AUGEX Model Review - AER

CITIPOWER / POWERCOR

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Citipower/Powercor Augex Model Review - AER

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Executive summary

CitiPower/Powercor engaged SKM to review the Australian Energy Regulator (AER) Augex (Augmentation Capex) model.

Developed by Nuttall Consulting, the Augex model is intended to be used by the AER to benchmark future reinforcement capital expenditure forecasts during the next Electricity Distribution Pricing Review (EDPR). The deliverables for this assignment included:

- A description of the Augex model (key characteristics, structure etc);

- The data requirements to populate the model

- Pros and cons of the model in respect of model architecture and suitability for purpose;

- Areas where the model could be improved. This will be particularly important in the AER's consultation process on the Augex model, which we understand will occur later this year.

Overview

The Augex model forecasts augmentation needs at an aggregate level using asset utilisation as the main driver. Idealised planning parameters are used to predict future augmentation requirements. The Augex model requires input data in two basic segment types: asset status data and planning parameters. The asset status data includes the asset utilisation profile and growth rate, which represents the current status of the asset and the expected future state, based on the growth rate. Planning parameters include utilisation threshold, capacity factor and augmentation unit cost. These establish the point at which capacity will be increased and calculate the cost of that capacity increase.

AUGEX model clarifications required

Having analysed the structure and calculations within the model, SKM identified several items that require clarification:

- The use of (1+k) in both the numerator and denominator of the capacity factor calculations, which effectively cancel each other out

- The definition of unit cost - what should be included (ie overheads, etc)

- The calculation of weighted average remaining utilisation (WARU) is calculated by Sumproduct((Utilisation threshold- Utilisation level),capacity at each utilisation level)/Total Capacity -0.5. The reason for subtracting 0.5 at the end is unclear.

Potential concerns with application of the model

Our commentary provided in Section 4 notes a number of items that CitiPower/Powercor should consider when responding to the AER consultation process for the Augex model, including:

- The ability of the AER to use the model input data and model outputs for both inter-company and intra-company benchmarking

- The potential volume of "unmodelled" capex likely to be included in the next CitiPower/Powercor augmentation capital expenditure forecasts compared with the AER's view that the majority of augmentation capex will be captured by the Augex model forecast

- The oversimplification of complex parameters, which limits the model's ability to forecast accurately in an environment where some of these planning parameters are extremely dynamic

- The sensitivity of the model to small changes in input parameters

Additional information required from AER

- Guidance on sub-segments within the 11 defined segment types – does AER want each DNSP to define their own?

- Guidance on the inclusion or exclusion of exceptional projects.

- Guidance on how planning standards should be converted into a threshold and standard deviation.

- How are complex, non-linear growth rates to be incorporated?

- Guidance on what to include in unit costs.

- Information for some of the lower segment types is not available through direct metering and will need to be implied. How will the relative uncertainty and inaccuracy that this will impose on these segment types be adequately dealt with in this model?

NOTE: This report is a modified version of the original report delivered to CitiPower/Powercor. Some comments and sections relating specifically to CitiPower/Powercor data have been removed.

1. Introduction

1.1 Scope of work

CitiPower/Powercor engaged SKM to review the Australian Energy Regulator (AER) Augex (Augmentation Capex) model.

Developed by Nuttall Consulting, the Augex model is intended to be used by the AER to benchmark future reinforcement capital expenditure forecasts during the next Electricity Distribution Pricing Review (EDPR). The deliverables for this assignment included:

- A description of the Augex model (key characteristics, structure etc);

- The data requirements to populate the model;

- Pros and cons of the model in respect of model architecture and suitability for purpose;

- Areas where the model could be improved. This will be particularly important in the AER's consultation process on the Augex model, which we understand will occur later this year.

1.2 Information provided

CitiPower/Powercor have provided details of the Augex model, including:

- "Guidance Document, AER Augmentation model – data requirements", AER, June 2011

- Microsoft Excel model, "AER Augmentation assessment tool for discussion with NSW DNSPs – June 2012 (with example data).xlsm"

- DNSP template— "2012 02 27 – NSW-ACT – 2014-19 – AA - Information collecting template.xlsx".

CitiPower/Powercor also provided:

- Regulatory Information Notices (RIN) template

- Sample 15-minute load data of chosen substations.
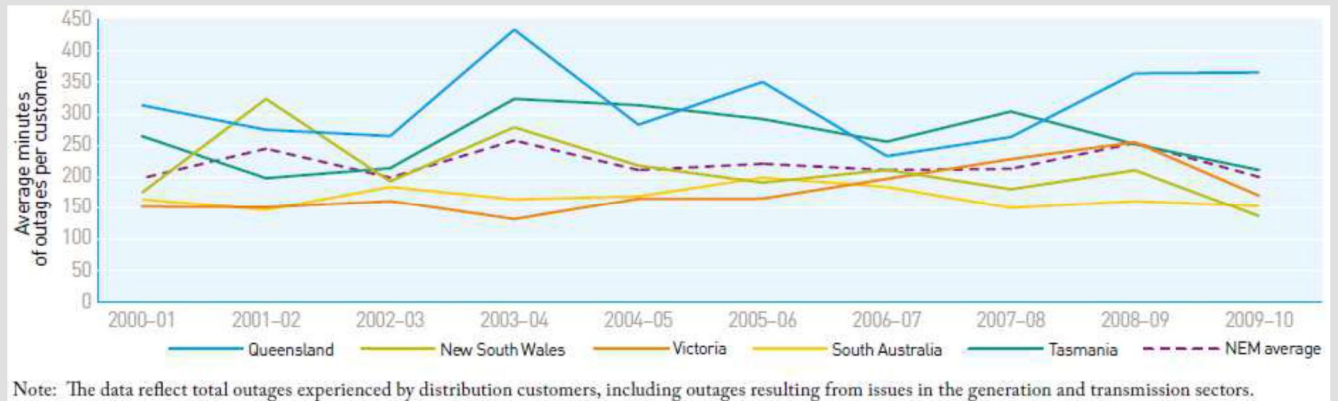
1.3 AER description

