2018-22

POWERLINK QUEENSLAND REVISED REVENUE PROPOSAL

APPENDIX 4.01

Nuttall Consulting - Review of AER Draft Decision

Delivering better value

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regulation and business strategy

Review of AER draft decision
Repex modelling advice

A report to Powerlink

Confidential final

9 November 2016

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Executive Summary

Introduction

The AER's draft decision has not accepted the component of Powerlink's replacement forecast, which Powerlink prepared using the AER's repex model. The AER developed an alternative forecast for this component of expenditure by extending the lives in Powerlink's repex model by one standard deviation.

Nuttall Consulting has been engaged by Powerlink to review the AER's reasoning on this matter. Dr Brian Nuttall, the original developer of the repex model, has conducted this review.

The AER's position was informed by an engineering review conducted by an external advisor, Energy Market Consulting associates (EMCa). A key part of the AER's reasoning for its position is that recent asset ages at replacement are longer than the lives Powerlink determined for the model.

Nuttall Consulting's review is limited to only the matters directly associated with the connection between asset replacement ages and the lives used in the repex modelling. It has not included other matters, such as the specific asset management findings of the project reviews conducted by EMCa or the other top-down techniques the AER applied, which are also relevant to the AER's final position. Further comments on the limitations of the Nuttall Consulting advice are included in the main body of this report.

Key findings

I consider that there are a number of flaws in elements of the AER's reasoning for extending the lives used by Powerlink in its repex model. The most significant of these are as follows:

- It is not appropriate to use only actual ages, as the AER and EMCa have, to estimate the mean life of the asset population. This method can be very biased as it does not allow for all the assets that have survived and the effect this information will have on the estimate of the mean life.
- My analysis indicates a greater level of consistency between the ages of actual replacements and what the model predicts via Powerlink's calibrated lives than suggested by EMCa and the AER. In my view, both EMCa and the AER have not sufficiently considered the age profile of the replacements, the age profile of the population, and the underlying survivor theory, when concluding that the actual replacement ages are not reflected by the model lives.
- I agree with the average age EMCa has calculated for towers. But this average age is driven by the diminishing numbers of a cohort of older towers that still remained on the network at that time. It would be expected that the final remaining towers in such a cohort would be significantly older than the mean age of the population. This finding is in accordance with the theory that underpins the repex model and is broadly consistent with the age of the towers that Powerlink's calibration model assumed would be replaced when calibrating the tower lives. Therefore, EMCa's observation regarding the average age of the replaced towers does

not, in itself, justify the need for an adjustment to the mean lives used in Powerlink's repex model for the towers population.

- Part of the reasoning for the AER and EMCa believing that model lives could be extended was that life extension techniques have not been allowed for by Powerlink. The ability of Powerlink to extend the model lives, via asset life extension techniques, is outside the scope of my review. But it is important to stress that for towers, life extension techniques are a major part of the Powerlink forecast and are allowed for in how Powerlink has applied the model for towers. As such, the Powerlink forecast for towers should be addressing EMCa and the AER's main concerns on this matter.
- The average ages reported by the AER and EMCa for switchgear and secondary systems are longer than the ages I have calculated from Powerlink data provided for this review. Contrary to the findings of the AER and EMCa, this data indicates that the average ages of the replaced assets are ***shorter*** than the mean lives used in the model. This finding seems to be in line with the theory underpinning the model, given the younger average age of the overall populations of these assets.
- Moreover, for the switchgear and secondary asset categories, my indicative analysis suggests that the inconsistency between the actual profile of replacement ages and what the model assumes, may well be slightly biased against Powerlink, not in its favour. That is, the mean lives Powerlink has determined for the overall populations may be slightly too long, relative to its recent past.

Given these findings, I do not consider it was valid for the AER to use its findings on actual ages, as it has, to support its argument for rejecting the Powerlink forecast and as a basis for calculating the alternative model lives it has used to produce its alternative replacement forecast.

1 Introduction

1.1 Background and scope

Powerlink has used the AER's repex model to prepare elements of its capital expenditure forecast for asset replacement activities, which forms part of its revenue proposal to the Australian Energy Regulator (AER), covering the period 2017/18 to 2021/22.

Nuttall Consulting was engaged by Powerlink to conduct a review of its application of the repex model, prior to the submission of Powerlink's revenue proposal. The report on this review (the original review report) was provided as a supporting document to Powerlink's revenue proposal[1].

The AER has published a draft decision on Powerlink's revenue proposal[2]. As part of this draft decision, the AER has rejected Powerlink's replacement forecast and developed an alternative and lower amount. This decision was informed by advice from an external advisor to the AER, Energy Market Consulting associates (EMCa)[3].

Powerlink has engaged us, Nuttall Consulting, to review and provide advice on the AER's draft decision, including the EMCa advice. This engagement focuses on the AER and EMCa's reasoning specifically associated with Powerlink's application of the repex model. Unless otherwise noted, references to the repex model refer to Powerlink's repex models submitted as part of its revenue proposal associated with the AER's draft decision.

This report details the findings of this review.

1.2 Capability to conduct the review

Dr Brian Nuttall has conducted this review and prepared this report.

Brian is the original developer of the AER's repex model. He also advised the AER on its application, including the method to calibrate the model's input parameters (i.e. asset lives and unit costs).

