Energy Infrastructure Investments

Directlink Joint Venture

Directlink
Revised Revenue Proposal

Attachment 5.4

Phacelift – Update to Bottom-up cost study

Effective
July 2015 to June 2020

January 2015

Phacelift

Bottom Up Cost Study – response to AER draft Determination

Abstract

Following the AER draft Determination on Directlink, the Directlink Joint Venture ('the Company') has removed the cable replacement program from operating expenditure. In its Revised Revenue Proposal these costs are now treated as capital expenditure. The Revised Revenue Proposal is supported by a Company prepared integrated Cable Replacement Program Business Case.

Consequently, the Bottom Up Cost Study (as submitted in May 2014) has been modified by the submission of this paper to remove:

- Company labour associated with cable repairs;
- Contractor labour associated with a cable fault;
- Costs associated with additional staff required to support the proactive replacement of the cables.

The Revised O&M model submitted with the Revised Revenue Proposal incorporates these changes. To assist the AER two sheets has been added to the Revised O&M model. One sheet presents the revised operating expenditure. The other sheet presents costs which have been reallocated from the original operating expenditure to capital expenditure[1].

This paper also undertakes a more detailed analysis of the historical cable faults to show that it is highly likely that cable faults will remain significantly greater than the three suggested in the AER's determination. Based on the known deteriorated state of the cable and its historical performance, the paper explains that the number of faults is more likely to exceed 7.5 per year and could be as high as 14 per year. This range is in the vicinity of 11.5 cable faults (on average) per year that were used as a basis for the May 2014 Bottom Up Cost Study.

This paper also advises on other changes made to the Revised O&M model. For example, the escalation rates for labour and materials have been set to 0% as requested by the AER.

Changes to the Revised O&M model

The O&M model submitted to the AER in May 2014 has been revised (the 'Revised O&M model') to incorporate the following changes.

Cable replacement strategy – CAPEX

The Company's Revised Revenue Proposal has acknowledged that labour costs associated with the proactive cable replacement strategy (included and costed in the Bottom Up Cost Study) should be treated as capital expenditure. The total expenditure includes cable purchase, cable joint purchase and

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[1] Note that the model's underlying design (and hence integrity) hasn't been modified in this change. Rather, the model uses two settings (TRUE and FALSE) in the 'Modelling Assumptions' worksheet to provide the revised data for operating expenditure and capital expenditure. The model then uses simple macros to paste the results of the two settings into the 'Summary OPEX' and 'Summary CAPEX' worksheets, as appropriate.

the additional staff required to support the proactive maintenance scenario (The Bottom Up Cost Study only recognised the cost of the cable and cable joints as being capital expenditure).

So that the AER can confirm the modifications an option has been added allowing the AER to view costs which have been excluded from OPEX. Using the option, identified costs can either be treated as OPEX (as per the original model) or ignored (as required in the Revised model). A new sheet 'Summary CAPEX' identifies the previous costs that are now considered to be capital expenditure.

CAPEX and OPEX costs in the Revised O&M model

The expenditure assigned to CAPEX in the Revised O&M model is as follows:

Table 1: Expenditure assigned to CAPEX in the Revised O&M model

(2014$)	2015/16	2016/17	2017/18	2018/19	2019/20	Total
APA Staff Costs	$475,159	$475,159	$475,159	$475,159	$475,159	$2,375,794
APA Material Costs	$6,600	$6,600	$6,600	$6,600	$6,600	$33,000
Contractor Labour	$250,363	$250,363	$250,363	$250,363	$250,363	$1,251,816
Contractor Materials	$0	$0	$0	$0	$0	$0

Whilst this expenditure is calculated in the Revised O&M model, it has been reported in the CAPEX part of the Revised Revenue Proposal. Table 1 has set the rates of escalation for labour and material to 0% (the original modelling assumed an annual rate of 2.5% and 3% respectively), and the MOMSCA percentage to 10% in accordance with instructions from the Company.

