. This forecast must use the predictive model the Australian Energy Regulator (AER) has indicated it will use as part of the process it will apply to assess expenditure forecasts. This model is called the AER augex model.

We have developed a forecast within this model using:

- asset data that JEN has used to populate template 2.4 of its Reset Regulatory Information Notice (Reset RIN) – the augex model template
- data JEN has provided to the AER in response to the AER's economic benchmarking and category analysis regulatory information notices
- JEN's historical (2009 to 2014) and forecast (2015 to 2020) augmentation expenditure.

The forecast produced by this model represents a "calibration" of the model parameters to reflect JEN's historical augmentations over the 4-year period from 2011 to 2014 (inclusive). This 4-year period reflects the movement in asset utilisation from 2010 to 2014, which are the two years defined in the Reset RIN.

Key model findings

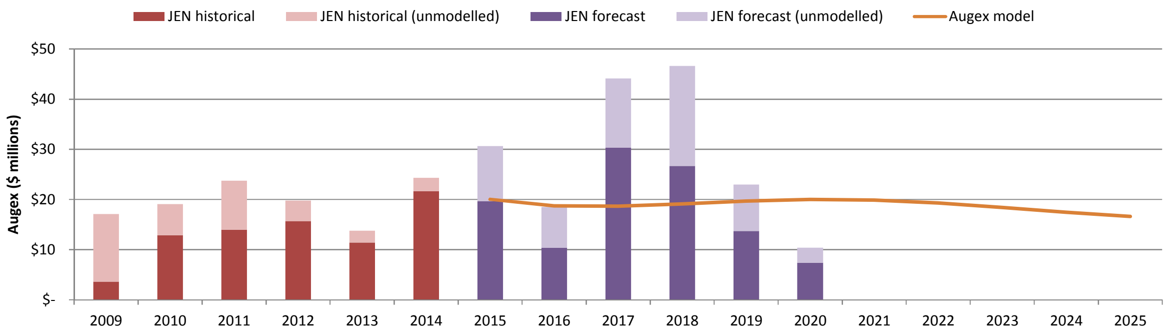

Fig E1 – JEN augex model forecast

The figure above shows the results of this modelling exercise. This figure shows the forecast produced by this augex model, compared to JEN's own augmentation forecast and its historical augmentation expenditure. This figure also indicates the component of JEN's augmentation expenditure, which it considers should not be assessed through the augex model as its primary driver is not due to capacity limits associated with the utilisation of the network assets.

At the average aggregate level, the model produces a similar forecast to JEN's own forecast, with the model's augmentation expenditure forecast 9% above JEN's forecast over the next regulatory period. The model shows more variation to JEN's forecast in each year. However, this may be expected because of the way the model aggregates, which effectively smooths expenditure.

Overall, at this aggregate level, this finding suggests that JEN's forecast reflects a continuation of past planning practices and criteria – if anything the criteria applied for JEN's forecast may be slightly more onerous. Assuming the AER accepts that JEN has been acting prudently and efficiently over the calibration period then these results support JEN's augex forecast (all thing being equal and accepting JEN's growth forecast), indicating that JEN's forecast benchmarks favourably compared to its own recent history.

The model's and JEN's forecast both indicate the need for an increase in augmentation expenditure over the next period compared to the 4-year calibration period. The model suggests that the need for the increase is driven by the positive growth in peak demand that JEN is forecasting for the next period, compared to the low and negative growth that occurred over the calibration period.

Analysis of forecast differences

The model breaks downs the forecast into sub-transmission lines, zone substations, HV feeders and distribution substations[1]. At this more disaggregated level, the model shows a more significant difference to JEN's forecasts over the next regulatory period; most notably:

- The model over-forecasts expenditure in the zone substation (by 52%) and HV feeder segments (by 19%), but under-forecasts expenditure in sub-transmission lines (by 59%) and distribution substation segments (by 52%).
- The direction of the variance in the augmentation capacity forecasts for sub-transmission lines is different to expenditure, with the model significantly over-forecasting capacity in this segment.

To understand what is causing the segment variances, we have re-calibrated the model parameters to reflect JEN's forecast over the 2015 to 2020 period and compared these to the model parameters, which underpin the model forecasts discussed above. Based upon this analysis, we have identified the following matters that cause the most significant unfavourable variances between the augex model's forecast and JEN's.

sub-transmission lines	For JEN's forecast, the capacity added when a need is identified (observed via the capacity factor in the model) has increased moderately and the cost of that capacity has increased significantly (nearly four-fold). This suggests that larger and more costly solutions to an identified augmentation need are included in JEN's forecast compared to its historical augmentations over the calibration period. On this matter, it is noted that only a small amount of expenditure was incurred over the calibration period ($2 million) for a relatively large amount of capacity added (89 MVA). We understand that this largely reflected some minor augmentations. Clearly, if these types of minor augmentation are not feasible over the forecast period then this could be a plausible explanation for the movement in these parameters.

[1] For HV feeders and distribution substations we have grouped JEN's urban and short rural segments together as the short rural elements of JEN's network represent a very small proportion.

zone substations	The model's utilisation threshold for JEN's forecast has reduced significantly, suggesting JEN is forecasting the need for an augmentation earlier than applied over the calibration period. However, some caution is needed in drawing conclusions from these results because JEN is expecting to add approximately 50% of its forecast capacity over the 2015 to 2020 period in 2015; however, there is not an equivalent pattern in expenditure. This is effecting the comparisons above, as it has such a significant effect on the forecast calibration.
HV feeders	The forecast parameters compare quite favourably to history. Although the capacity factor has increased, suggesting JEN is forecasting that more capacity will be added to address its forecast needs, this capacity will be at a lower cost. The net effect is a lower cost solution in JEN's forecast compared to its recent history. However, as with zone substations above, some caution is needed in these results because JEN is expecting to add approximately 40% of its forecast capacity over the 2015 to 2020 period in 2015 without the equivalent pattern in expenditure. This is effecting the comparisons above, as it has such a significant effect on the forecast calibration.
Distribution substations	The model's utilisation threshold for JEN's forecast has reduced significantly, suggesting JEN is forecasting the need for an augmentation earlier than applied over the calibration period. That said, this threshold is still quite high (i.e. the model suggests JEN is, on average, planning to augment a substation when it is 130% above its cyclic rating). Therefore, given JEN is still forecasting a decline in expenditure for this segment, this matter may be of less concern.

With regard to these matters, it is worth noting the following:

- Some movements in the parameters may be explained (at least partly) by JEN's probabilistic planning approach where more costly solutions result in higher utilisation threshold being required to justify the solution (and vice versa).
- The parameters for the sub-transmission lines and zone substations will be more affected by the small volumes of larger projects, which may have more widely varying costs. Therefore, we may expect wider variations in parameters from one period to another in these segments.
- JEN will need to consider the large amounts of capacity being added in 2015 in a number of segments. It may need to consider whether this is due to needs in the historical calibration period and in which year "as commissioned" costs would lie to determine how this capacity may be affecting the model parameters of either the historical or forecast period.

Summary

In summary, we have used the augex model to prepare an alternative forecast of JEN augmentation needs. This forecast has been "calibrated" to reflect the planning parameters used and costs incurred by JEN over 2011 to 2014.

This model produces a forecast 9% higher than (the modelled component of) JEN's augmentation forecast. This result suggests that JEN's augmentation forecast benchmarks favourably compared to its own recent history.

We have also used the model to identify the main causes of the differences between JEN's forecast and the augex model's, which in turn suggests the technical matters that may differ between JEN's historical augmentations (over the calibration period) and JEN's forecast augmentations.

1 Introduction

1.1 Background and scope

Jemena Electricity Networks (JEN) has engaged us, Nuttall Consulting, to assist in its preparations for its next regulatory determination by the Australian Energy Regulator (AER). This determination will cover the regulatory period from 2016 to 2020.

As part of this engagement, we were requested to:

- develop a model of JEN's augmentation capex (augex) using the AER's augex model
- prepare a forecast using this model using the approach that the AER has described in its documentation on this model
- undertake additional studies using this model to test the sensitivity of the model's forecast to key assumptions
- reconcile this model's augex forecast to JEN's own forecast to identify the areas of significant difference
- prepare an independent report that can be used as a supporting document to JEN's building block proposal to the AER, which explains the model development and analysis.

This document serves as the report indicated above.

The following definitions are used in this report:

- **Augmentation capex** (or **augex**) has the meaning given to it by the AER in its recent advice on how it will conduct expenditure forecast assessments, which broadly covers the demand-driven reinforcement, extension or enhancement of the network, excluding similar activities due specifically to the connection of customers.
- We use the term **AER augex model** to mean the generic excel workbook that the AER has advised it will use as an assessment technique in its determinations – and the AER calls the augex model.
- We use the term **JEN augex model** to mean the model we have prepared of JEN's network using the AER augex model. The JEN augex model is used here to produce augex forecasts of the JEN network.
- We use the term **asset** here in a very general sense to reflect the physical unit of network that is accounted for in the AER augex model. This typically reflects an individual line or an individual substation[2].