Brian has applied the repex model on numerous occasions, including when providing advice to the AER and to network service providers. There are numerous public reports associated with these modelling exercises available on the AER's website.

In addition, Brian conducted the original review by Nuttall Consulting of Powerlink's repex modelling, noted above, and prepared the original review report.

[1] Powerlink revenue proposal, Appendix 5.04, Nuttall Consulting Forecasting Methodology Review, November 2015
[2] AER Draft Decision, Powerlink transmission determination 2017-18 to 2021-22, September 2016 (AER draft decision)
[3] EMCa, Review of forecast non-load driven capital expenditure, July 2016, and Addendum report, August 2016.

1.3 Limitations of review and advice

The lives in Powerlink's repex model have been calibrated to reflect the replacement activities of the previous 5-year period (2010 to 2015)[4]. The AER's reasoning for its alternative replacement forecast is based upon its views that Powerlink's recent historical replacements do not reflect prudent and efficient activities. To support this view, it draws on findings and views from various argument streams, most notably:

- EMCa and its own analysis of historical replacement ages and views on the implications of these findings on the lives used in Powerlink's repex model
- EMCa's findings from detailed engineering reviews of a sample of historical projects
- top-down comparative analysis of other measures that the AER considers are relevant to Powerlink's historical replacements, including expenditure trends and various technical metrics (e.g. network age, asset utilisation, and network reliability).

Nuttall Consulting has been engaged to address the first stream, which is specific to Powerlink's application of the repex model and how the AER developed its alternative forecast.

This review has ***not*** involved any detailed engineering reviews of Powerlink's historical or forecast replacement projects. Furthermore, although in some instances I will touch upon matters associated with top-down considerations of Powerlink's repex modelling, this is only where it relates to specific matters raised by EMCa and the AER on Powerlink's application of the repex model.

For the avoidance of doubt, my findings presented here are largely independent of the views the AER may form from the other streams of its reasoning. Therefore, my findings, on their own, will not justify the appropriateness or otherwise of Powerlink's replacement forecast. Powerlink will still need to address the other matters that the AER draws into its reasoning for rejecting Powerlink's forecast and developing an alternative.

1.4 Structure

This report is structured as follows:

- Section 2 will set out some general theoretical matters related to the relationship between asset ages at replacement and asset population lives, which are relevant to the repex model and the AER's position.
- In Section 3, I will address the specific matters raised by the AER and EMCa on each of the three asset categories reviewed by EMCa, namely towers, switchgear, and secondary systems.

[4] Noting that Powerlink has made some adjustments to the raw actual volumes in order to calibrate the repex model.

2 Life calibration and asset replacement age

2.1 Introduction

I disagree with the AER and EMCa's view that findings on the actual ages of recent historical replacements can be used, as they have, to indicate that the repex model lives are too short.

In this section, I will discuss in general terms the theoretical considerations associated with the repex model and asset lives. I will demonstrate why actual replacement ages can provide a misleading view of the appropriateness of the mean life of an asset population.

The EMCa addendum raises concerns with the difference it has found between the actual ages of assets observed in the historical replacement projects that EMCa has reviewed and the lives used in the Powerlink repex model[5]. It uses these findings to support its argument that the repex model lives are too short.

This view is accepted by the AER and forms part of its reasoning for arguing that the lives used in Powerlink's repex model are too short[6]. Importantly, the AER uses the scale of the difference found by EMCa as a major factor in supporting it extending the lives in the model by one standard deviation in order to produce its alternative forecast[7].

The main concerns raised by EMCa and accepted by the AER appear to be twofold:

- It considered that there is an inconsistency between the average age at replacement of the actual assets it has reviewed and the lives used in the repex model, which Powerlink determined via the model's calibration process. It calculates that the average age is longer than the lives in the model, and considers that this finding supports its view that the model's lives are too long
- It notes the young age of some replaced assets and considers that this may be inappropriately reducing or biasing the calibration of the model lives, such that they are shorter than they should be.

I will address these two concerns separately below.

2.2 The average actual age at replacement as an estimate of the mean asset life

The average actual age at replacement for a sample of projects is **not** a good indicator of the mean replacement life for the overall asset population. It can be grossly misleading in

[5] EMCa, Review of forecast non-load driven capital expenditure – addendum report, August 2016, pp 34

[6] AER draft decision, Attachment 6, pp 6-44 and pp 6-46 to 6-47

[7] AER draft decision, Attachment 6, pp 6-48

extreme circumstances. Even if all projects over the calibration period are included, the average age of the replacements is still not a good estimate for the mean replacement life of the asset population.

As such, EMCa's findings on average replacement ages and their distance from the model lives should hold very little, if any, weight in the AER's reasoning for the repex model lives being too short.

In appreciating the theoretical reasons for this view, the following is relevant. When estimating the mean life of a population of assets from information, which reflects a short period in the overall life of the population (i.e. a period that is significantly shorter than the anticipated life of the assets), the age of assets at their time of replacement is only one part of the information that informs the estimate of the mean life of the population. The other equally important information concerns the ages of all the other assets that have *survived* over that period. That is, the mean life is a function of the volumes and ages of the assets that were replaced over this period ***and*** the volumes and ages of the assets that have survived over the period. Without this additional information on these survived assets, we are likely to have an estimate of the life that is biased towards the average age of the asset population. It is worth noting that this is the same point I made in my original review report, when raising concerns with Powerlink's draft modelling of towers[8].