The remaining expenditure in the Revised O&M model has been allocated to OPEX, as follows:

Table 2: Expenditure allocated to OPEX in the Revised O&M model

(2014$)	2015/16	2016/17	2017/18	2018/19	2019/20	Total in AER Period
APA Staff Costs	$650,294	$517,292	$524,084	$522,525	$520,019	$2,734,214
APA Material Costs	$1,158,444	$1,072,898	$1,083,568	$1,082,463	$1,098,633	$5,496,007
Contractor Labour	$935,542	$454,540	$513,032	$463,865	$478,877	$2,845,857
Contractor Materials	$4,862	$4,400	$4,400	$4,400	$4,400	$22,462
Total in FY	$2,749,143	$2,049,129	$2,125,084	$2,073,254	$2,101,929	$11,098,539

In addition to the rates of escalation being set to 0% and the MOMSCA set to 10%, Table 2 also shows:

- the effects of adopting the Gotland solution for the Phase Reactors. From FY 2016/17 the dry ice cleaning of the phase reactors is no longer required. Rows 55 to 60 in sheet 104(2) have been added to reflect this change. The impact of the change is to add an expenditure of $553 per year for the inspection of air filters in the remaining 4 years of the regulatory period (compared to the AER draft Determination of $0 per annum). The total expenditure on this item for the regulatory period has changed from $96,099 (AER) to $108,142.

- the effect of adopting the proactive cable replacement strategy. The number of cable outages per year have been increased from 3 (AER) to 12[2]. This change has resulted in a change in expenditure for Prestart Inspections from $23,079 (AER) to $38,826.

Green shading has been used throughout the model to identify changes made in the model.

Cable Fault Analysis

Impact of Cable Faults

The Bottom Up Cost Study adopted the historical number of cable faults (on average 11.5 per year have occurred) as the value for determining the bottom up operating expenditure. The modelling assumed that this number of cable faults would continue during the next regulatory period unless further maintenance strategies were deployed by the Company.

Rectification of each cable fault is a labour intensive process involving a considerable number of Directlink and contractor staff hours. The Bottom Up Cost Study determined that 11.5 cable faults per year would contribute $1.846 million to the budget (excluding the MOMCSA overhead but including escalation), as shown in Table 3.

Table 3: Cable Repair Costs shown in original submission (excluding MOMCSA overhead)[3]

With Escalation (2014$)	2015/16	2016/17	2017/18	2018/19	2019/20	Total in AER Period
APA Staff Costs	$115,994	$118,894	$121,867	$124,913	$128,036	$609,705
APA Material Costs	$5,923	$6,100	$6,283	$6,472	$6,666	$31,443
Contractor Labour	$229,162	$234,891	$240,763	$246,782	$252,952	$1,204,549
Contractor Materials	$0	$0	$0	$0	$0	$0
Total						$1,845,697

The Bottom Up Cost Study found that the high number of cable faults was contributing to a reactive maintenance regime. When a cable fault occurs the affected Directlink System is off-line until the fault is repaired. During the repair Directlink staff are heavily involved in coordination of the repair and were therefore unable to perform their normal duties. For safety reasons during the cable repair other Systems may also be taken out of service.

The Bottom Up Cost Study showed the considerable staff effort involved in the repair of each fault (95 hours per fault). While coordinating the repair of faults Directlink staff are forced to defer normal duties. Once the repair was complete they then have to catch up on the work that was deferred.

This reactive environment prevented the existing staff from undertaking the necessary planning to move to a proactive cable replacement program, and was likely to result in a continuation of the current high rate of cable faults. The Bottom Up Cost Study noted that insufficient resources were available in this reactive environment to analyse where cable faults might occur. Unless spare skills were available (a) to analyse likely failure locations, (b) to plan for the cable replacement, and (c) to update documentation

[2] This change has been made in accordance with the Cable Replacement Program Business Case.
[3] Note that these costs have been allocated in total to capital expenditure.

to match current conditions, the Company will not be able to show any substantial reduction in average cable faults from that estimated by this analysis.