The AER released the paper, "Review of distribution reliability outcomes and standards — national workstream issues paper" in August 2012. The information in Figure 1-1 (from the paper) references the Augex model and indicates the intended use of the model as well as various interpretations of planning standards that may be used to establish the "bright line" threshold. The term, "bright line", threshold is not mentioned in the Augex model documentation provided to SKM MMA.

Figure 1-1: Example of the benefit of output based standards

The AER has developed an augmentation capex tool (augex model) for use in future regulatory assessments. The tool is undergoing final refinement and calibration before it is adopted in future assessments. This process will involve the NSW distribution businesses and other interested parties (such as other DNSPs) as the AER will be looking to progressively implement this tool over time. The tool evaluates whether a proposed network investment is economically justified by assessing the expected asset utilisation. The key to the augex model is establishing the threshold above which the augmentation of major assets is justified (the 'bright line' threshold). This threshold varies depending on the reliability standard that applies to the DNSP. Under the augex model, the AER applies the bright line threshold to DNSPs' augmentation capex forecasts and then undertakes further analysis to assess whether there are underlying factors to explain any discrepancy.

Under an N-1 deterministic standard, the 'bright line' threshold above which augmentation is justified is where expected asset utilisation is notionally 50 per cent. Under an N-2 deterministic standard, the threshold is notionally 33 per cent. In Victoria, based on their economic test framework, the corresponding number for N-1 is expected to be closer to 60-70 per cent or more depending on the degree of preparation of each distribution business for managing outage events.

Figure 1: System Average Interruption Duration Index (SAIDI) Performance

Note: The data reflect total outages experienced by distribution customers, including outages resulting from issues in the generation and transmission sectors.

Source: AER, State of the Energy Market 2011, p10
Further information on relative distribution reliability performance is available in the AER's State of the Energy Market 2011 report2.

2. Overview of the Augex model

SKM reviewed the structure, formulae and macros in the Augex model to understand the algorithms applied to the input data to produce the capital forecast results. An overview and flowchart describing the model are provided in this section.

2.1 Description of Augex model

The Augex model – a Microsoft Excel spreadsheet using a combination of cell formulae and Visual Basic programming code (VBA) – has been developed as a tool to help the AER assess capital expenditure forecasts for Distribution Network Service Providers (DNSPs). A model focussed on replacement capital expenditure – the "Repex" model – has been used to assess replacement capex in previous determinations. .

The Augex model forecasts augmentation related capex, ie capex primarily to increase the capacity of the network to allow for load growth. The data required to populate the model will be requested by the AER via Regulatory Information Notices (RIN). The guideline describing the model signals the AER's intention to determine intra- and inter-company benchmarks from historical augmentation capex levels. The benchmarks are intended to be used to identify elements of augmentation capex forecast requiring more detailed review before a determination is made by the AER.

The Augex model forecasts augmentation needs at an aggregate level using asset utilisation as the main driver. Idealised planning parameters are used to predict future augmentation requirements. Each network is to be represented in the model as a set of user definable network segments, ie generally a set of substations or lines. The high-level segments suggested by the AER are shown in Table 2-1. Each DNSP can define segments within these segment groups to fit the structure and assets within their network.
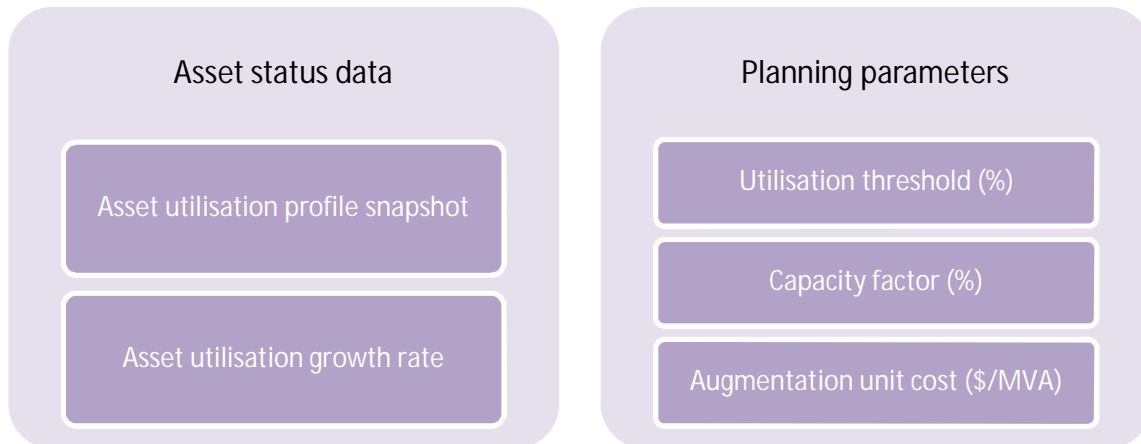
Table 2-1: Segment groups

Group ID	Group
1	Sub-transmission lines
2	Sub-transmission substations
3	Zone substations
4	HV feeders – CBD
5	HV feeders – urban
6	HV feeders – short rural
7	HV feeders – long rural
8	Distribution substations – CBD
9	Distribution substations – urban
10	Distribution substations – short rural
11	Distribution substations – long rural

2.2 Input data

The Augex model requires input data in two basic categories: asset status data and planning parameters. The asset status data includes the asset utilisation profile and growth rate, which provides a view of the current status of the asset and the expected future state based on the growth rate. Planning parameters include utilisation threshold, capacity factor and augmentation unit cost. These establish the point at which capacity will be increased and calculate the cost of that capacity increase. Figure 2-1 illustrates the input data requirements.