This bias can be demonstrated by a simple example as follows[9].

Assume we have a population of assets that have all been installed in the same year, and the retirements for this population will be approximately normally distributed by age, such that the standard deviation is the square root of the mean replacement life.

Also assume that at the start of a 5-year observation period there were 500 assets in this population, which were all 25 years old. That is, we have 500 assets that we now know survived to be at least 25 years old. Furthermore, over the 5-year period, we know we retired 24 assets because they reached the end of their life. That is, these 24 assets were retired between the ages of 25 and 30 years.

If we use the average age at the time of retirement as an estimate of the life of the population, we will calculate this life to be approximately 27.5 years.

However, the actual mean life that would fit these assumptions is 40 years, which can be calculated by solving the following formula:

$$\frac{assets\ retired}{assets\ retired + assets\ survived} = \frac{\int_{age}^{age+5} N(mean\ life, SD)}{1 - \int_{age}^{\infty} N(mean\ life, SD)},$$

where *N(mean life, SD)* is the probability density function of the normal distribution. The left hand side of this formula is the proportion of assets retired over the 5-year observation period. The right hand side is a conditional probability, which represents the probability that an asset will be retired over this 5-year period, given it has already survived to the beginning of the period.

8 Powerlink revenue proposal, Appendix 5.04, Nuttall Consulting Forecasting Methodology Review, November 2015, pp 40.
9 Note, this is a simplified example to demonstrate the principles. I am not claiming that this represents an actual situation.

Alternatively, assume that at the start of a 5-year observation period there were still 500 assets in this population, but these were all 50 years old. Also, assume that over the 5-year period, we know we retired 425 assets because they reached the end of their life. That is, these 425 assets were retired between the ages of 50 and 55 years.

For these alternative assumptions, if again we use the average age at the time of retirement as an estimate of the life, we will calculate this life to be approximately 52.5 years. We may also mistakenly believe that this must be a very good estimate as it has been calculated from a very high proportion of the replaced assets (85%). However, using the formula above, the actual mean life that would fit these assumptions is still 40 years.

Clearly, in both cases, the average age of replacement is a very poor estimate of the mean life of the population.

I will discuss the consistency of the specific ages of Powerlink's asset replacements and the mean lives used in the model in Section 3 when I discuss EMCa's findings on specific asset categories.

2.3 The relevance of the distribution of actual assets ages on the calibration

The actual ages of the assets at the time of their replacement are ***not*** used in the method Powerlink uses to calibrate the asset life (or the AER has used previously to calibrate the repex model). As such, a finding that some assets within a sample of replacement projects have been replaced at an age much younger than the model life does not mean, on its own, that the model calibration has been, or would be, biased in some way towards a shorter life.

The calibration method used by Powerlink (and the AER) only makes use of the volume of replacements, not the ages at replacement. This method has inherent assumptions that the model set up (i.e. asset classifications) and retirement probability model (i.e. the normal distribution with the standard deviation set of the square root of the mean life) are approximately valid. That is, together they should represent the asset aging and replacement decision processes for that population.

In effect, this calibration method is implicitly assuming that the replacement profile forecast by the model over the calibration period is a reasonable representation of the actual replacement profile. It is not trying to "fit" a probability distribution to represent this profile. Therefore, the deduced mean life is sensitive to the volume of replacements it is calibrated to, but not the distribution of the ages of those replacements.

Importantly, related to the same points made above on the average age, there may well be assets that are being replaced at a much younger age than the mean life. Observing these younger replacements, does not on its own, mean that the life will be biased to be too short. The volume of these young replacements, or the proportion of these relative to older replacements, will depend on the overall age profile of the asset population. For example, if you have a population of assets that is dominated by a large number of young assets compared to older assets, you are likely to observe more assets being replaced at an age that is younger than the mean life of the population.

Therefore, what is more relevant to the accuracy of the model or any bias in its forecasting is the proportion of assets replaced at specific ages rather than the volumes at specific ages. As such, it is not valid to draw conclusions about the reasonableness of the model lives or infer any bias introduced by these lives because of the observed young ages of some replacements, ***unless*** the overall profile of asset replacement ages has been considered in the broader context of the age profile of the population and the underlying assumptions of the model. EMCa and the AER do not appear to have considered this latter matter when drawing conclusions from their findings on the ages of assets at their replacement.

I will discuss specific asset profiles in Section 3 when I discuss EMCa's findings on specific asset categories.

3 Asset category review findings

3.1 Towers

3.1.1 EMCa review

EMCa reviewed four of eight projects involving the age-related replacement of towers. These four projects covered 80% of the interventions (tower replacements or refits) used to calibrate the model lives.

EMCa's key findings specific to the repex modelling were as follows[10]:

- The repex model lives for towers could be too short because the average age of the sample towers at replacement were 12 years longer than the mean replacement life for towers in corrosion zone D, calibrated through the model (i.e. 52 years compared to 40 years for the model life)
- The tower replacement lives in the future could be even longer because historically Powerlink had not used life extension techniques.

The AER agreed with these findings[11].