[2] Note the difference here to an asset in the repex model – or JEN's systems – which is likely to account for a sub component of the augex model's asset.

In addition, all expenditure and costs shown in this report represent **direct real 2015 dollars**.

1.2 Nuttall Consulting experience in this task

Nuttall Consulting, using Dr Brian Nuttall (the author of this report), developed the excel workbook that serves as the basis of the AER's augex model and advised the AER on its possible roles and application in regulatory determinations.

Moreover, we were engaged by the AER to provide advice that informed the AER's current determinations of the Victorian and Tasmanian Distribution Network Service Providers (DNSPs). As part of these engagements, Dr Nuttall developed models and forecasts using the AER's repex model. Although the augex model is aimed at a different expenditure activity (network augmentation, rather than asset replacement) it is broadly based upon similar principles.

1.3 Methodology overview

The methodology we have used to undertake this assignment can be considered in terms of two phases, as follows.

1 Phase 1 – In the initial phase we have developed the JEN data (e.g. asset loading and ratings) that is required to develop an augex model. We have sourced JEN data from JEN's planning group to prepare this data. This has involved the development of a series of excel workbooks (model input workbooks) that hold the JEN source data and house the various business rules and calculations we have used to prepare the model input workbooks.

2 Phase 2 - In the second phase, we have constructed augex models using the set of model input workbooks. These augex models have been used to prepare a forecast, which is then reconciled to JEN's forecast.

During these two phases, we have held a number of meetings with JEN's network planning group to discuss data needs, present and review the workbooks and models prepared through these phases, and facilitate the reconciliation phase.

These various meetings have been aimed at ensuring the appropriate data is provided by JEN. However, we have not undertaken any formal review or audit of the raw data sourced from JEN. Therefore, this report should not be taken as an assurance of the accuracy or validity this underlying data. For example, although we have advised on the type of asset rating required for the model, we have not reviewed the rating data provided by JEN, or its underlying parameters, to confirm its validity.

1.4 Key information sources

We have used the following information to develop the JEN augex model:

- the AER augex model and AER augex model handbook, published on the AER website
- JEN's planning data, which has been provided in various forms and is discussed in more detail later in this report – we understand that this data will underpin the data provided in the augex model template of JEN's Reset Regulatory Information Notice (Reset RIN)
- Data series of JEN's historical "network-initiated" augmentation capex (2009 to 2014) and JEN's augmentation capex forecast (2015 to 2020)[3]. This forecast was broken down into the categories defined in the augex template of JEN's Reset RIN (table 2.4.6), including the component that we were requested to not model. In line with the explanations provided in the AER's augex model handbook, we understand that this "unmodelled" component reflects projects and programs allocated to the AER's augmentation expenditure category, but which JEN considered are not primarily capacity and utilisation driven – and so, are not suitable for assessment through the AER's augex model.

1.5 Structure

This report is structured as follows:

- In section 2 we provide an overview of the AER augex model, summarising how it develops a forecast, its inputs and outputs, and how the AER may use it to assess a DNSP's augmentation forecasts.
- In section 3 we discuss the data and assumptions used to prepare the various model input workbooks.
- We discuss the methodology we have used to develop the JEN augex models from these model input workbooks in section 4.
- Section 5 summarises the results from this modelling exercise, and compares this with JEN's forecast.
- In Section 6 we analyse the differences between the model's forecast and JEN's.
- In Appendix A we provide the results of sensitivity studies.

[3] Provided in the email, dated 20/3/2015

2 The AER's augex model

Before explaining the development of JEN's augex model, we first provide an overview of the AER's augex model and its application. This should help provide some context to the results and discussions in the sections that follow.

2.1 Overview of augex model

The AER augex model is an excel workbook, with a structure, formulas and VBA functions and macros set up by the AER in order that it can be used by the AER to develop a network model of a DNSP and use this to prepare augex forecasts.

The DNSP's network is constructed within the AER augex model as a series of asset populations. The model uses a probabilistic augmentation algorithm to make predictions of augmentation needs for this population. The probabilistic augmentation algorithm assumes that the maximum utilisation that an asset will reach before it must be augmented (called its utilisation threshold in the model) is normally distributed across any asset population represented within the model.

From this, the model predicts future augmentation volumes based upon a current utilisation profile for an asset population represented in the model.

The AER has indicated that it will use this model to make top-down assessments of a DNSP's augex forecast. In this regard, it has indicated that it may use the model in two ways to develop a benchmark forecast:

1. **Intra-company** – it will develop a benchmark forecast within the model that reflects the historical augmentation decisions of the DNSP (this reflects an assumption that these decisions were prudent and efficient)
2. **Inter-company** – it will develop a benchmark forecast within the model that reflects its view of the appropriate augmentation decisions it has determined from the set of DNSPs (this reflects an assumption that the DNSP's decisions were not prudent and efficient, and so it has substituted its view on this matter from the augex models of other DNSPs).

Importantly, for the augex modelling discussed here, we have only considered the intra-company benchmark role.

The inter-company benchmark would require far more extensive modelling and analysis across all DNSPs, which is not part of our scope. Moreover, as far as we are aware, the AER has not indicated the precise approach it would apply to develop such a benchmark forecast.

2.2 AER augex model form, inputs and output

2.2.1 Network specification inputs – network segments and groups

As indicated above, a DNSP's network is defined as a series of distinct asset categories within the augex model. These are called network segments in the AER's documentation and represent the set of network assets that may have similar planning arrangements i.e. lines or substations.

To facilitate analysis and reporting, each network segment defined in the model is assigned to a smaller set of groups. In this regard, a model may use a large number of network segments, to improve the accuracy of the analysis, but a much smaller number of groups to provide aggregate forecasts for reporting (and benchmarking) purposes.

2.2.2 Network specification inputs - Utilisation profile

A utilisation profile must be provided for each network segment used in the model. This profile represents a snap shot of the utilisation of the population of assets in that segment for the initial year of the model. That is, the utilisation profile is essentially a vector that holds the volume of assets (measured in capacity units e.g. MVA) at one-percentage increments of utilisation.

The timing of an augmentation is typically sensitive to the maximum demand on an asset. That is, it is the amount of the maximum demand that is above various capacity limits of an asset that defines the risks and/or service constraints associated with using the asset. Therefore, within the augex model, the utilisation of any asset (e.g. the utilisation of a line or substation) is defined as:

- *the maximum demand on that asset / the assets capacity limit or rating*.

The model itself does not define exactly how the maximum demand or capacity must be specified. However, the AER has indicated its preference for these in an effort to place all DNSPs on a consistent basis[4], where:

- the maximum demand should be weather corrected to represent a 50% probability of exceedance condition (and reflect normal network arrangements)
- the capacity of an asset should reflect the thermal rating, assuming a normal load cycle if applicable (i.e. an asset's normal cyclic rating).

It is important to note that once the units of capacity in a segment are defined, all measures of utilisation, capacity being augmented, or capacity needing to be augmented are reported in the model on that basis.

2.2.3 Network specification inputs – utilisation growth

To predict a network's augmentation needs, the model needs to first predict what the utilisation of the network will be in the future. To do this, the model requires the growth

[4] See discussion in Section 5 of AER augex model manual.

in utilisation (assuming no augmentation) to be input for each network segments. This is essentially the growth in maximum demand for each network segment.

The model represents this growth as a single annual compounded growth rate (percentage growth in one year) that should represent the average annual growth rate over the period being considered (note here that the model does not hold individual growth rates for each year of the forecast period).

2.2.4 Planning parameters inputs

The model uses four planning parameters to define the approach it uses to predict future augmentation needs:

- The utilisation threshold, which is represented as a normal probability distribution, is defined by two parameters:
  - the mean utilisation threshold
  - the standard deviation of the utilisation threshold.

  The utilisation threshold specifies when existing capacity requires augmentation, and is used to measure this amount from the utilisation profile. In this way, this parameter defines how the *need* for augmentation is measured.

- The capacity factor reflect the amount of additional capacity that is added to the network, given the amount of existing capacity that requires augmentation. It is defined as a proportion of the capacity requiring augmentation.

  For example, if the capacity factor is set at 50%, this means that if the model calculated that 100 MVA of the existing capacity will require augmentation in the future then it will assume that 50 MVA of capacity is added to the network to address that need.

  This parameter relates to the *scale*, in capacity terms, of the augmentation solution that is used to address a *need*.

- The third parameters reflects the average augmentation unit cost, where a unit is specified in the units of capacity (i.e. $ / kVA of capacity).

  That is, the capacity added to the network, calculated via the utilisation threshold and capacity factor, multiplied by the augmentation unit cost produces the expenditure forecast.

2.2.5 Model outputs

The model produces various outputs. These outputs provide various measures of the input utilisation profile, such as average utilisation, average threshold, total quantity of capacity, and total augmentation cost (i.e. quantity x augmentation unit cost).

The model also produces forecasts (by year over a 20-year period), including augmentation capacity volumes, augmentation expenditure, and average utilisation.

These various outputs are provided at the network segment, segment group and total network level. When averages are calculated at the network group or network level, the model uses a weighted average using the augmentation cost of each asset category as the weighting.