The output of the Augex model is sensitive to the input data and as some of the inputs are more subjective than others, the selection of these parameters may significantly impact the resulting capex forecast. SKM recommends a sensitivity analysis be conducted using a populated model to examine the sensitivity to changes in the various input data.

Figure 2-1 : Augex model input data

The Augex model requires data to be entered on two input data worksheets:

- **"Table"**

- **"Asset data"**

2.2.1   "Table" worksheet

The "Table" worksheet lists out the 11 high-level segment groups suggested by AER and defines the base year of the forecast. It can be considered the "initialisation" of the model.

2.2.2   "Asset data" worksheet

All the data from the DNSP template must be converted and entered into the "Asset data" worksheet in the model. The elements in the "Asset data" worksheet represent the DNSP's asset base.

A breakdown of the content of the "Asset data" worksheet is provided in **Error! Reference source not found.**.

2.3   Augex model calculations

Based on the planning parameters and asset utilisation profile, the Augex model produces summary information of the utilisation profile at both individual segment and group level. A detailed description of the calculation of the key parameters for the utilisation profile such as total augmentation value and weighted utilisation threshold will be shown in this section. The model also produces a 20 year, year-by-year augmentation forecast which covers information such as "Augmentation capacity added", "Weighted average Utilisation" and "Augmentation expenditure".

2.3.1   Internal calculation worksheets

There are three worksheets in the Augex model which are mainly used to produce charts and aid/enable/facilitate calculation. They are not expected to be edited by the user.

"Utilisation profile (Inst)" worksheet

This worksheet is very similar to sheet "Asset data" worksheet, as the capacities of each segment are aggregated to group level. It is also used to produce the charts in the "Utilisation profile chart" worksheet.

"Utilisation profile" worksheet

This worksheet is used to calculate the remaining utilisation (Utilisation threshold – Capacity at each level) and produce charts.

"Utilisation profile (RL, remaining life)" worksheet

This worksheet includes the capacity at each remaining utilisation level. In this worksheet we noted that the formulae in Column F (Quantity = 10) are inconsistent with the rest of the worksheet and appear to have been "hard coded". It is unclear why.

2.3.2   Calculation worksheets

There are two worksheets in the Augex model which are viewed and edited by the user.

"Utilisation profile worksheet summary"

This worksheet summarises a range of input data at the segment level. It contains Excel formulae only; VBA calculation is not involved. A description of the contents of the summary sheet is provided in **Error! Reference source not found.**.

"Aug Forecast" worksheet

This worksheet creates the augmentation expenditure forecast, which is presented at segment level. A description of the contents of the "Aug forecast" sheet is provided in **Error! Reference source not found.**. As detailed in Appendix C, the additional capacities added in forecast years are calculated internally using VBA subroutines. The detailed description of VBA functions is provided in the following section.

2.3.3   Visual basic code

Before running the actual capacity forecast-related calculation functions, the model undergoes an initialisation stage to make sure all the values will be displayed correctly in the spreadsheet. After initialisation the calculation functions run to produce the model output which is the augmentation capex forecast. The initialisation and calculation functions are described in the following text and are illustrated in

Figure 2-2, Figure 2-3, and Figure 2-4.

Initialisation function – Initcalcs())

This function checks the number of elements in the input worksheet ("Asset data"), fills in the pre-setup formulae ("Aug forecast" worksheet, row 21-22) and initialises the calculation.

Calculation functions – Aug_calc (main function), Ugr_all, Ugrowth (probabilistic calculation)

Probabilistic algorithm – the conditional probabilistic calculation is performed within function **Ugrowth()**
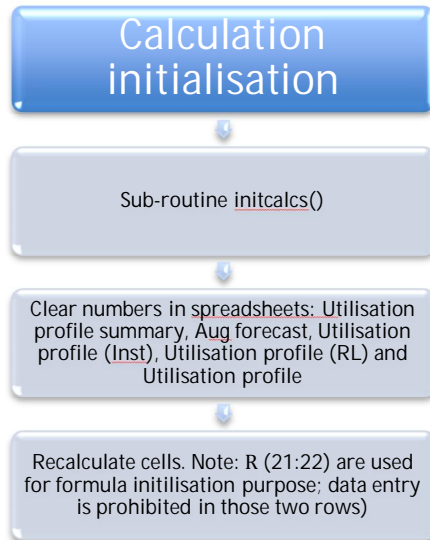
Figure 2-2 : Initialisation function 'initcalcs'