3.1.2 Nuttall Consulting comments

3.1.2.1 Actual average age at replacement vs model life

I do not consider it is valid to draw a conclusion that Powerlink's calibrated tower lives are too short, based solely on the finding of the older average ages of replaced towers. EMCa's finding on the older age of replacements is broadly consistent with the Powerlink repex model calibration process.

The average age of the sampled projects is driven very much by three projects, which are related and cover 70% of the interventions used to calibrate the model lives. These three projects concern the replacement of the older grillage towers in Far North Queensland in the highest modelled corrosion zone (DEF).

The 2010 age profile used in the model indicates that these towers represent a large portion of the oldest towers in this corrosion zone still remaining on Powerlink's network. Therefore, noting the points made in Section 2 on the relationship between average age and asset lives, it should be expected that the average age of these towers will be noticeably longer than the mean life of the population of towers in this corrosion zone. As I understand matters, these towers reflect the remaining proportion of towers with a grillage foundation in the historical population, and so it is reasonable to consider that these remaining towers will have survived well beyond the mean life of that population.

[10] EMCa, Review of forecast non-load driven capital expenditure – addendum report, August 2016, pp 7-13
[11] AER draft decision, Attachment 6, pp 6-45

Furthermore, my analysis of Powerlink's calibration model suggests that there is not a major inconsistency in what the model is assuming will occur for the calibrated life and what has occurred over the calibration period. For the calibrated life, the calibration model predicts a very significant portion of these older towers were replaced. That is, it is these assets that the model is allowing for through its life calibration when ensuring its predicted volume of interventions matches the actual intervention numbers.

The important point here is that if we used the much older life suggested by the average age then the model would be inconsistent with what has actually occurred as it would no longer predict the need to replace these older towers.

Although I consider that EMCa's view on the relevance of the average age to the model lives is not valid, I have found two possible issues with Powerlink's modelling of towers through my analysis:

- Although as noted above there is not a major inconsistency in the older age of the replaced assets compared to the lives, I have found an inconsistency between the calibration volumes and the 2010 age profile. As I understand matters, the 2010 age profile does not include some of the replacement volumes used in the calibration because of when towers were removed and replacements commissioned. This difference appears to be a significant number, and therefore, it may be important to ensure that the calibration volumes and the 2010 age profile are consistent.
- Powerlink is calibrating the life to reflect the end-of-life of a tower (before a major intervention such as a replacement, life extension, or operational refurbishment). For the purposes of developing the forecast, a 5-year offset is then applied to this life to reflect Powerlink's view of the optimal economic timing for performing the life extension intervention. However, a noticeable portion (around 20%) of the calibration volume is this life extension intervention. Given this observation, it will be important to ensure that the interventions in the calibration period are reflective of the end-of-life timing.

3.1.2.2 Life extensions and model lives

The Powerlink forecast model allows for the types of life extension suggested by EMCa. Furthermore, the forecast average life of the towers population, allowing for the life extensions inherent in the forecast model assumptions, is significantly longer than suggested by Powerlink's calibration lives.

The EMCa addendum criticises Powerlink for not using life extension techniques historically, and suggests that the model lives could be extended further through more extensive use of these practices.

Obviously, it is valid that the lives of towers will be increased significantly if life extensions are applied. But this approach is consistent with how Powerlink has modelled tower interventions within its forecast repex model. The predominant end-of-life intervention assumed in the Powerlink forecast model *is* a life extension. I understand that Powerlink is assuming this intervention will achieve around a 20-year extension to the replacement life of towers. The only towers this assumption is not applied to in Powerlink's forecast are the very few remaining towers with grillage foundation, which Powerlink considers a life extension is usually not economic.

Because of how the forecast model is set up and applied, these much longer final lives for towers are not contained in the model. However, they are inherent in the forecast assumptions. Therefore, it is important to appreciate that the lives used by the Powerlink forecast model reflect the age of a tower for this initial life extension intervention. They are not the ultimate replacement life of a tower; these lives would be significantly longer as noted by EMCa.

For example, using the 20-year life extension anticipated by Powerlink, I have estimated through the Powerlink repex model that the average intervention life of its overall tower population will be 52 years. This is calculated directly from the lives used in the forecast model. But the average final replacement life for the overall population, subsequent to the anticipated life extensions allow for by the Powerlink forecast, will be much longer at 72 years.

This finding seems to be in line with EMCa's views on the future effects of life extensions and suggests the Powerlink forecast model is consistent with those views.

3.1.2.3 Other comments

EMCa has made general statements that imply Powerlink's tower lives are short compared to what EMCa may have expected[12]. However, I am concerned that the presentation of these lives in the context of the repex model and Powerlink's forecast could be misunderstood by others, resulting in incorrect inferences being drawn if these lives are compared to the tower lives of other TNSPs.

Much of EMCa's discussion on the Powerlink tower lives (either actual or used by the model) relates to towers in Powerlink's highest corrosion zones (DEF), which will have the shortest lives within the overall tower population. Furthermore, as noted above, for the majority of towers in the future, the model lives relate to the asset age relevant to the first major life extension activity or the life of the tower if this intervention was not applied. They do *not* reflect the age when the towers will ultimately be replaced, which I have shown above will be much later.