2.3 Calibration

The calibration of a DNSP's model is the critical process that is applied by the AER to produce the intra-company benchmark model.

The calibration process concerns deriving the set of planning parameters that reflects the actual augmentation outcomes (volumes and expenditure) over the calibration period (e.g. the last 5 years)[5].

The following process can be used to calibrate the augex model[6].

This process relies on calculating three parameters for each network segment (or segment group) from the available data, namely:

- the augex in that segment (or segment group) over that period
- the capacity added (through augmentation) in that segment (or segment group) over that period
- the capacity that required augmentation in that segment (or segment group) over that period.

2.3.1 Augmentation unit cost

The augmentation unit cost parameters for each segment is simply the augex divided by the capacity added to the segment.

2.3.2 Volume planning parameters

The utilisation threshold parameters (mean and standard deviation) and capacity factor for each segment need to be set to ensure the model reflects the capacity added (through augmentation) over the calibration period.

However, the calculation of these planning parameters is more complicated because:

- we have three parameters to determine and typically only one variable (the total capacity added)
- we are looking at history and not predicting into the future.

Therefore, the calibration of the utilisation threshold parameters is slightly more involved and involves the following:

[5] The model can also be calibrated to other periods, such as a forecast period, provide appropriate expenditure and capacity data is available.

[6] The AER augex model manual does not discuss the calibration process in any detail. However, we understand the AER will apply a similar process to the one it has indicated it will use to calibrate its repex model. The process we have defined here should reflect this similar process.

- First, in the absence of better information, the need to determine the standard deviation is removed by making it dependent on the mean. We have assumed that the standard deviation is the square root of the mean to reflect a similar assumption the AER has advised it will use for the repex model calibration process.
- Second, the capacity factor is set at a specific value. There are various ways this could be calculated. Here, we have estimated it from the JEN data provided.
- Third, an augex model is developed to reflect the beginning of the calibration period, with the growth set to represent the growth that occurred over the calibration period. The mean utilisation is determined within this model to ensure that the forecast produced by the model over the calibration period equals actual capacity added due to augmentations during the calibration period.

The above defines the process that will typically be applied. However, this process will not produce a utilisation threshold parameters in circumstances where, on average, there has been negative growth in a segment.

This is the case for JEN over the historical period studied here. There are various methods to allow for this situation. In section 4.3, we will explain how we have adjusted this calibration process to derive JEN’s utilisation thresholds.

2.4 Alterations to the published AER model

We have not changed the underlying structure, format, and predictive algorithm of the AER augex model. However, we have added a number of sheets to aid in the modelling and reporting exercise.

These additional sheets are used to:

- perform the calibration process and scenario analysis.
- aid in the reporting of results and to produce comparisons with the JEN’s forecast.
- hold the JEN forecast and JEN’s historical augex.

3 Development of model input workbooks

3.1 Introduction

This section summarises the development of the data that is necessary to construct and calibrate the JEN augex model. This data has been prepared in a set of excel workbooks, based upon source data provided by JEN's network planning group. This set of workbooks are called the model input workbooks here.

The individual workbooks are structured around the data necessary to prepare the data for the four network groups in the JEN augex model:

- sub-transmission lines
- zone substations
- HV feeders
- distribution substations.

Each of these workbooks hold the key input data for each asset (i.e. line, substation or feeder), covering the data necessary to prepare a utilisation profile, including:

- the assets maximum demand, under normal conditions and weather corrected to a 50% probability of exceedance equivalent
- the assets normal cyclic rating
- exclusion criteria, which reflects whether the asset should be included in the model (e.g. to reflect circumstances where the asset is in JEN's source data set but not owned by JEN or was not commissioned in the relevant year).

This section discusses how we have prepared this model input data. It is worth noting the model input workbooks also contains the formulas necessary to prepare actual model data discussed in next section. The mechanics of this are not discussed here and the actual workbooks should be referred to for this purpose.

3.2 General set up

3.2.1 Specification of model base year and calibration period

The base year and calibration period have been set to reflect the historical data that JEN must submit in its RINs. This should reflect the years and periods that the AER will use for its modelling exercise.

The base year of the model is the year that reflects the utilisation profiles held within the model. That is, the first year forecast by the model is the year after the base year.

The base year has been set to 2014 to reflect the latest loading and rating data that will be defined in JEN's Reset RIN. It is understood that this year and forecast also reflects the basis JEN has used to prepare its augex plans that will form its augex forecast in its building block proposal.

The calibration period reflects the 4-year period prior to the base year, but inclusive of it. As such, the calibration period covers 2011 to 2014. That is, the model is calibrated to reflect the augmentations (i.e. the network-initiated capacity added and augex) that occurred in 2011, 2012, 2013 and 2014.

Importantly, this 4-year period has been used because the Reset RIN collects historical utilisation data for 2010 and 2014. This only covers a 4-year period of growth in utilisation (i.e. growth from summer 2009/10 to summer 2013/14). That is, to cover a 5-year calibration period, which included 2010, we would need to run the model from 2009 to make it predict what would need to be augmented in 2010, but the Reset RIN does not collect the utilisation data for that year[7].

3.2.2 2010 and 2014 weather correction factors

Although, JEN prepares 50% PoE forecasts down to its individual zone substations and HV feeders, it has not historically weather correct its actual maximum demand that are required to prepare JEN's augex model. Consequently, the JEN source data provides the actual peak demand on an asset in 2010 and 2014.

To reduce the burden of developing weather corrected maximum demands (down to individual distribution substations), we have used a fixed correction factor, applicable to all assets in a year, to weather correct maximum demands in the relevant years (i.e. 2010 and 2014).

These two weather correction factors were calculated from the JEN coincident network-level actual peak demand and 50% PoE weather corrected demand that have been reported in JEN's 2013 and 2014 category analysis RINs (table 5.3.1)[8].

This simplification was considered reasonable given:

- the asset aggregation approach used by the augex model
- the expected accuracy of the augex model
- the role the AER may use the model for in assessing an augex forecast.

The table below summarises the underlying data and weather corrections factors we have used.

[7] It is also worth noting that table 2.4.6 of the Reset RIN requires augex to be reported as the aggregate over 2010 to 2013. Therefore, JEN has provided the annual augex over this period in order that we can calculated augex covering 2011 to 2013 and add this to its reported 2014 figure.

[8] This data and calculation are contained in "Network Weather correction data - 2014" workbook

Table 1 2010 and 2014 weather correction factors

	2010	2014
Raw coincident MD (MW)	958	988
50% PoE weather corrected coincident MD (MW)	953	937
50% PoE weather correction factor	**0.995**	**0.947**

3.2.3 Adjustments to remove the effect of future developments

The augex model requires growths rates for each segment over the forecast period, 2015 to 2020. For sub-transmission lines, zone substations, and HV feeders, these growth rates are determined from the forecast loading of the assets in those segments. However, JEN's data files for these segments typically allow for its planned developments, and therefore, this can affect forecast growth rate calculations for any asset.

For this reason, JEN provided data that removed the effects of its planned developments on future loading. This removed the planned assets, and the associated loading affect, of its planned TMA, EPN and BMS zone substation developments from the JEN loading and rating files discussed below.

3.3 Sub-transmission line workbook

This section covers the data and calculations contained in the sub-transmission lines model input workbook, "NC STlines calcs v3".

3.3.1 JEN maximum demand and rating data sets

JEN does not record the maximum demand of individual sub-transmission lines. Therefore, to estimate the maximum demand on each line it has performed load flow analysis of each of its sub-transmission loops, using the non-coincident maximum demands of the zone substations in each sub-transmission loop.

This analysis has been performed for its network arrangements in both 2010 and 2014, using the actual zone substation maximum demands; and from 2015 to 2023, using the zone substation 50% PoE forecast maximum demands.

JEN has provided the results of this analysis in a single workbook[9]. This workbooks provide data on each sub-transmission line, covering:

- line identification, including originating and terminating substation (or tee)
- nominal voltage
- summer normal rating from 2003 to 2020 (MVA)

[9] "Subt augex -2010, 2014 v8 with CA calcs BMS,TMS.xlxs", provided in an email, dated 4/3/2015

- the line maximum demand (as calculated from the load flow analysis) for 2010 and 2014 to 2023 (MVA)
- various comments on the status of the lines, its ownership, and adjustments to the study files
- JEN's calculations of the capacity requiring "network-initiated" augmentation and "network-initiated" capacity added to the network over the calibration period and forecast period.

It is important to note that JEN ran the load flows studies referenced here using the loop arrangements relevant to 2014, but the zone substations loadings for 2010[10].

3.3.2 Adjustments to the RIN amended data set

We have made the following adjustments to this amended data set to prepare the model data:

Exclusions

The lines associated with the future development of the TMA and BMS substations have been excluded from the 2010 and 2014 data sets.

Maximum demand calculations

The line maximum demands (MVA) in JEN's data set have been weather corrected using the weather correction factor discussed in Section 3.2.2.

Line rating data

The line rating (MVA) has been taken directly from the JEN data set.