The Company has recognised this issue by including the need for additional staff in the Cable Replacement Program Business Case.

Data set used in the analysis

The analysis presented in this paper relies on the same basic data set as provided to the AER in the first submission, with further data added to both ends of the data set. The additional data sets have been included to remove doubt about the use of 11.5 cable faults per year (on average) presented in the Bottom Up Cost Study.

Historical Cable Fault Data

The following plots the number of cable faults that have occurred on Directlink since Financial Year 2002/03.

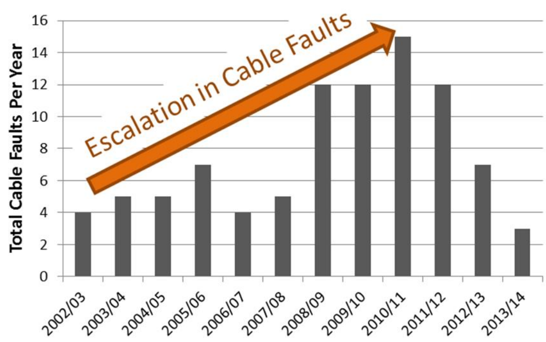

Figure 1: Total Cable Faults FY 2002 to 2013

Figure 1 shows that the number of cable faults has increased from 4 in FY 2002/03 to 15 in FY 2010/11. Fitting a straight line to the 9 years of observed cable faults (from 2002/03 to 2010/11) indicates that over this period cable faults have increased by an average of 1.28 faults per year. The sustained rate of increase suggests that the reliability of the cables is deteriorating.

The equation of the line of best fit can be used to estimate the number of future cable faults. This prediction is based on an assumption the Company continues the purely reactive maintenance strategy utilised from FY 2002/03 to FY 2010/11.

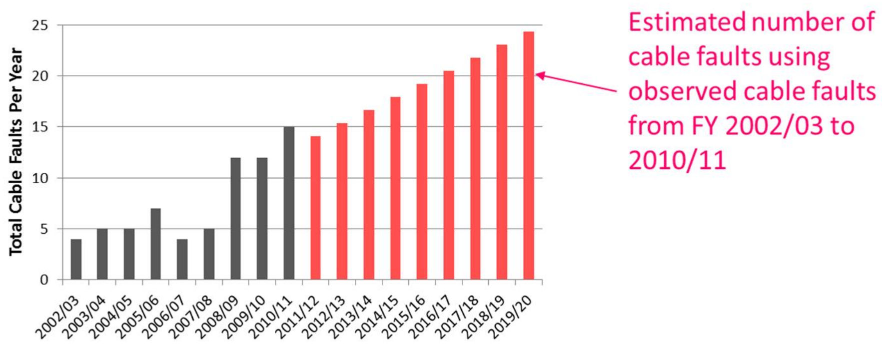

Figure 2: Using historical data to estimate cable faults to FY 2019/20

Figure 2 uses historical data to estimate the number of cable faults with no strategic intervention by the Company. The figure reveals that the number of cable faults would reach 23.35 in FY 2019/20. Facing the possibility of such an unacceptably large number of cable failures the Company had trialled a program of replacing a few larger sections of cable over the last few years. Analysis of cable fault data indicates the trial has controlled the escalating trend shown in Figure 2. This point is discussed in the following sections.

Role of the cables

Directlink transmits power using direct current (DC). The incoming AC mains power is converted into DC where it is carried on a pair of cables to the other end of the link. At the other end of the link the DC power is converted back to AC mains power.