This should be an important consideration if the AER (or EMCa) is comparing (or benchmarking) Powerlink's model tower lives with the tower lives seen by other TNSPs. In this regard, any comparative exercise would need to allow for this high corrosion zone. It would also be important to ensure that equivalent lives are being compared. That is, Powerlink's model life for towers in a D corrosion zone needs to be compared against the tower age of other TNSPs when they perform their first major life extension work – not the life of the tower after this has occurred.

So for example, the more relevant comparisons of repex model lives for Powerlink's forecast against other TNSPs would be:

[12] EMCa, Review of forecast non-load driven capital expenditure – addendum report, August 2016, pp 9

- whether a mean age of 35 years for the first major refit/refurbishment of a tower in a high corrosion zone equivalent to Powerlink's DEF zone is appropriate
- whether a mean age of 53 years for the first major refit/refurbishment of a tower in a corrosion zone equivalent to Powerlink's C zone is appropriate.

It is also important that the lives being compared are derived using the appropriate probability theory and not lives deduced from the average age at replacement (as discussed in Section 2 above). For example, from Powerlink's forecast repex model, I estimate that the average age of the towers in the D corrosion zone that are forecast by the model to be refit in the next regulatory period will be 40 years old, which is noticeably older than the mean life for this intervention.

3.2 Switchgear

3.2.1 EMCa review

EMCa reviewed six projects involving the age-related replacement of switchgear. Only three of these projects covered assets replaced during the calibration period. Nonetheless, these three projects covered a significant proportion of the volume of replacements used to calibrate the model lives, ranging from 44% for circuit breakers to 65% for isolator and earth switches.

EMCa's key findings specific to the repex modelling for switchgear is that the repex model lives could be too short because the average age of the replacements it sampled were on average 7 years longer than the replacement lives calibrated through the model[13].

The AER agreed with this finding[14].

3.2.2 Nuttall Consulting comments

3.2.2.1 Actual average age at replacement vs model life

I do not consider it is valid to draw a conclusion that Powerlink's calibrated switchgear lives are too short, based solely on the finding of the average ages of replaced switchgear. From my analysis, the age of switchgear replaced over the calibration period is broadly consistent with the Powerlink repex model calibration process.

From the replacement data provided by Powerlink[15], I cannot replicate EMCa's finding that the average age at replacement is longer than the Powerlink's repex model lives. In fact, I find the opposite; the repex model lives are slightly longer than the average age of the replaced assets. This alternative finding seems to occur whether I use the projects sampled by EMCa or the full set of replacements provided by Powerlink. These alternative findings are summarised in Table 1 below.

[13] EMCa, Review of forecast non-load driven capital expenditure – addendum report, August 2016, pp 18-25
[14] AER draft decision, Attachment 6, pp 6-46
[15] "Switchgear Age Profile and Project Comparison.xls" provided in the email, dated 17/10/2016 and "Switchgear - Proportion of Equipment Removed.xlsx" provided in the email, dated 3/11/2016

The shorter age at replacement compared to the repex model life is in line with the discussion in Section 2 on average ages and replacement lives, whereby for switchgear the average ages of the asset populations are young compared to the asset lives. As such, it is expected that the ages of assets currently being replaced may appear lower than the repex model life.

Table 1 – model life and average age comparisons for switchgear

Asset	Repex model life	EMCa sample replacement age	Replacement age for all projects	Average age of age profile
Circuit breakers	34.2	30.3	31.4	17.8
Current transformers	33.2	32.1	28.6	16.8
Isolation and earth switches	39.8	36.2	36.1	20.1
Voltage transformers	34.6	29.7	29.8	17.0

Source - Nuttall Consulting analysis based on data provided by Powerlink

The consistency of the repex model and the actual observations can also be seen by comparing the age profile of the replacements with the 2010 age profile of the asset population. In this regard, if we compare the proportion of actual assets replaced at particular ages we should expect this to reflect the relevant conditional normal distribution (i.e. the probability an asset will be replaced over the 5-year period, given it survived to 2010).

This comparison is shown in the four figures below, which cover the four asset categories indicated in the table above. These figures show the proportion of actual replacements by installation date (blue bars) relative to the ideal proportion assumed by the repex model (red line)[16].

The figures show that the model provides a reasonable match to the actual replacements over the calibration period. These graphs *do* indicate that there is an increased number of young replacements than assumed by the model, most notably for circuit breakers and voltage transformers. However, if it is assumed that these replacements are valid and reflect a replacement process that is consistent through the calibration and forecast period, it suggests there may be some underlying dynamic that is not captured by the model. For example, a cohort of assets within the population that has a younger life and so could be modelled as a separate category.

[16] The profile of actual replacements is an estimate provided by Powerlink. The total volume of replacements in this profile does not fully correspond to the calibration volume. However, the difference is small and should not affect the inferences drawn from these figures.

Importantly, my indicative investigations through the model suggest that this model inaccuracy may be biased against Powerlink and not in its favour[17]. That is, this inconsistency is not shortening the overall population life; it is slightly increasing it.