Primary area type

JEN has advised that all its sub-transmission lines should be classified as primarily supplying urban customer types.

3.4 Zone substation workbooks

This section covers the data and calculations contained in the zone substation model input workbooks:

- "NC ZSS 2014 calcs v2"
- "NC ZSS 2010 calcs v2".

[10] This is because the change in demand, used by the model, is measured as the sum of the demands in individual lines. Changes in the loop arrangements can change this measure, without there being any actual change in demand on the loop (e.g. adding a tee point into the loop).

3.4.1 JEN maximum demand and rating data sets

JEN has provided two data files, in the form of excel workbooks, that it uses to plan its zone substations[11]. These workbooks reflect the data it used for its planning analysis in 2010 and 2014.

These workbooks provide data on each zone substation, covering:

- the substation name
- the actual summer and winter measured maximum demand from 2010 to 2014 (MVA, MW and MVAr)
- the summer and winter 50% PoE forecast maximum demand from 2015 to 2024 (MVA, MW, MVAr)
- the 2010 and 2014 summer normal and N-1 cyclic rating (MVA)
- various comments on the status of the substation and its ownership
- JEN's calculations of the capacity requiring "network-initiated" augmentation and "network-initiated" capacity added to the network over the calibration period and forecast period.

3.4.2 Adjustments to the RIN amended data set

We have made the following adjustments to this amended data set to prepare the model data:

Exclusions

The following exclusions have been applied to substation data:

- The substation identified in the JEN files as not owned by JEN have been excluded. This covers the following substations: ACI, APF, BK, KLO, MAT, MB, SA, TT, VCO and WT.
- The substations identified in the JEN files as not commissioned in 2010 or 2014 have been excluded from the 2010 and 2014 calculations, respectively.

Maximum demand calculations

The 2010 and 2014 substation summer actual maximum demands (MVA) in JEN's data set have been weather corrected using the weather correction factor discussed in Section 3.2.2.

Substation rating data

The summer normal cyclic rating (MVA) for each substation has been used to determine its utilisation. This rating has been taken directly from the JEN data set[12].

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[11] "2014 JEN Load Demand Forecasts – For Augex (with 2020 ratings) BMS,TMS" and "6 Zone Substation Actuals and Forecasts_JUNE 2010 with CA calcs", provided in an email, dated 4/3/2015

[12] The normal cyclic rating for each substation in 2010 and 2014 is provided on sheet "ZSS Ratings" of the JEN data file for 2014.

Primary area type

JEN has advised that all its substations should be classified as primarily supplying urban customer types.

High and low growth segments

Each substation has been assigned to a high or low growth category, based upon whether or not the zone substation is forecast to have negative or positive growth over the 2015 to 2020 period.

3.5 HV feeder workbooks

This section covers the data and calculations contained in the HV feeder model input workbooks:

- "NC HV feeder 2014 calcs v2"
- "NC HV feeder 2010 calcs v2".

3.5.1 JEN maximum demand and rating data sets

JEN has provided two data files, in the form of excel workbooks, that it uses to plan its HV feeders[13]. These workbooks reflect the data it used for its planning analysis in 2009 and 2014.

These workbooks provide data on each HV feeder, covering:

- the feeder name, including supplying zone substation and feeder number
- the summer and winter actual measured maximum demand from 2010 to 2014 (amps and MVA)
- the summer and winter 50% PoE forecast maximum demand from 2015 to 2024 (MVA, MW, MVAr)
- the 2010 and 2014 normal cyclic rating (MVA)
- JEN's calculations of the capacity requiring "network-initiated" augmentation and "network-initiated" capacity added to the network over the calibration period and forecast period.

3.5.2 Adjustments to the RIN amended data set

We have made the following adjustments to this amended data set to prepare the model data:

Exclusions

The following exclusions have been applied to the feeder data:

[13] "2014 JEN Load Demand Forecasts – For Augex (with 2020 ratings) BMS,TMS" and "7 Feeders Actuals and Forecasts_JUNE 2010 –CA added calcs v2", provided in an email, dated 4/3/2015

- JEN has advised us of the HV feeders in the data set that it does not own. This covers ACI, SA 002, SA 005, SA 006, and SA 008. These feeders have been excluded.
- Feeders with a zero maximum demand in the data sets, in the relevant years (i.e. 2010 or 2014), have been assumed to not be in service that year, and therefore, these feeder have been excluded for that year.

Maximum demand calculations

The 2010 and 2014 feeder actual summer maximum demands (MVA) in JEN's data set have been weather corrected using the weather correction factor discussed in Section 3.2.2.

Line rating data

The normal cyclic rating (MVA) for each HV feeder has been used to determine its utilisation. This rating has been taken directly from the JEN data set.

3.6 Distribution substation workbook

This section covers the data and calculations contained in the distribution substation model input workbooks:

- "NC DS Model - Clean For Augex Model v2".

3.6.1 JEN maximum demand and rating data set

JEN has provided a data file, in the form of an excel workbook, that provides the loading and rating data of its fleet of distribution substations in 2010 and 2014.

These workbooks provide data on each distribution substation in each year, covering:

- the substation name, type and supplying feeder
- the estimated maximum demand in 2010 to 2014 (MVA)[14]
- the 2010 and 2014 normal cyclic rating (MVA)
- JEN's calculations of the capacity requiring "network-initiated" augmentation and "network-initiated" capacity added to the network over the calibration period and forecast period.

3.6.2 Adjustments to the RIN amended data set

We have made the following adjustments to this amended data set to prepare the model data:

[14] We understand that this data has been derived from a combination of JEN's current system, which makes use of available smart meter data, and its old system (called SUPS), which estimated the maximum demand based upon customer types supplied by the distribution substations and their assumed energy use profiles.

Maximum demand calculations

These 2010 and 2014 feeder maximum demands (MVA) in JEN’s data set have been weather corrected using the weather correction factor discussed in Section 3.2.2.

4 Augex model development

4.1 Overview

As discussed in Section 2.3, the process to calibrate a model and prepare a forecast requires the preparation of two augex models:

- The 2010 calibration model – This model is developed from the 2010 loading and rating data. The planning parameters are calculated within this model to ensure the forecast produced by the model to 2014 (i.e. capacity added and augex) matches what actually occurred.
- The 2014 forecast model – This model is developed from the 2014 loading and rating data. This model is used to prepare the forecasts over the next period, using the planning parameters developed in the 2010 calibration model.

The development of these two models, including the calibration process, is discussed in this section.

4.2 Augex model development

4.2.1 Segmentation

The model produces forecasts for a set of network segments that represent the DNSP's network. As such, each segment defined in the model requires its own set of inputs (i.e. utilisation profile and planning parameters) and the model produces forecasts for each segment.

Segments have been developed that reflect the network type and the growth category (forecast only) defined in the model input workbooks (discussed in Section 3).

The rational for this classifications is as follows:

- Network type – Segments have been developed to reflect sub-transmission lines, zone substations, HV feeders and distribution substations. This breakdown is reasonable given:
  - it is in line with the categorisation defined by the AER
  - it reflects a similar categorisation used in JEN to study and plan its own network
  - it would be expected that the asset utilisation and demand drivers associated with these network types could differ (i.e. the utilisation of a zone substation may not be a good indicator of the utilisation of the feeders supplied by this substation)

- it would be expected that there would be significantly different costs per unit of capacity, given the significantly different asset types that constitute these network types
- it would be expected that there would be significantly different utilisation thresholds, given the significantly different affect the loading in these network types, relative to the rating, would have on security and reliability of supply.

- High and low growth classification – For the zone substation only, and only for the forecasting model, segments have been defined to separate the zone substations with positive and negative growth rates.

  This breakdown was requested by JEN because the regions with forecast high growth rates have higher utilisations, on average, than those in lower growth regions. This classification was not applied for the calibration model as there was not such a clear relationship with the average utilisation. As such, within the 2010 calibration model all zone substations are classified in one segment.

JEN requested that we did not classify HV feeders and distribution substations in urban and short rural as it did not believe there was a sufficient population of short rural assets to make the calibration of the model parameters for the short rural segments accurate and meaningful.

Due to the small population of short rural assets, we believe it is unlikely that this simplification will affect the results presented here in a material way – or affect the inferences we have drawn from them. Therefore, we accepted JEN's request and have not applied such a classification for calibration purposes. However, should the AER perform any intercompany benchmarking using the augex model, this simplification may need to be reconsidered.

Based upon the above, the table below summarises the groups and segments we have developed for the JEN augex models.

Table 2 JEN augex model network segments

Network Group	Network segment	Model segment name
Sub-transmission lines	All sub-transmission lines	Urban
Zone substations[a]	High Growth Urban	HGUrban
	Low Growth Urban	LGUrban
HV feeders	All HV feeders	Total HV feeders
Distribution substations	All distribution substations	Total DSS

a – these two segments have been combined into one aggregate Urban segment for the calibration model

4.2.2 Utilisation profiles

Utilisation definition

In the model, the utilisation of an asset (e.g. an HV feeder or zone substation) is defined as:

Utilisation (%) = weather corrected peak demand (MVA) / asset rating (MVA).