Directlink actually comprises three separate DC cable systems ('Systems'). Each System comprises a converter station at each end of the link and a pair of DC cables ('cables') connecting the two converter stations. The cable route between the two converter stations is just under 60km in length as noted in the following figure:

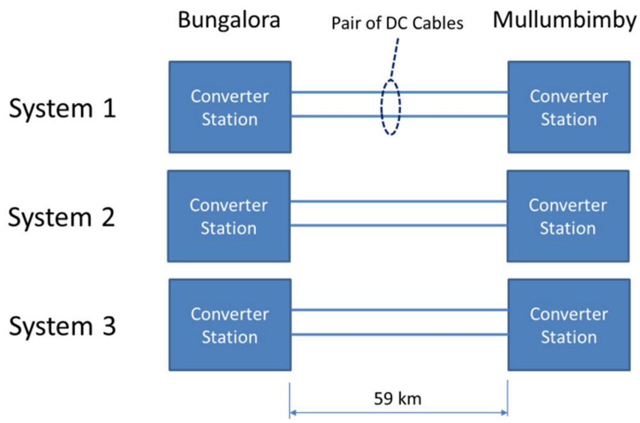

Figure 3: Directlink comprises three separate Systems

As shown in Figure 3 Directlink consists of a total of six cables across the three Systems. The six cables are all installed next to each other. They are buried under-ground or laid in Galvanised Steel Trough above ground.

Each cable pair is dedicated to one pair of converters. When a cable fault occurs the affected system is removed from service until the cable fault is repaired. The six cables all lay next to each other so for safety reasons during a cable repair it is necessary to de-energise the remaining Systems whenever personnel may come into contact with the live cables.

Repairing a cable fault requires the exact position of the fault to be located. Then the cable must be exposed. Significant earthworks are required when the fault has occurred in a section of the underground cable. No earthworks are required when the fault occurs where the cable is located above ground. A section of cable is then removed around the cable fault and sufficient new cable installed to replace the removed section. During the cable repair two new cable joints are installed either side of the fault.

Replacing longer sections of cable

A cable fault can allow water ingress to the affected cable. The water can then lead to degradation of the cable for some distance around the original fault. In these areas cable degradation increases the likelihood of multiple failures around the original fault (fault clusters). The Company has responded to these fault clusters by trialling the replacement of longer sections of cable around the original fault to reduce the possibility of further faults near that location. The first such trial replacement of approximately 300 metres of cable occurred on System 2, in July 2010. This was followed by longer sections of cable being replaced on System 1 in June 2011 and on System 3 in July 2011. Over the past 3 years trial replacements of longer sections of cable have replaced approximately 2 km of old cable. The trial has shown that the strategy is likely to reduce the number of cable faults. The trial highlights that the proactive maintenance strategy detailed in the Cable Replacement Program Business Case will successfully reduce the number of cable faults.

The following figure shows the number of cable faults since the introduction of the trial replacements.

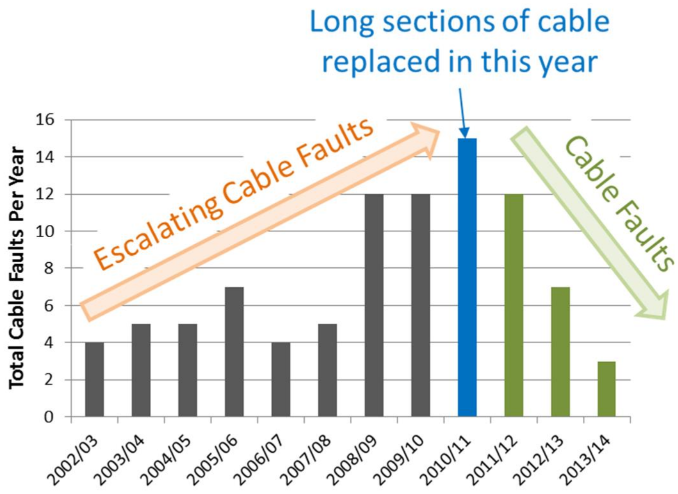

Figure 4: Cable Faults highlighting the years that longer sections of cable were replaced

Figure 4 shows the total cable faults on the Directlink Systems from FY 2002/03 to FY 2013/14. The replacement of longer sections of cable occurred across the FY 2010/11 which is shown as the blue bar in the figure. Figure 4 presents the cable faults at an aggregated Directlink level.