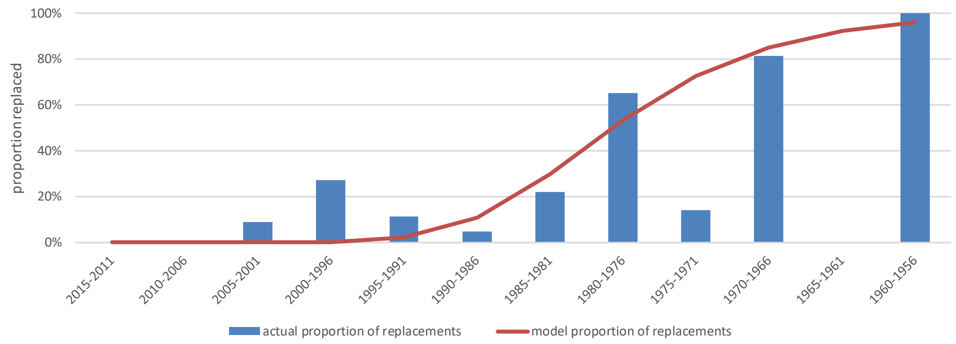

Figure 1 Proportion of replaced assets – circuit breakers

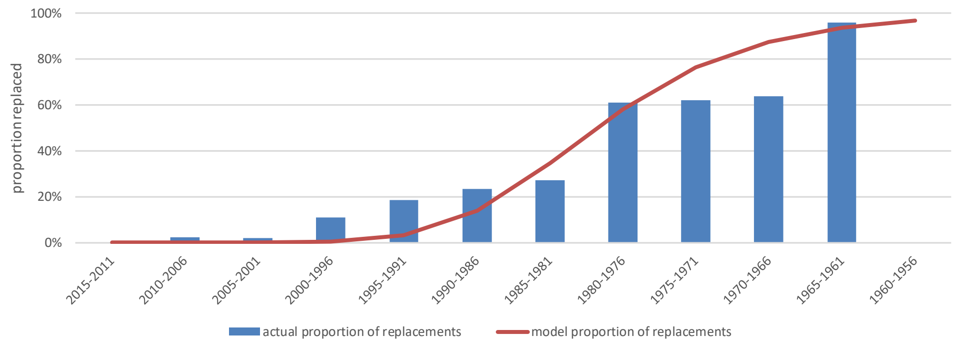

Figure 2 Proportion of replaced assets – current transformers

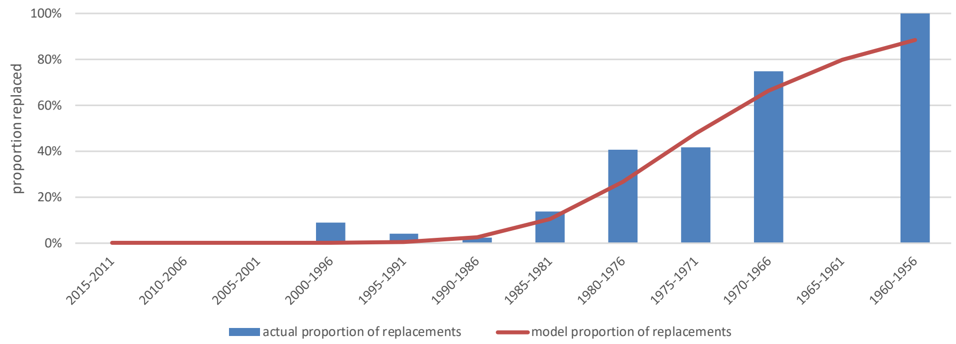

Figure 3 Proportion of replaced assets – isolating and earth switches

[17] To investigate this matter, I split each asset category into two. One reflects a small portion of the assets that may be replaced at a younger life. The second reflects the asset replaced at the normal life.

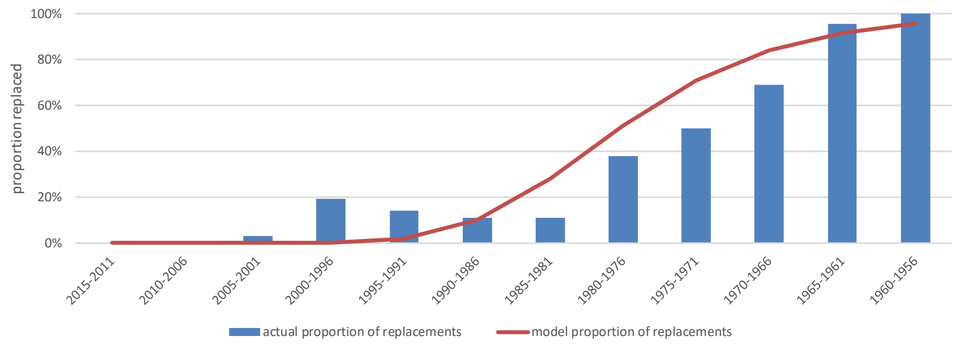

Figure 4 Proportion of replaced assets – voltage transformers

3.3 Secondary systems

3.3.1 EMCa review

EMCa reviewed five projects involving the age-related replacement of secondary systems. As I understand matters, this review only covered the bay/non-bay secondary system asset category, and did not include the communications asset category.

The projects covered 96 (31%) of the 312 secondary system replacements used to calibrate the Powerlink repex model.

EMCa's key findings specific to the repex modelling for secondary systems are[18]:

- the average actual age at replacement of the equipment is 7 years longer than the repex model assumes
- the actual age at replacement of the older equipment is significantly longer than the repex model life.