For each segment, two utilisation profiles have been prepared reflecting the loading in 2010 and 2014. These profiles use the following asset ratings defined in the model input workbooks.

Table 3 augex model asset rating definitions

Network type	asset rating
Sub-transmission lines	normal cyclic thermal rating
Zone substations	substation normal cyclic thermal rating
HV feeders	normal thermal rating (cyclic where relevant)
Distribution substations	normal cyclic thermal rating

It is important to note that any capacities referred to in this report as inputs or outputs of the JEN augex model are measured on the above basis. This also includes any references to utilisation and the augmentation unit costs.

Scaling of distribution substation ratings in the augex models

JEN has a significant portion of distribution substations with a very high utilisation, which is near or above the model's maximum utilisation input limit (150%). Therefore, to ensure that this limit does not affect our modelling, we have scaled the distribution rating by a factor of two and performed all calibration and modelling using this scaling.

To avoid confusion, in the tabulated results presented in this report, we use unscaled values in order that they can be readily interpreted by JEN. However, we also present the scaled values in brackets in order that they can be reconciled to the model files.

Summary model inputs

The utilisation profiles need to be viewed through the augex model. However, to aid in the validation of the model, the following table summarises some important parameters associated with this set of profiles.

Table 4 Summary loading, rating and utilisation data in the augex models

Segment	Weather correct peak demand (MVA)		Asset capacity (MVA)		Average utilisation (%)		Asset capacity >100% utilisation (MVA)	
	2010	2014	2010	2014	2010	2014	2010	2014
All sub-transmission lines	**1399**	**1353**	**3664**	**3759**	**38.2**	**36.0**	**0**	**0**
High Growth Urban	N/A	484	N/A	680	N/A	71.2	N/A	32
Low Growth Urban	N/A	518	N/A	938	N/A	55.3	N/A	0
All zone substations	**1026**	**1002**	**1520**	**1617**	**67.5**	**62.0**	**33**	**32**
All HV feeders	**1275**	**1219**	**2184**	**2289**	**58.4**	**53.2**	**80**	**17**
All distribution substations[a]	**1127**	**1085**	**2104 (4207)**	**2495 (4991)**	**54 (27)**	**43 (23)**	**11 (23)**	**7 (14)**

a – brackets indicate distribution substation parameters, allowing for the rating scaling that is applied in the model

4.2.3 Load growth

For each segment, the growth in peak demand is an important input that drives the forecast. The growth rates used in the two models are calculated as the average annual compound growth rate as follows:

- For the 2010 calibration model, the growth rates reflect the weather corrected peak demand from 2010 to 2014, as this period reflects the 4 years of growth that the planning parameters are calibrated to represent.
- For the 2014 forecast model, the growth rates reflect the weather corrected peak demand from 2014 to the end of the next regulatory period, 2020.

For both models, the growth rate used for each segment is calculated by summing the maximum demand of all assets in that segment in the two relevant years and then calculating the growth rate from these two aggregate measures[15].

Distribution substation growth rate adjustment

A significant portion of the growth seen in the peak demand for distribution substations is due directly to customer connection activities, and so, does not drive network augmentations.

It was agreed with JEN to assume that 50% of the growth in peak demand will relate to these connection activities. Therefore, for modelling purposes, this 50% scaling factor has been applied to the distribution substation growth rates in the model.

Furthermore, the growth rate for the forecast period could not be calculated by the method discussed above because a forecast of the 2020 loading of individual substations loadings is not available. Therefore, JEN provided in the data files discussed in Section 3.6 an adjusted forecast growth rate that it had determined, which it considered was applicable to all substations for modelling purposes. JEN has derived this growth rate from its forecast 50% POE network-level growth rate, scaled by the 50% scaling factor noted above.

The table below summarises the segment growth rates used in the JEN augex model, calculated using the method described above.

[15] For the avoidance of doubt, it is not calculated as the simple average (i.e. mean) growth rate across all assets in the segment.

Table 5 Augex model growth rates

Segment	Average annual growth rate	
	2010 to 2014	2014 to 2020
All sub-transmission lines	**-0.83%**	**1.69%**
High Growth Urban	N/A	2.52%
Low Growth Urban	N/A	-0.78%
All zone substations	**-0.58%**	**0.88%**
All HV feeders	**-1.11%**	**2.62%**
All distribution substations	**0.12%**	**0.68%**

4.3 Model calibration

4.3.1 Set up of calibration data

As discussed in Section 2.3, the initial phase in calibrating the augex model, involves determining a number of parameters (for each segment) that reflect the augmentations that have occurred over the calibration period (2011 to 2014).

The parameters and the method used to calculate these are as follows:

augex	This is determined at the segment group level from the 2011 to 2014 augex data provided by JEN.
capacity added	The capacity added can be estimated from the difference between the capacity in 2014 and the capacity in 2010 for that segment. However, JEN considered that, for most segments, this calculation would be effected by customer-initiated projects and replacement projects, which also resulted in capacity being added over that period. Therefore, JEN provided the "network-initiated" capacity added over this period in the data files discussed in Section 3.
capacity requiring augmentation	The capacity requiring augmentation can be estimated for each segment by summing the capacity for each asset in a segment where the capacity changed from 2010 to 2014. For the reason discussed above on the capacity added parameter, JEN provided the "network-initiated" capacity requiring augmentation over this period in the data files discussed in Section 3, based upon its known set of augmentations.

The table below summarises the calibration data for each segment in the JEN augex model, calculated using the method described above.

Table 6 Augex model calibration parameters

Segment	augex $ (millions)	capacity added (MVA)	capacity requiring augmentation (MVA)
All sub-transmission lines	**2.00**	**89**	**328**
High Growth Urban	N/A	N/A	N/A
Low Growth Urban	N/A	N/A	N/A
All zone substations	**32.51**	**98**	**99**
All HV feeders	**10.43**	**80**	**107**
All distribution substations[a]	**19.19**	**57 (114)**	**58 (115)**

a – brackets indicate distribution substation parameters, allowing for the rating scaling that is applied in the model

4.3.2 Determining planning parameters

The calibration of the planning parameters is performed using the 2010 calibration model. This model is populated using the 2010 utilisation profiles and 2010 to 2014 load growth, as defined above, and the planning parameters for each segment are determined to ensure the model outputs the parameters set out above (in Table 6).

As discussed in Section 2.3.2, we used an adjustment to the typical calibration process because of the negative growth rates over the calibration period required by the model. This adjusted process can be consider in terms of two parts:

- calculating the unit cost and capacity factor parameters
- calculating the utilisation threshold parameters.

These two steps are discussed in turn below.

4.3.2.1 Calculating the $/kVA and capacity factors

The calculation of the unit costs ($/kVA) and capacity factors is not affected by the negative growths; and therefore, we have used the typical process to determine this set of parameters.

The process involves the following, using the parameters shown in Table 6:

1. we have calculated the augmentation unit costs ($/MVA) for each segment, based upon the formula:
   - augex in segment group / total capacity added in segment group

   Noting each segment in the segment will use the same augmentation unit cost.
2. we have calculated the set of capacity factors for each segment, based upon the formula:

- capacity added (for that segment) / capacity requiring augmentation (for that segment).

4.3.2.2 Calculating the utilisation threshold parameters

In circumstances of positive growth, the utilisation threshold is determined through the model by finding the threshold value that forces the model to forecast the capacity that was known to have been added over the calibration period. However, in circumstances such as JEN's, where a segment has a negative growth rate over the calibration period, the model will always produce a forecast of zero capacity added. Therefore, it is not possible to determine a utilisation threshold[16].

There are various approaches to allow for this situation. The most usual would be to split the segment into two: one capturing the regions with positive growth and the other the regions with negative growth. In this situation, the typical calibration process can be applied, using the segment with positive growth.

For JEN, we did not consider that this approach was usable as there was only a small portion of the network with positive growth and it was difficult to distinguish the underlying regional growth from the effects of load transfers. Therefore, we used an alternative approach that we believe should result in a reasonable estimate of the utilisation threshold that reflects JEN's planning decisions over the calibration period.

In this approach, we have adjusted the peak demand growth rates by a set factor in order to produce a positive growth rate. This adjusted growth rate is used in the calibration model to derive a utilisation threshold in the usual way. However, this threshold is then adjusted (outside of the model) by the adjustment factor that was applied to the growth rate. This adjusted threshold is then used for forecasting purposes.

Because there is some variability in the adjusted threshold with the assumed adjustment to the growth rate, we have conducted a number of studies varying the adjustment rates from 0.5% per annum to 5% per annum in steps of 0.5%.

The following process has been used to apply this approach:

1. Input the unit cost and capacity factor planning parameters in the 2010 calibration model
2. Assume the standard deviation of the utilisation threshold, for each segment, is the square root of the mean for that segment.
3. For each adjustment rate:
   a. Calculate the adjusted model growth rate, using the adjustment rate (see formulas in model files)[17].
   b. Using the model, determine the mean utilisation threshold parameter that sets the model's forecast of capacity added to the network to be equal the actual

[16] It is worth noting that, for related reasons, the accuracy of threshold derived in this way also may be affected by small positive growth rates.
[17] The adjustment is not applied to the growth rate if the growth rate is already greater than the adjustment rate.

capacity added in the relevant segments. Excel's goal seek function is used for this purpose

c. Calculated the adjusted mean utilisation threshold by applying the adjustment (over the calibration period) to the threshold determined in step 3b above – noting these are applied as downward adjustments to the threshold.