Figure 4 shows the reducing trend of cable faults in the last three Financial Years (shown as green bars). The downward trend observed in this aggregated analysis fails to recognise the consequences of sustained system outages due to the Mullumbimby converter fire in August 2012.

To analyse the impact of the Mullumbimby converter fire it is necessary to analyse cable fault data for each System individually.

More detailed Cable Fault analysis

The more detailed analysis starts by examining cable faults occurring on each System[4] for the period FY 2002/03 to 2013/14.

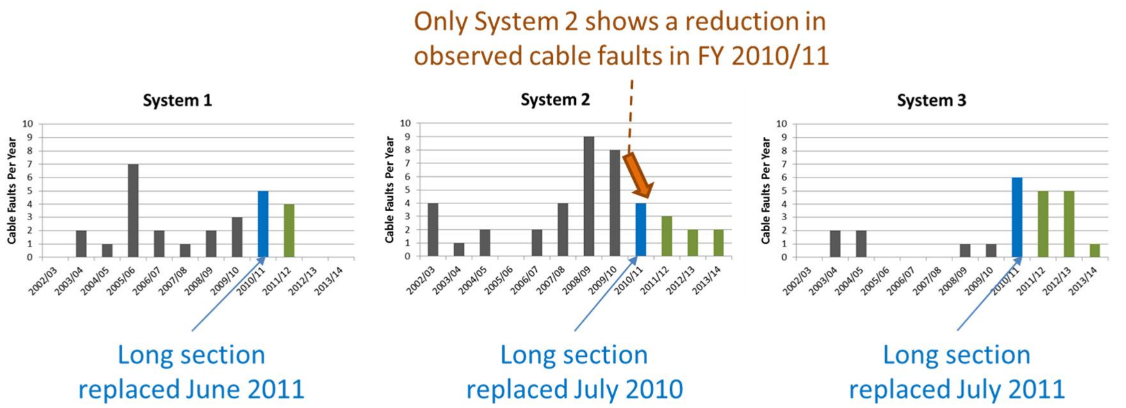

Figure 5: Observed Cable Faults per System 2002/03 to 2013/14

The first observation from Figure 5 is that cable faults on each system are (largely[5]) independent of the other Systems. The next observation is that only System 2 shows a reduction in the cable faults in FY 2010/11. This is not a surprising result since the replacement of a large section of cable around observed fault clusters only occurred on Systems 1 and 3 at the very end of FY 2010/11.

The green bars in Figure 5 show years after the replacement of a larger section of cable. For all three Systems the figure shows that in 2011/12 there was a decreased number of cable faults compared to the year in which the larger length of cable were replaced.

Looking at FY 2012/13 and 2013/14 there is an apparent decrease in the number of cable faults occurring on System 1. This lack of failures is actually a consequence the Mullumbimby Converter Fire which occurred in August 2012. The converter station was completely destroyed forcing the System 1 cable pair out of service. Cable faults can only be detected when the System is energised which will not occur until the converter station is replaced in late 2015. The number of cable faults occurring on System 1 will not be known until after this date. For the purposes of further analysis it is assumed that once energised the System 1 cables will show a similar number of cable faults to that observed on Systems 2 and 3.

A review of the Mullumbimby converter fire recommended that the other two converter stations be shut down. This occurred in August 2013 through to the end January 2014 (a total of 6 months).

The replacement of large sections of cable on all three systems in FY 2010/11 means it is not possible to rely on prior cable faults when estimating future cable faults (this analysis was shown in Figure 2). In addition, the Mullumbimby converter fire in August 2012 resulted in extended outages for the three Systems. These factors mean that cable faults occurring after large sections of cable were replaced must

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[4] Refer to the Appendix for a brief explanation of System versus individual cable analysis.
[5] A fault on one cable has occasionally affected the other cable in the pair. To-date a cable fault on one system has not caused a cable fault on another system.

be adjusted to reflect what would have occurred if the Systems had been available. This adjustment provides a realistic estimate of the aggregated number of Directlink cable faults.