It also notes some other matters that are more relevant to engineering considerations, but do have some connection to repex modelling, namely:

- the "bundling" of the replacement of older and younger assets may be causing a "relatively" low life
- it may not be appropriate to model the iPASS secondary system replacement within the repex model, because it is a type-specific need that may not be reflective of the population.

The AER agreed with these findings[19].

[18] EMCa, Review of forecast non-load driven capital expenditure – addendum report, August 2016, pp 26-32
[19] AER draft decision, Attachment 6, pp 6-46

3.3.2 Nuttall Consulting comments

3.3.2.1 Actual replacements and the model life

I do not consider it is valid to draw a conclusion that Powerlink's calibrated secondary system life is too short, based solely on the finding of the longer ages of some replaced secondary systems.

From the replacement data provided by Powerlink[20], I cannot replicate EMCa's finding that the average age at replacement is longer than Powerlink's repex model lives. Similar to my findings above on switchgear, I find the repex model life is slightly longer than the average age of the replaced assets. This difference is most pronounced when I use the full set of replacements provided by Powerlink. My alternative findings are summarised in Table 2 below.

Table 2 – model life and average age comparisons for bay/non-bay secondary systems

Asset	Repex model life	EMCa sample replacement age	Replacement age for all projects	Average age of age profile
Secondary systems	20.2	20.1	17.7	12.8

Source – Nuttall Consulting analysis based on data provided by Powerlink

The shorter age at replacement compared to the repex model life is in line with the discussion in Section 2 on average ages and replacement lives, whereby the average age of the asset population of the secondary systems is young compared to the asset life. As such, it is expected that the ages of assets currently being replaced may appear lower than the repex model life.

With regard to the EMCa finding that the older replaced assets have an age older than the repex model life, this should not be a contentious finding. Unless an asset population has no assets older than the life, we should expect to see some assets being replaced at an age older than the mean life. Given the development of the Queensland network and typical asset lives, it should be expected that the secondary asset categories will have passed that point in time. As discussed in the section above on average ages, this finding is entirely consistent with the theoretical foundations of the repex model. If we have an age profile that extends across the mean life of the population then we should find some assets being replaced before the mean life and some assets being replaced after this life.

As with switchgear, the consistency of the model and the real world can be seen by comparing the age profile of the replacements with the 2010 age profile of the asset population.

Figure 5 below shows the volume of replacements by age relative to the age profile. Figure 6 shows the proportion of actual replacements by installation date relative to the ideal proportion assumed by the repex model (in a similar format to the figures shown above on switchgear).

[20] "Secondary Systsems.xlsm" provided in email dated 17/10/2016

These two figures show that there is a large increase in the volume of secondary systems installed from around 1995. The oldest of these are being replaced in increasing proportions. However, there still remains a smaller number of much older assets, installed from around 1975, which are still being replaced.

Figure 6 indicates that there is a modest inconsistency between the model and the actual replacement, where the spread of the age is wider than suggested by the model. This shape suggests that the model may not be capturing the replacement dynamics accurately. As discussed in my previous report, it suggests there could be two replacement mechanisms, one reflecting an asset technology with a short life and another one with a longer life[21]. As I also discussed in the original report, this often occurs when modelling secondary systems because the different technologies that have evolved over time have differing lives (i.e. the move from electro-mechanical relays to electronic, and then to microprocessor).

I have repeated the indicative analysis I applied in my previous report to investigate this matter[22]. In this analysis I have split the age profile into two and calibrated two separate lives: one reflecting a notional shorter age technology and one reflecting a notional longer age technology. Importantly, this revised analysis has found a similar result to that discussed in my original report: this model inaccuracy may result in a small bias against Powerlink rather than in its favour. That is, this simplification is causing a slightly longer aggregate life for the overall population rather than a shorter life.

Additionally, some of the inconsistency seen in the younger assets could be due to the replacement of the iPASS secondary systems, noted by EMCa. I will discuss the modelling implication of this further below.

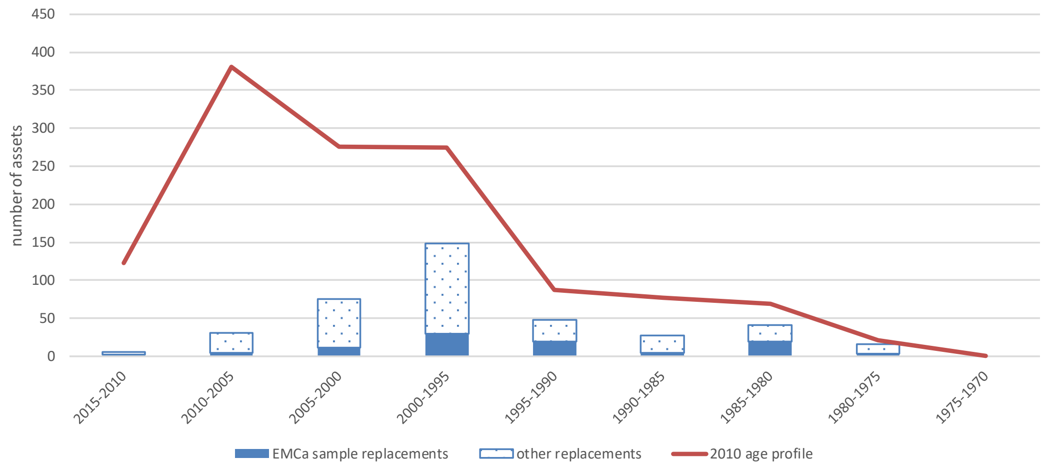

Figure 5 Secondary system age profile and replacement profile

[21] Powerlink revenue proposal, Appendix 5.04, Nuttall Consulting Forecasting Methodology Review, November 2015, pp 47
[22] Powerlink revenue proposal, Appendix 5.04, Nuttall Consulting Forecasting Methodology Review, November 2015, pp 47