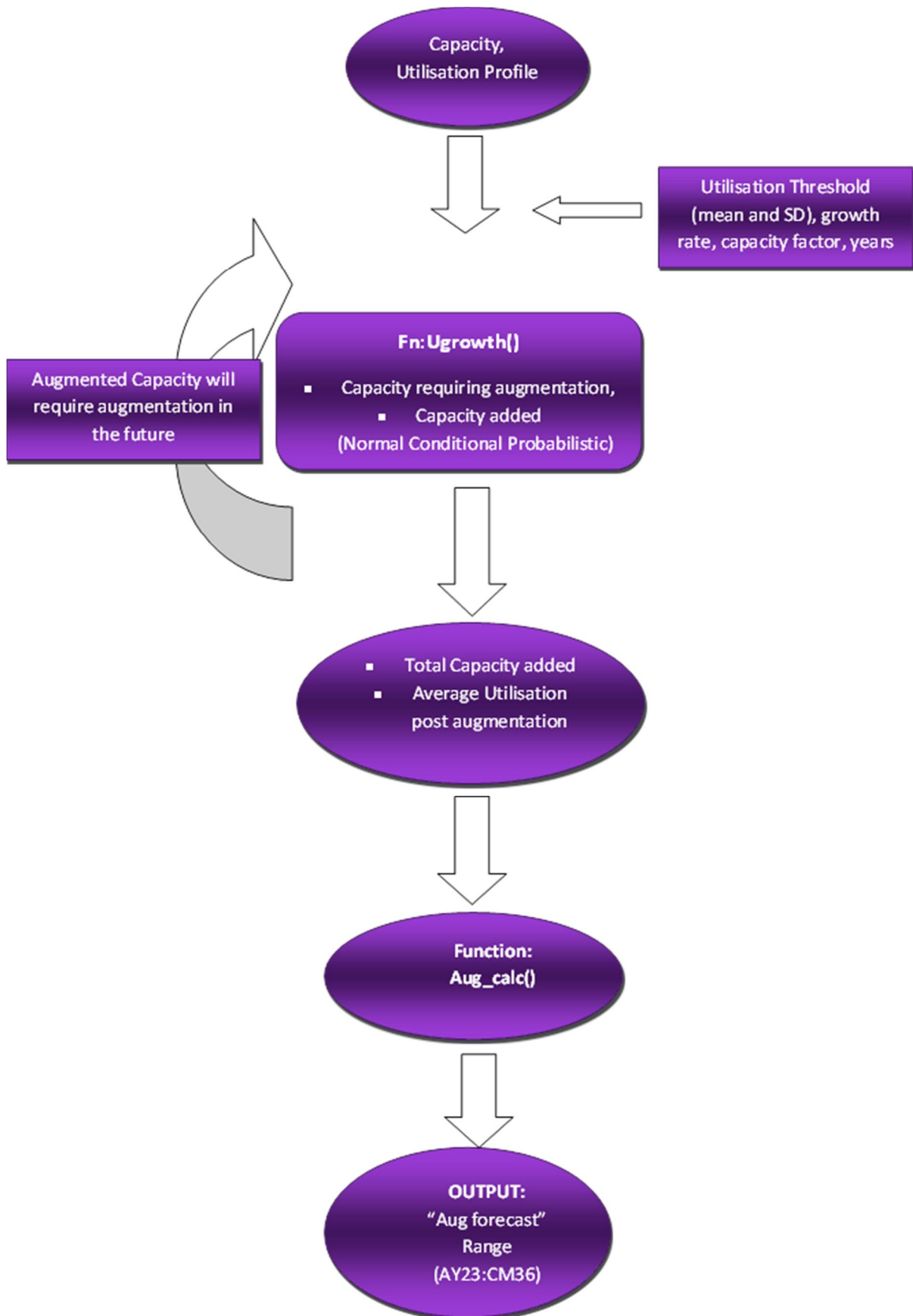Figure 2-3 : Overview of the calculation

Figure 2-4 : Probabilistic algorithm

Function Ugrowth

Input: Utilisation, load growth rate, capacity, capacity factor, utilisation threshold mean, utilisation threshold SD, Probabilistic method (normal), Years of projection

Calculate the probability at each level of utilisation based on the cumulative probability density function 'r1 = Application.WorksheetFunction.NormDist(ui, alpha, beta, True)'

Calculate the forecasted utilisation in the future year based on demand growth:

$U\_year = U\_year0 * (1 + \text{load growth})^{\text{year}}$

Similar to 'r1', determine the cumulative probability of U_year: 'r2'

Calculate the proportion of the assets that will require augmentation as utilisation increases in the future, conditional probability theorem is applied.

Proportion = (r2-r1)/(1-r1)

Capacity requiring augmentation = Proportion * capacity;

New utilisation after augmentation= forecasted utilisation / (1+capacity factor)