The chart below summarises the results of this process, indicating the adjusted threshold calculated for each adjustment rate. Based upon these results, we have selected the adjusted thresholds defined by the 2% adjustment rates, as these define the point where the threshold begins to flatten.

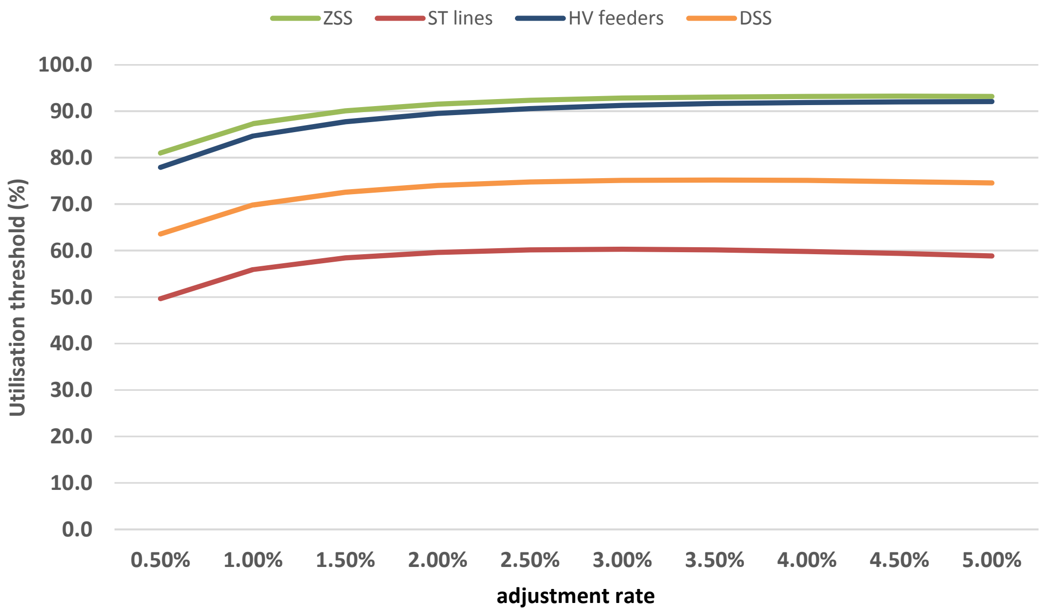

Figure 1 Utilisation thresholds by adjustment rate

4.3.3 Summary of calibrated planning parameters

The table below summarises the segment planning parameters used in the JEN augex model, calculated using the calibration method described above.

Table 7 Augex model calibrated planning parameters

Segment	Augex unit cost $'000 / MVA	capacity factor	Mean utilisation threshold (%)
All sub-transmission lines	331.8	0.99	92
All zone substations	22.5	0.27	60
All HV feeders	130.1	0.75	90
All distribution substations[a]	337.9 (169.0)	0.99	148 (74)

a – brackets indicate distribution substation parameters, allowing for the rating scaling that is applied in the model

4.4 Set up of calibrated forecasting model

The 2014 forecasting model is populated using the 2014 utilisation profiles and 2014 to 2020 load growths, as defined above.

The “calibrated” forecast uses the set of planning parameters derived through the process discussed above.

5 Augex model results

5.1 Augmentation forecasts

5.1.1 Aggregate results

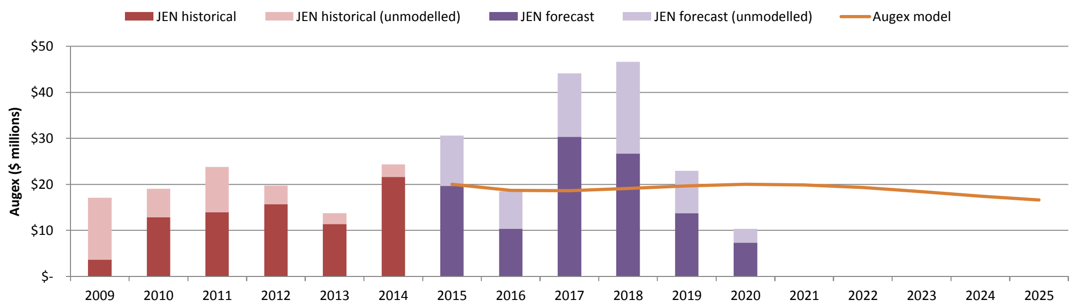

Figure 2 JEN augex model forecast comparison

Figure 2 above shows the aggregate expenditure forecast produced by the calibrated augex model (orange line) compared against JEN's forecasts (the purple bars). The chart also shows JEN's historical expenditure (red bars). This figure also indicates the component of JEN's augmentation expenditure that has not been assessed through the augex model.

The JEN augex model forecasts that JEN's augex will increase by approximately 22% from historical levels over the calibration period (assuming the calibration basis is valid). This direction of movement in augex is in line with JEN's forecast, which also indicates augex will increase in the next regulatory period compared to the calibration period.

In this regard, the average augex over the next period predicted by the model is similar to JEN's forecast, with the model forecasting 9% above JEN's forecast. The model suggests that the need for the increase is driven by the positive growth in demand that JEN is forecasting for the next period compared to the low and negative growth that occurred over the calibration period (see Table 5).

In any specific year over the forecast period, the model may show a greater variation to JEN's forecast. However, this may be expected because of the probabilistic way the model makes predictions, which effectively smooths augex. As such, the model (as set up here) would not be expected to predict specific large projects, which will cause the year-by-year pattern in JEN's forecast.

Overall, at this aggregate level, this finding suggests that JEN's forecast reflects a continuation of past planning practices and criteria – if anything the criteria applied for JEN's forecast may be slightly more onerous. Assuming the AER accepts that JEN has been acting prudently and efficiently over the calibration period then these results support JEN's augex forecast (all thing being equal and accepting JEN's growth forecast), indicating that JEN's forecast benchmarks favourably compared to its own recent history.

5.1.2 Segment group results

We have also compared JEN's forecast to the model at the network segment level. Table 8 and Table 9 below present results at this level.

These tables shows the 4-year annual averages of JEN's historical expenditure and augmentation capacity added (2011-2014) and its forecast expenditure and augmentation capacity added for the next regulatory period (the modelled components only). These averages are compared against the annual average forecast by the augex model. As the augex model smooths augmentation needs, two averages are provided in the table, reflecting the average over only the next regulatory period (2016-2020), and the average over the forecast period to the end of the next regulatory (2015-2020).

Table 8 – JEN augex model – network segment summary augmentation expenditure

	NSP average augex per annum			Augex model average augex per annum			
	historical	forecast	forecast	augex	diff to NSP	augex	diff to NSP
	2011-14	2016-2020	2015-2020	2016-20	forecast	2015-20	forecast
	$ millions	$ millions	$ millions	$ millions	%	$ millions	%
ST lines	0.50	2.22	1.92	0.92	-59%	0.89	-54%
ZSS	8.13	7.36	7.98	11.20	52%	10.98	38%
HV feeders	2.61	4.54	4.51	5.42	19%	5.62	25%
DSS	4.44	3.56	3.60	1.69	-52%	1.64	-54%
Total	**15.68**	**17.68**	**18.01**	**19.24**	**8.8%**	**19.12**	**6.2%**

Table 9 – JEN augex model – network segment summary augmentation capacity added

	NSP average per annum			Augex model average per annum			
	historical	forecast	forecast	capacity	diff to NSP	capacity	diff to NSP
	2011-14	2016-2020	2015-2020	2016-20	forecast	2015-20	forecast
	MVA	MVA	MVA	MVA	%	MVA	%
ST lines	22	27	24	41	54%	42	76%
ZSS	25	22	41	34	52%	34	-16%
HV feeders	20	32	47	42	29%	41	-13%
DSS	14	10	10	5	-49%	5	-46%
Total	**81**	**91**	**122**	**121**	**34%**	**123**	**0.9%**

The expenditure differences can also be seen in the four charts below, which show the profile of (the modelled component) of augmentation expenditure in each segment group.