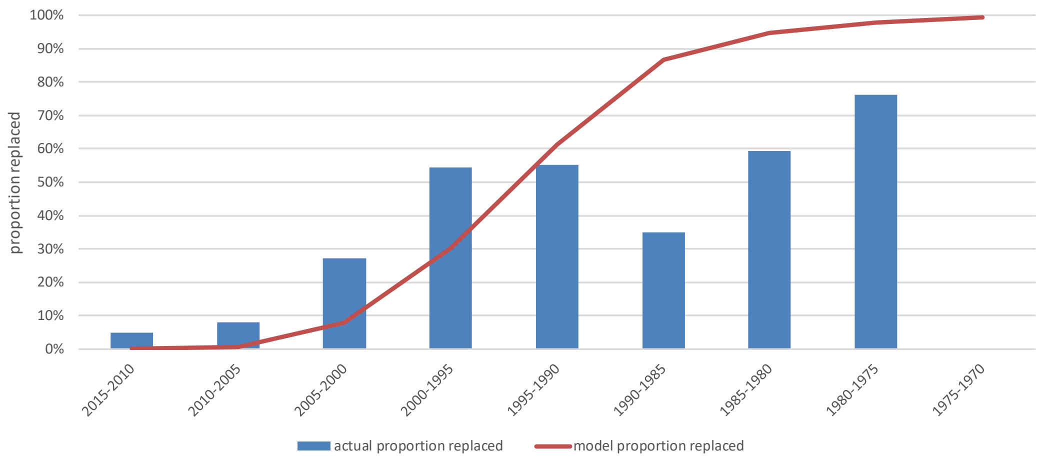

Figure 6 Secondary system proportion of replacements

Although I consider that EMCa's view on the relevance of the actuals age of replacements to the model lives is not valid, through my review I have found an inconsistency in the actual replacement volume discussed above and the volume Powerlink used to calibrate the mean life of the secondary system asset category.

In this regard, the actual replacement profile shown in the above two figures is derived from the difference between the 2015 and 2010 age profiles. The total volume of actual replacements calculated from this replacement profile is 398. However, the volume used to calibrate the model was 312.

Powerlink has advised that there are two reasons for this difference[23]:

- **Boundary issue** - the new asset that replaced the old retired asset was created in the Powerlink data system in the 2010 financial year. That is, it was created prior to the calibration period, based on the project closure date. However, the removal of the old financial asset from the data system occurred in the 2011 financial year.
- **Scope of works** - the switchyard was changed in size and/or reconfigured such that the asset quantity of secondary systems in the new switchyard reduced from those in the old switchyard.

Powerlink has also advised that this inconsistency should result in a longer calibrated life, rather than a shorter life, but noted that it was correcting some inconsistencies for its revised proposal[24].

I cannot claim that I have assessed this matter in any detail. Nonetheless, I would agree, in principle, with Powerlink that if the calibration volume has not included a portion of the asset retirements then the calibrated life would be longer than the true mean life for the asset population.

[23] Powerlink email, dated 8/11/2016
[24] Powerlink email, dated 8/11/2016

3.3.2.2 Other matters

With regard to EMCa's "bundling" concern, this matter is also raised by the AER[25]. Whether or not bundling is appropriate in any specific circumstance is an engineering consideration, which is beyond the scope of this advice. Nonetheless, it is worth noting that most NSPs will bundle these types of projects to some degree. Therefore, all NSPs' economic lives will capture bundling to some degree.

From the repex model's point of view, it is not concerned with what is driving the need to replace, only that in aggregate across the population it results in a distribution of lives that can be modelled. Furthermore, the calibration method is valid if it is reasonable to assume that "bundling" similarly affects the forecast period as it has the calibration period.

As such, the fact that Powerlink has "bundled", on its own, does not indicate that the model or its lives are invalid. This would need to be considered through the engineering considerations and/or through benchmarking of the lives. If benchmarking is used, then it will need to ensure it is normalised for the mix of Powerlink's secondary technologies.

With regard to the appropriateness of allowing for the iPASS technology in the model, it is correct that it would not be appropriate to allow for a type-specific short lived asset if the replacement was not consistent between the calibration period and the forecast period. In this circumstance, it would be appropriate to remove this asset type from both the age profiles and the calibration volumes, and forecast any needs for this asset type externally from the model.

However, it is also important to recognise that the model allows for a distribution in the economic lives of individual assets. Therefore, if this type-specific issue represents part of the distribution in lives across the population then it may not be necessary to remove this asset type from the model.

Noting my comments above on the causes and significance of the inconsistency between Powerlink's actual replacement profile and the model, Powerlink would need to consider this matter further to decide whether it is more appropriate to remove the iPASS secondary systems from the model and calibration process (i.e. the age profile volumes and calibration volumes).

[25] AER draft decision, Attachment 6, pp 6-44