Output:
1. Utilisation after augmentation
2. Augmented capacity
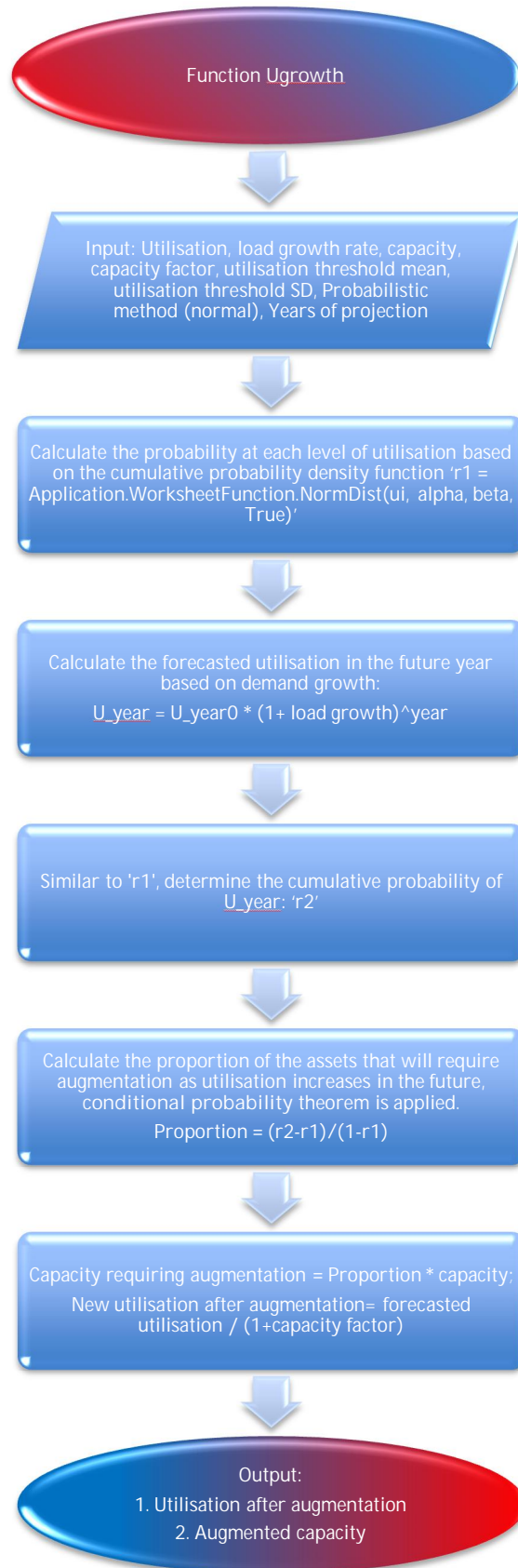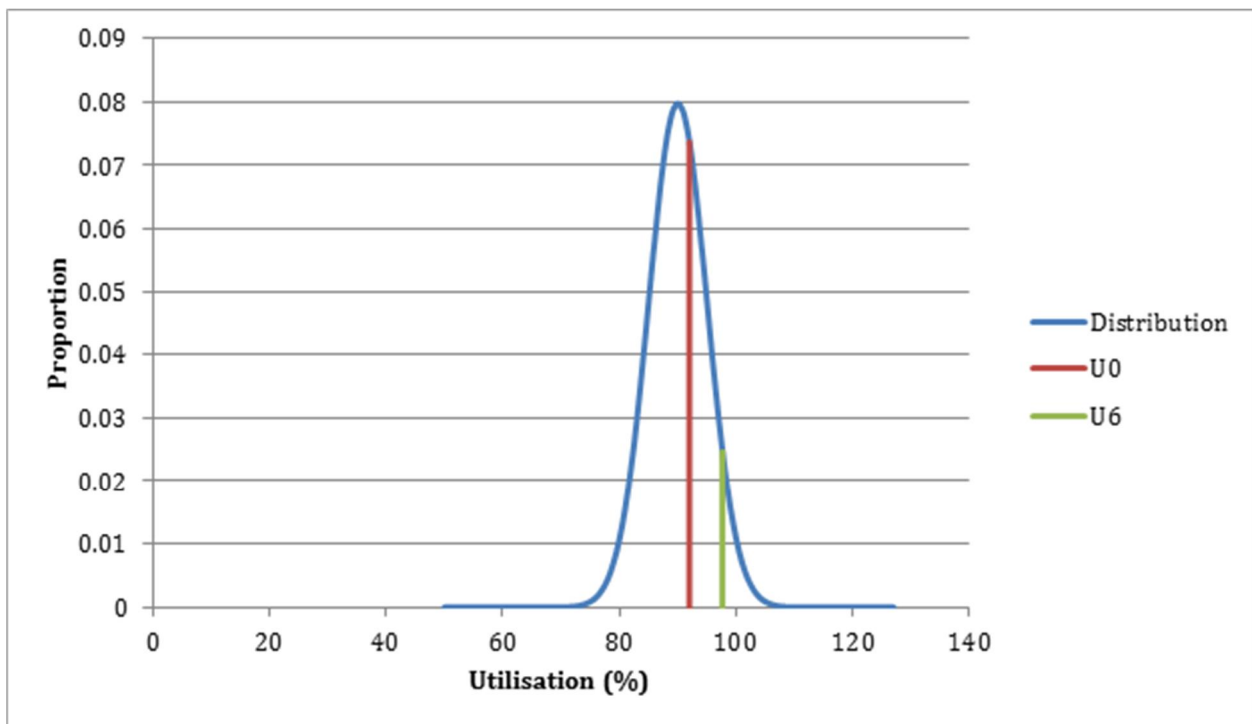
2.3.4 Conditional probability algorithm

Fundamental to the working of the model is the probabilistic algorithm that uses the function **Ugrowth(),** as shown in Figure 2-4. This function determines the capacity required for augmentation. A more detailed description is exemplified below/in the five-step process below.

Step 1: Create an unconditional probability distribution based upon the planning parameters (utilisation threshold mean and standard deviation). See blue line in Figure 2-5 below. In this example, mean and standard deviation of the utilisation threshold are set at 90 and 5, respectively.

Step 2: Determine the year-by-year increase in the level of utilisation based upon maximum demand growth rate. For example, Figure 2-5 shows the level of utilisation currently at 92%. If maximum demand is growing at 1% pa, the utilisation level will be increased to $92 * (1 + MD\ growth)^{year} = 92 * (1 + 0.01)^6 = 97.66$ after six years, illustrated by the green line in Figure 2-5.