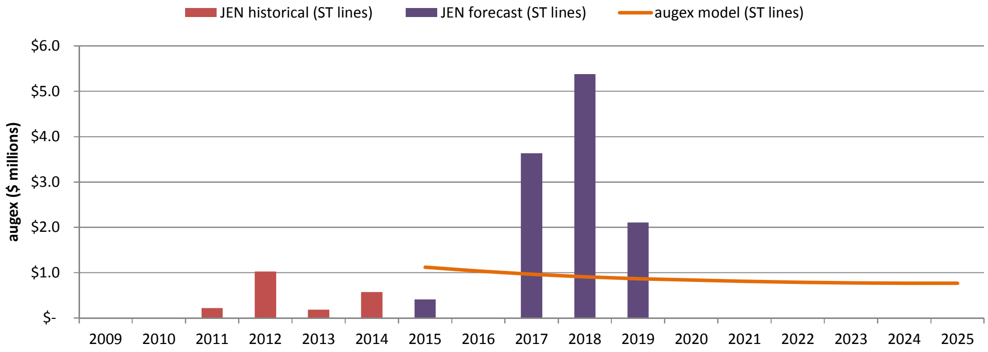

Figure 3 JEN augex model – sub-transmission line segment comparisons

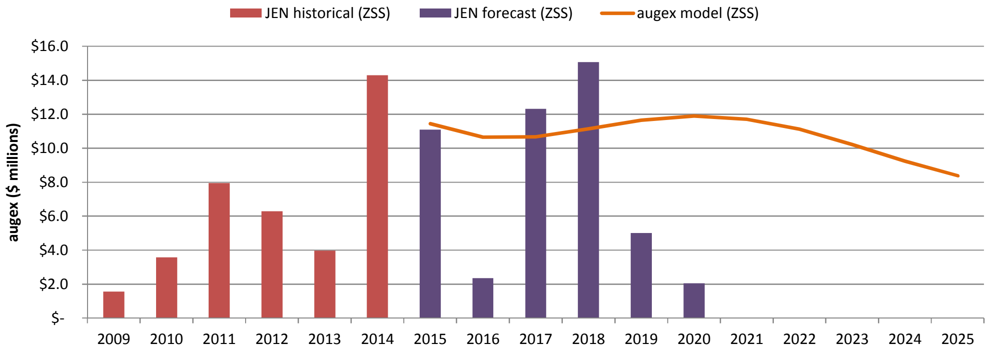

Figure 4 JEN augex model – zone substation segment group comparisons

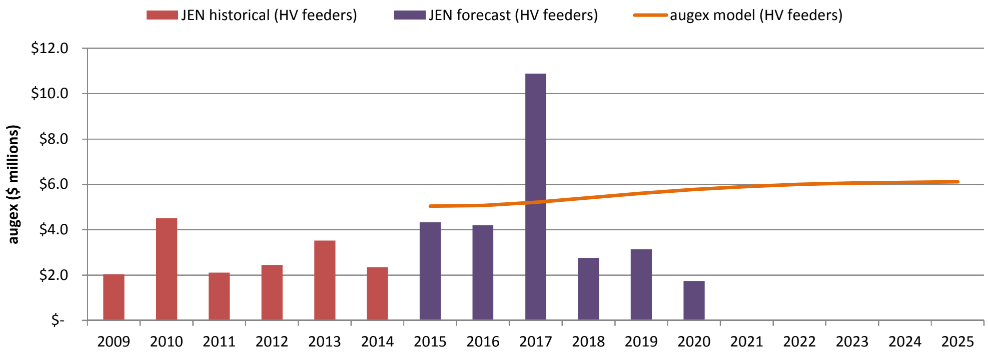

Figure 5 JEN augex model – HV feeder segment group comparisons

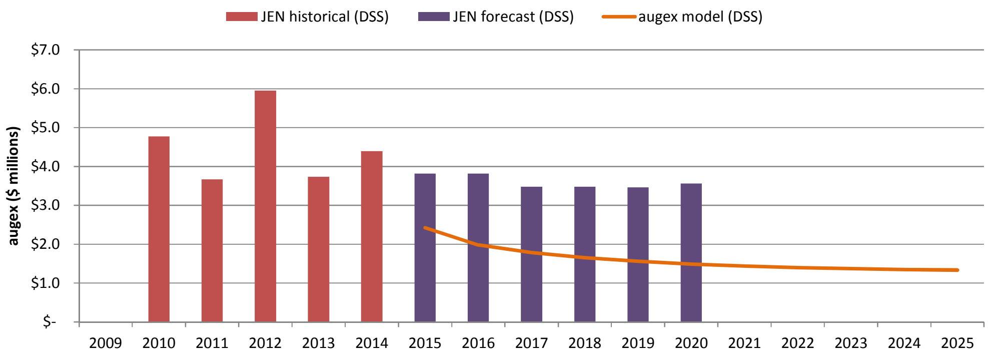

Figure 6 JEN augex model – distribution substation segment group comparisons

These tables show a greater variance between the model and JEN's forecast for each segment group. Furthermore, for some segments there are significant changes in the scale and direction of the variance between expenditure and capacity.

- The JEN augex model forecasts a significantly lower augex compared to JEN's forecast in the sub-transmission lines and distribution substation segments:
  - The distribution substation segment shows the greatest difference (in dollar terms), where the augex model's forecast is 52% lower than JEN's forecast, representing a $9 million reduction over the next regulatory period. The capacity results show a similar scale and direction of the difference.
  - The sub-transmission lines segment shows a slightly lower difference of $7 million over the next period; although this represents a 59% reduction compared to JEN's forecast.

    The capacity results shows a reversal in these findings, with the model significantly over-forecasting the capacity added in this segment.
- The JEN augex model forecasts a significantly higher augex compared to JEN's forecast in the zone substation and HV feeder segments:
  - The zone substation group shows the greatest difference of $19 million over the next period, representing a 52% increase on JEN's forecast.

    The capacity results show a similar scale and direction of the difference over the next regulatory period. However, they show a reversal in direction when 2015 is brought into the comparison period, which is not seen in the expenditure results.
  - The HV feeder group shows the smaller difference of $4 million, which represents a 19% increase on JEN's forecast.

    Similar to the findings on zone substations above, the capacity results show a reversal in direction when 2015 is brought into the comparison period, which is not seen in the expenditure results.

We explore the causes of these differences in the following section.

6 Analysis of forecast differences

6.1 Introduction

In the previous section we noted that the model's forecast of augmentation expenditure was 9% higher than JEN's forecast. However, we also found that:

- there were more significant variations between the model's and JEN's forecast expenditure at the segment level, both over and under JEN's forecast
- there were some changes in the direction of the difference for the capacity forecast in some segments
- for zone substation and HV feeders, there was significant change in the direction of the difference in capacity when 2015 was included in the comparison – this result was not seen in expenditure forecast, indicating a significant difference in the distribution of the capacity forecast compared to the expenditure forecast.

In this section, we examine these matters in more detail in order to understand what factors within the model and JEN's forecast are causing them.

6.2 Analysis of the forecast differences

To understand what is causing the segment variances, we have re-calibrated the model parameters to reflect JEN's forecast over the 2015 to 2020 period and then compared these to the parameters, which underpin the model forecasts presented in the previous section. We have also examined the distribution of the JEN capacity forecast over the forecast period.

Table 10 below summarises these two sets of model parameters. This table also indicates whether the movement in the parameters reflect a more or less favourable position for JEN's forecast compared to its history – in an intra-company benchmarking sense.

In this context, a movement in the parameter would be deemed by us to benchmark less favourably where the forecast parameter would suggest a more risk averse outcome or more costly augmentation in JEN's forecast compared to history. The following points are important in appreciating the physical significance of a movement in one of the three model planning parameters:

- Utilisation threshold - an unfavourable movement of the utilisation threshold would reflect a reduction in this parameter; this movement would suggest the *need* for an augmentation is being forecast earlier than historically
- Capacity factor – an unfavourable movement of the capacity factor would reflect an increase in this parameter; this parameter relates to the preferred augmentation solution, and an increase suggests more capacity is being added to address a need than has occurred historically

- Unit cost ($/kVA) – an unfavourable movement of the unit cost would reflect an increase in this parameter; this parameter also relates to the preferred augmentation solution, and an increase suggests a more costly solution (per unit of capacity added) than has occurred historically.

It is important to stress that, although we may be able to observe these movements and classify them here as favourable or unfavourable (in an intra-company benchmarking sense), this is not to say that the unfavourable movement is clearly imprudent or inefficient (or, likewise, a favourable movement is prudent and efficient). There may be good reasons why an unfavourable movement is necessary[18]. For example, in the event that small incremental augmentations have been exhausted, the next available solution could be a large augmentation, which would result in an increase in the capacity factor.

Table 10 model planning parameter comparison

	capacity parameters				expenditure parameter	
	utilisation threshold (%)		Capacity factor		$/kVA	
Segment	Augex model	JEN forecast	Augex model	JEN forecast	Augex model	JEN forecast
ST lines	60	70	0.27	0.32	23	80
ZSS	92	76	0.99	0.56	332	197
HV feeders	90	91	0.75	0.93	130	96
DSS[a]	148 (74)	131 (65)	0.99	0.99	338 (169)	364 (182)

red	unfavourable movement in parameter
orange	small change in parameter (<10%)
green	favourable movement in parameter

a - brackets indicate distribution substation parameters, allowing for the rating scaling that is applied in the model

The changes in the model parameters explain the segment results presented in the previous section (Table 8 and Table 9) as follows:

- Sub-transmission lines

  The lower utilisation threshold used by the calibrated model, compared to that deduced for JEN's forecast, means that the augex model finds a greater need for augmentation than is allowed for in JEN's forecast. However, when the model finds this need, it adds less capacity (as a per-unit of need) through the effect of the capacity factor.