Figure 2-5 : Utilisation of sample asset

Step 3: The model works out the proportion of capacity required for augmentation at a future utilisation level based upon the current level of utilisation. In the conditional probability algorithm, proportion is calculated by $Proportion = \frac{r2-r1}{1-r1}$, where r1 and r2 are the cumulative probability at each utilisation level. For example, at utilisation level U=92, r1 can be represented by the red shaded area in Figure 2-6. Consider conditional probability theorem, where $P(A|B) = \frac{P(A \cap B)}{P(B)}$, based upon the probabilities (r1 and r2) calculated from current and future levels of augmentation,

$$Proportion\ required\ for\ augmentation = \frac{r2 - r1}{r1'} = \frac{r2 - r1}{1 - r1}$$

Step 4: Determine the capacity requiring augmentation in each year. This can be calculated by (capacity at each? utilisation level) * (Proportion from Step 3).

Step 5: Augmented Capacity = capacity requiring augmentation (from Step 4) * (1+capacity factor)[1].

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[1] As per section **Error! Reference source not found.** SKM question the need for this final step

Figure 2-6 : Conditional probability theorem example
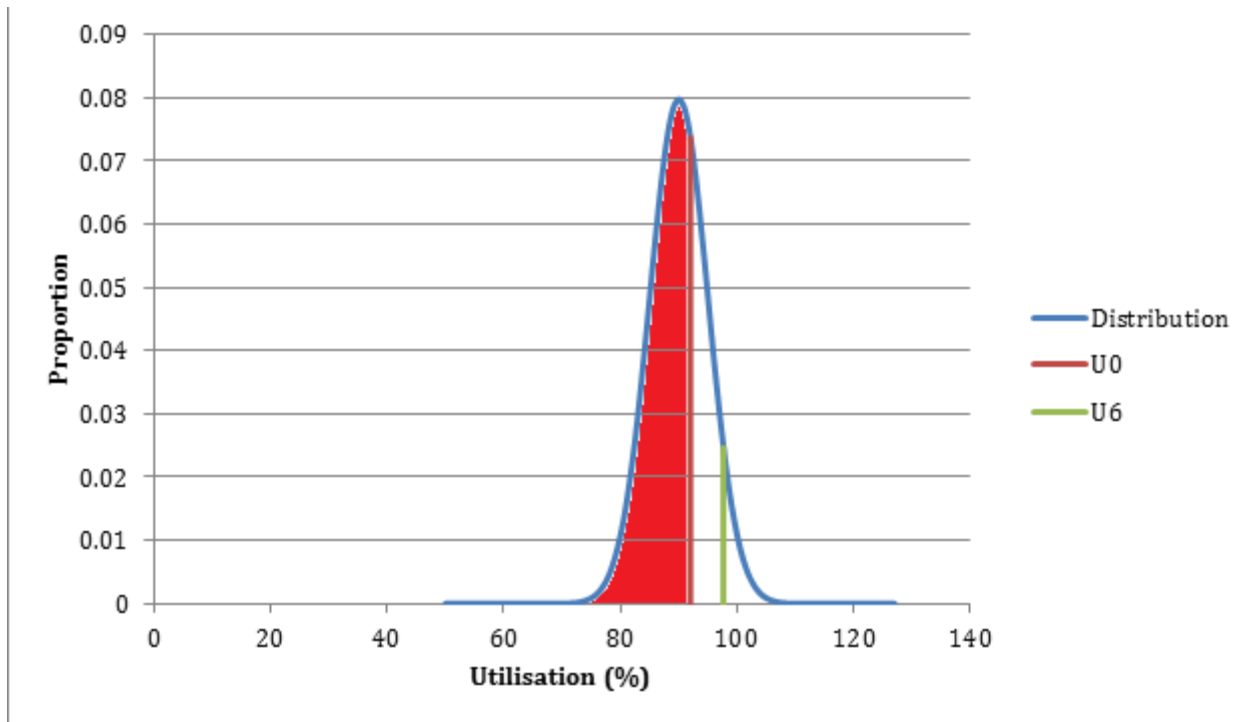
Two detailed sample calculations of function **Ugrowth()** are included in Appendix A.

2.4   Issues and errors identified in Augex model code

SKM did not detect any errors in the code as it stands. However, there are several issues that appear to be inconsistent with the application and may warrant clarification during the consultation period. Some of the items listed below may not detrimentally affect the outcome of the model; however, they do complicate its interpretation.

1.   The application of the capacity factor in the calculations. The capacity required for augmentation is multiplied by (1+k), (where k is the capacity factor), in the probabilistic calculation function **Ugrowth().** The result is then multiplied by k and DIVIDED by (1+k) in the main function for the purpose of calculating capacity added. In this case, the factor (1+k) does not play a mathematical role in the function as the (1+k) in numerator and denominator cancel out. Therefore, a clarification of factor (1+k)'s presence in the code is required.

2.   In function **Ugr_all()**, the model calculates unaugmented capacity via (total capacity minus augmented capacity). However, the calculated results are not used elsewhere in the function or passed to other functions as an output, which makes this part of calculation redundant.

3.   In the "Asset data" worksheet, the definition of unit cost needs clarification about what should be included (ie overheads, etc) and will be highly dependent on the definition of the segment the cost applies to.

4.   In the "Utilisation profile summary" worksheet, the weighted average remaining utilisation (WARU) is calculated by Sumproduct ((Utilisation threshold - Utilisation level), capacity at each utilisation level)/Total Capacity - 0.5. The reason for subtracting 0.5 at the end is unclear.

3. Analysis of data requirements

The Augex model requires input data in specific formats which have been described in Section 2.2. This section summarises the specific data requirements and identifies gaps between the data available within CitiPower/Powercor's systems and the Augex model's requirements. It also provides details of the steps required to convert CitiPower and Powercor raw data into the format required by the model.

3.1 Augex model data requirements

Figure 3-1 provides an overview of the input requirements for the Augex model. The majority of these inputs are entered on the "Asset Data" worksheet in the model, including:

- Unit cost per MVA

- Capacity factor

- Maximum demand growth per annum

- Utilisation threshold mean and standard deviation (need to be chosen very carefully)

- Augmentation method (1. normal distribution)

- Utilisation profile – capacity at each utilisation level

Figure 3-1 : Model input requirements
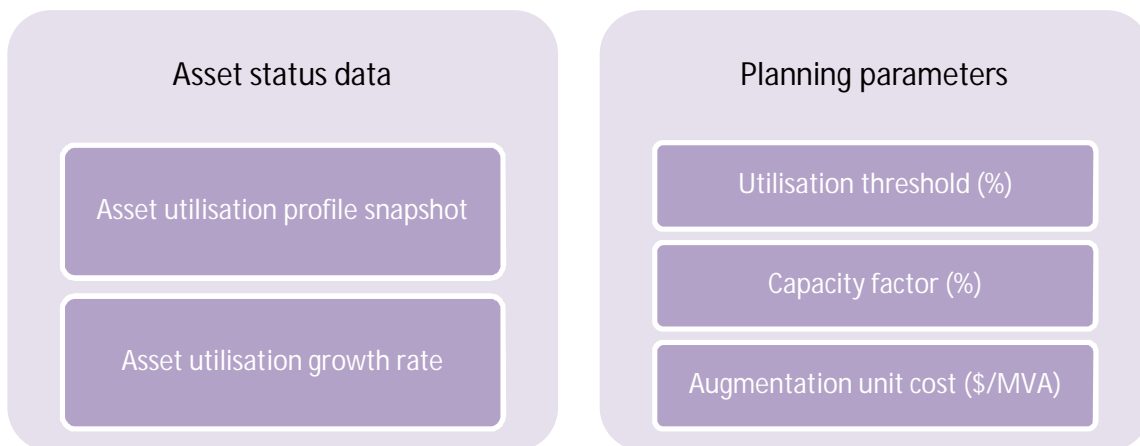
The AER provides some guidance on preparing the input data and suggests alternative ways for data to be approximated if actual data is not captured by the DNSP. In particular the Information Collecting templates.xls worksheet, "Aug.capex assessment (6.14)" Part 4 advises that:

"*Where actual maximum demand is not measured at individual substations within a category, ActewAGL should estimate the demand and utilisation, based on customer types and numbers supplied from the substation.*"

And in Part 6:

"*ActewAGL is allowed to define the most appropriate network segments for this assessment tool. Individual segments should be defined to capture differences in the main drivers of augmentation, such as growth rates, augmentation unit costs, or utilisation thresholds.*".

Overall, the data requirements for this spreadsheet are deceptively simple. However, parameters such as the threshold, measured in MVA, are critical to the overall calculation. From discussion with CitiPower/Powercor,

establishing this parameter, and its associated standard deviation, will be challenging and require the design rules to be translated into a statistical form.

3.2 CitiPower/Powercor data gaps

This section has been removed.

3.3 Steps required to produce Augex model input data

This section has been removed.

4. Recommendations

Having reviewed the Augex model methodology and its proposed application by the AER, SKM provides the following commentary and recommendations.

4.1 Benchmarking

The AER has stated its intention to use the Augex model to conduct both inter-company and intra-company benchmarking.

Intercompany benchmarking may be possible for some of the input data; for example, the planning parameters such as utilisation threshold and unit costs. Comparability will depend on how the segments are defined by each DNSP. If segments are defined similarly within each of the segment types suggested by the AER, intercompany benchmarking may be possible. Care should be taken in making comparisons as the AER definitions are broad and may interpret differently by DNSPs, which could result the AER benchmarking items that are not comparable.

Details have not been provided about what the intra-company benchmarking may include; however, this could include a calibration of the model output against previous expenditure levels similar to that undertaken when the Repex model was used in earlier determinations. A calibration of the model may be undertaken after the model has been populated with input data provided and compared to augmentation capex levels from previous years. If these levels are consistently higher or lower than the model forecast, a calibration of the results may be applied. The calibration of model forecasts against the DNSP's previous expenditure levels is one interpretation of intra-company benchmarking.

Another possibility for intra-company benchmarking is that the unit costs proposed for specific segments could be compared to actual costs of completed projects for similar works to establish intra-company benchmarks.

4.2 Unmodelled augmentation capex

The Augex model guideline acknowledges that there may be some augmentation capex not modelled by the Augex model approach; however, it makes it clear that the expectation is that the majority of augmentation capex is captured by the Augex model methodology. The example provided in the Augex model guideline to illustrate unmodelled augmentation capex is fault-level mitigation projects.