  The aggregate effect of these two parameters, nonetheless, is that the model forecasts significantly more capacity should be added, compared to JEN's forecast.

  Offsetting this effect however is the unit cost parameter, which is less than JEN's forecast by a factor of nearly four. The effect of this is that, even though the model

[18] In our view, the point being made here is no different to caveats that apply to any top-down benchmarking exercise, and so, should not be interpreted as a deficiency of the model or the analysis presented here. For example, in the case of a regulatory review, the regulator could apply other assessment techniques to determine whether an unfavourable movement was likely to reflect an imprudent or inefficient decision.

forecast more capacity compared to JEN, it forecast that this will be at a significantly lower cost than JEN's forecast.

- Zone substations

  The significantly higher utilisation threshold in the model means it forecasts the need for much less augmentation than allowed for in JEN forecast. However, when it finds this need, it adds more capacity than JEN (through the capacity factor).

  The aggregate effect of these two parameters (over the 2015 to 2020 period), is that the model forecasts less capacity should be added, compared to JEN's forecast.

  Offsetting this effect however is the unit cost parameter, which is significantly higher in the model than JEN's forecast. The effect of this is that, even though the model forecasts less capacity compared to JEN, it forecasts that this will be at a significantly higher cost than JEN's forecast.

  The change in direction of the capacity variance over the 2016 to 2020 period is because JEN is expecting to add approximately 50% of its forecast capacity over the 2015 to 2020 period in 2015; however, there is not an equivalent pattern in expenditure.

- HV feeders

  The utilisation thresholds are very similar and therefore the model finds the need for augmentation is at very similar levels to JEN's forecast. However, JEN's forecast adds more capacity when it finds the need; hence, the model is below JEN's forecast (over the 2015 to 2020 period).

  However, similar to zone substations, this under forecast in capacity is offset by the higher unit cost parameter in the model, which is significantly higher than JEN's forecast. The effect of this is that, even though the model forecasts less capacity compared to JEN, it forecasts that this will be at a higher cost than JEN's forecast.

  Also similar to zone substations, the change in direction of the capacity variance over the 2016 to 2020 period is because JEN is expecting to add approximately 40% of its forecast capacity over the 2015 to 2020 period in 2015; however, there is not an equivalent pattern in expenditure.

- Distribution substations

  The significantly higher utilisation threshold in the model means it forecasts the need for much less augmentation than allowed for in JEN's forecast. However, when it finds this need, it adds similar amounts of capacity compared to JEN (through the capacity factor).

  The aggregate effect of these two parameters (over the 2015 to 2020 period), is that the model forecasts that significantly less capacity should be added, compared to JEN's forecast.

  The unit costs are similar in scale and therefore this lower level of forecast capacity in the model translates into a similar lower expenditure forecast.

6.3 Identification of key matters

Based upon these findings, we have identified the key technical matters that underpin the unfavourable movements in the model parameters present above.

sub-transmission lines	For JEN's forecast, the capacity being added when a need is identified (as observed via the capacity factor) has increased moderately and the cost of that capacity has increased significantly (nearly four-fold). This suggests that larger and more costly solutions to an identified augmentation need are included in JEN's forecast compared to its historical augmentations over the calibration period. On this matter, it is noted that only a small amount of expenditure was incurred over the calibration period ($2 million) for a relatively large amount of capacity added (89 MVA). We understand that this largely reflected some minor augmentations. Clearly, if these types of minor augmentation are not feasible over the forecast period then this could be a plausible explanation for the movement in these parameters.
zone substations	The reduction in the utilisation threshold for the forecast period suggests JEN is identifying needs much earlier than recent history. However, some caution is needed in considering these results because JEN is expecting to add approximately 50% of its forecast capacity over the 2015 to 2020 period in 2015; however, there is not an equivalent pattern in expenditure. This is effecting the comparisons above, as it has such a significant effect on the forecast calibration.
HV feeders	The forecast parameters compare quite favourably to history. Although the capacity factor has increased, suggesting more capacity is added when a need is identified, this capacity is at a lower cost. The net effect is a lower cost solution in JEN's forecast compared to its recent history. However, as with zone substations above, some caution is needed in considering these results because JEN is expecting to add approximately 40% of its forecast capacity over the 2015 to 2020 period in 2015 without the equivalent pattern in expenditure. This is effecting the comparisons above, as it has such a significant effect on the forecast calibration.
Distribution substations	The reduction in the utilisation threshold for the forecast period suggests JEN is identifying needs earlier than recent history. That said, this utilisation level is still quite high (i.e. the model suggests JEN is, on average, planning to augment a substation when it is 130% above its cyclic rating). Therefore, given JEN is still forecasting a decline in expenditure for this segment, this matter may be of less concern.

With regard to these matters, it is worth noting the following:

- Some movements in the parameters may be explained (at least partly) by JEN's probabilistic planning approach where more costly solutions result in higher utilisation threshold being required to justify the solution (and vice versa).
- The parameters for the sub-transmission lines and zone substations will be more affected by the small volumes of larger projects, which may have more widely varying costs. Therefore, we may expect wider variations in parameters from one period to another in these segments.
- JEN will need to consider the large amounts of capacity being added in 2015 in a number of segments. It may need to consider whether this is due to needs in the historical calibration period and in which year "as commissioned" costs would lie to determine how this capacity may be affecting the model parameters of either the historical or forecast period presented above.

A Sensitivity studies

To examine the sensitivity of the model forecast to certain assumptions, two sensitivity studies have been performed. These studies examine the sensitivity of the expenditure forecast to the following:

- Demand growth forecast (peak demand study) – As noted above, the assumed maximum demand growth is an important driver of the forecast expenditure in the model.

  Therefore, studies have been undertaken to examine the sensitivity of the model expenditure forecast to a ± 0.5% change in the 2014-2020 per annum growth assumption used in the model.

- Utilisation threshold (utilisation threshold study) – The model forecast will be sensitive to the assumed utilisation threshold. Furthermore, the relationship will not be linear, and therefore, it may not be obvious how a change in threshold will affect the forecast (e.g. through intercompany benchmarks, should these become available)

  Therefore, studies have been undertaken to examine the sensitivity of the model forecast to a ± 5% change in the utilisation threshold.

The two tables below show the results of these two studies. Table 11 shows the change in the model forecast (over the next period) from the base case (the calibration model forecast).

These studies show that the augex forecast produced by the model is very sensitive to the forecast demand growth parameters input into the model. In this regard, a reduction in the demand forecast (e.g. due to an adjustment by the AER) would result in a fairly substantial reduction in the expenditure forecast (i.e. a 0.5% per annum reduction in the compound maximum demand growth rate results in a 22% reduction in expenditure forecast by the model). This sensitivity is relatively symmetrical with a 0.5% per annum increase in the growth rate resulting in a 22% increase in expenditure.

On this sensitivity, it is important to note that, given JEN's growth rate is approximately 1% to 3% per annum (depending on the segment group), a 0.5% reduction (in absolute terms) would represent a very significant reduction in the total level of growth in maximum demand that occurred over this period. Therefore, this high sensitivity is not unexpected.

The forecast is also sensitive to the assumed utilisation threshold. These studies indicate that a 5% reduction in threshold will result in a 25% increase in expenditure, with a 5% increase resulting in a similar level of reduction. Again, this sensitivity is not unexpected as we may expect that a 5% increase in a threshold could result in a deferment of an augmentation by around 5 years for growth rates of around 1% per annum.

Table 12 shows the difference to JEN's forecast augex for each sensitivity study (and the base case forecast discussed in main body of this report). At the segment level, only the

JEN's zone substation forecast remains above the model for the two more onerous studies.

Table 11 Sensitivity study results – change in forecast expenditure

	Utilisation threshold study		Peak demand study	
	+5%	-5%	+0.5% pa	-0.5% pa
Sub-transmission lines	-16.3%	19.6%	23.9%	-25.0%
Zone substations	-24.8%	23.7%	20.7%	-21.2%
HV feeders	-24.5%	27.1%	21.0%	-20.7%
Distribution substations	-23.7%	30.8%	27.8%	-30.2%
Total	**-24.2%**	**25.1%**	**21.6%**	**-22.0%**

Table 12 Sensitivity study results – Difference to JEN's forecast over 2016 to 2020 ($ millions)

	Base case	Utilisation threshold study		Peak demand study	
		+5%	-5%	+0.5%	-0.5%
Sub-transmission lines	$ 6.52	$ 7.27	$ 5.62	$ 5.42	$ 7.67
Zone substations	-$ 19.21	-$ 5.31	-$ 32.46	-$ 30.81	-$ 7.36
HV feeders	-$ 4.38	$ 2.27	-$ 11.73	-$ 10.08	$ 1.22
Distribution substations	$ 9.34	$ 11.34	$ 6.74	$ 6.99	$ 11.89
Total	**-$ 7.73**	**$ 15.57**	**-$ 31.83**	**-$ 28.48**	**$ 13.42**