In discussion with CitiPower / Powercor it became apparent that there may be significant components of the capex forecast for this business that will not be captured by the Augex model approach. Some examples of unmodelled augmentation capex are:

- CBD security projects CitiPower is involved in

- Joint planning requirements likely to have a high level of capex for Powercor during the next regulatory period

- Projects driven by reliability criteria rather than insufficient capacity

4.3 Oversimplification of complex parameters

Analysing the customer-demand growth has become considerably more complex over recent years due to increasing customer awareness about the environmental cost of energy consumption and increasing retail power prices.

The rapid growth of embedded generation sources such as rooftop solar photovoltaic (PV) cells in response to government incentives has dramatically changed the shape of overall household consumption, leading to noticeable changes to the network utilisation. Forecasters are predicting that by 2020 as many as one in three residences will have a rooftop PV system. Typical system sizes increased from an average of 1.4 kW in 2008 to over 3 kW in early 2012.

Rooftop PV is a good example of a technology that will potentially change the utilisation profile and growth rate over time.

At this stage, the model can only accommodate a single demand growth rate figure and assumes that the utilisation profile will remain constant over time, which could significantly compromise the accuracy of any estimation.

Appendix A. Asset data worksheet description

"Asset Data" worksheet contents and location		COMMENT /CLARIFICATION REQUIRED
Columns A to E	Name of the segment and the category it belongs to	
Column G	Capacity factor is defined as "the proportion which defines the amount of capacity that is to be added to the network, eg if A= the capacity requiring augmentation and k= capacity factor, additional capacity = A* k".	The definition of the capacity factor is different from the conventional definition in generation . In generation, capacity factor $= \dfrac{\text{actual output of a power plant}}{\text{Potential output if fully operating}}$
Column H	The annual maximum demand (MD) growth rate of each segment	This information is reported in the RIN template
Column F	Unit cost	Clarification of the definition of unit cost is required. What components are to be included in unit cost, eg labour cost, materials, overhead etc.
Columns I & J	Utilisation threshold mean and utilisation threshold standard deviation	These are the key planning parameters which determine the amount of capacity requiring augmentation. It appears that the DNSPs will determine the values of these parameters for each segment. The parameters will firstly be entered into the DNSP template.
Column K	Augmentation method	The augmentation method is currently set to 1, representing a normal probabilistic algorithm.
Column L to FG	Asset utilisation profile	The utilisation profile is presented as a frequency distribution. Capacity at each utilisation level is calculated as the frequency during the year at each utilisation level multiplied by the rated capacity (MVA) of the segment. The proportion of total rating in utilisation band can be found in part 4 of the RIN template. In the RIN template, the capacity is calculated at an aggregated level (ie 0%-20%, 20%-40%, etc) whereas in the Augex model, capacity at each utilisation is required. This means certain approximations might be required when converting data from the template. A more precise way to populate the model, would be to produce a frequency distribution based on half-hourly or hourly meter data of the segment if such information can be provided by the DNSP.

Error! Reference source not found. provides an illustration of the Asset utilisation profile.

Appendix B. Utilisation profile summary worksheet description

"Utilisation profile summary" worksheet contents		COMMENT /CLARIFICATION REQUIRED
Column F	Total capacity	Total capacity is calculated by adding the capacities at each utilisation level.
Column H	Augmentation cost	Aug cost = total capacity * unit cost. This formula applies to both segments and segment groups.
Column M	Weighted average remaining utilisation (WARU)	The weighted average remaining utilisation is calculated by Sumproduct ((utilisation threshold-utilisation level),capacity at each utilisation level)/total capacity -0.5. The reason for subtracting 0.5% at the end is unclear.
Column O	Weighted average utilisation threshold (WAUth)	The weighted average utilisation threshold is calculated by the sum of individual utilisation threshold for each segment weighted by the segments augmentation cost.
Column Q	Weighted average utilisation (WAU)	For each segment, the weighted average utilisation is the difference between WAUth and WARU divided by WAUth in the Augex model. Further explanation of the purpose of this calculation would assist in understanding the model.
Columns R to V	Remaining utilisation	The utilisations are divided into 5 bands: ">1, >0.85, >0.5, >0.2, <=0.2". The Augex model calculates the remaining utilisation based on the weighted average utilisation threshold. It is calculated via WAUth*(1-utilisation band)
Columns W to AA	Augmentation cost in each band	Augmentation cost = Unit cost * Total capacity below utilisation threshold level.
Columns AB to AF	Proportion of utilised asset in each utilisation band	This is measured by augmentation cost.
Columns AG to AI	Max, min and average utilisation threshold in each segment group based on individual segment.	

Appendix C. Aug Forecast worksheet description

"Aug Forecast" worksheet contents		COMMENT /CLARIFICATION REQUIRED
Columns E to AX	Utilisation threshold mean and standard deviation	The values are taken directly from the "Asset data" worksheet
Columns AY to BR	Augmentation capacity added over the 20-year forecasting period	This is calculated via the Visual Basic function (Function Aug_calc (utilisation, capacity at each utilisation, growth rate, capacity factor, utilisation threshold mean, utilisation threshold SD, method, 20 (20 years)). Detailed explanation of the coding scheme is provided using flow charts in Figure 2-2, Figure 2-3, and Figure 2-4.
Columns BS to CM	20 years, year-by-year weighted average utilisation level of each segment	VBA calculation, detailed explanation provided in Figure 2-3
Columns CN to DH	Year-by-year forecast over a 20-year period of weighted average remaining utilisation	The remaining utilisation of each segment is calculated by weighted average utilisation forecast * unit cost which is inconsistent with the definition, ie utilisation threshold – utilisation
Columns DI to EB	Augmentation expenditure forecast	Forecast capacity added * Augmentation unit cost