On page 7-19 of Attachment 7 'Operating Expenditure' the AER determination Note 33 states:

> The 7.5 faults in 2013 is imputed due to the varying numbers of circuit outages over the period

The note indicates the AER's acceptance that the number of cable faults should be adjusted to account for system availability.

System Availability

The following figure plots the availability of each system. The availability is calculated as the number of hours the system is available over the financial year.

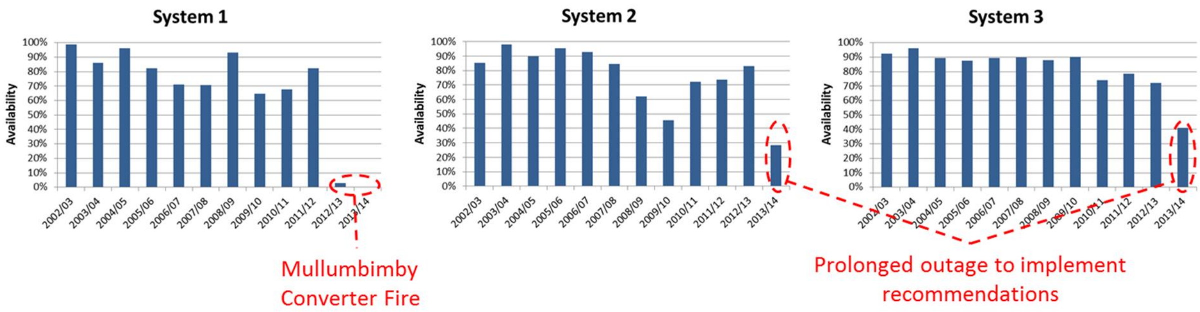

Figure 6: Availability for each System

As expected, Figure 6 shows the shut-down of System 1 after the Mullumbimby converter fire. System 1 was (largely) unavailable in FY 2012/13 and totally unavailable in 2013/14. The subsequent 6 month shut-down of Systems 2 and 3 are also clearly shown in FY 2013/14.

Adjusted Cable Faults

Adjusting the observed cable faults shown in Figure 5 by the system availability shown in Figure 6 results in the following figure:

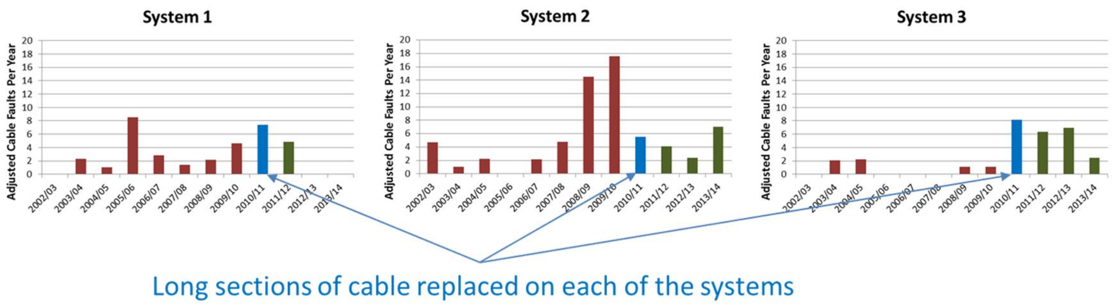

Figure 7: Adjusting Cable Faults by System Availability

Referring to Figure 7, all three systems show that the number of cable faults decreased in the first full year after the replacement of a large section of cable in FY 2010/11. In all three systems the decrease is relatively minor. The figure also shows that the trend does not continue. On System 3 faults increase in 2012/13 and on System 2 faults increase (significantly) in 2013/14. This suggests that while the trial replacements of longer sections of cable has addressed the fault clusters it has not adequately address cable degradation which has occurred around earlier cable faults.

Table 4 shows the information available from Figure 7 that can be used to estimate cable faults during the three years following the commencement of the trial cable replacement program.

Table 4: Summary of Adjusted Cable Faults after large sections of cable replaced

Year	FY 2011/12	FY 2012/13	FY 2013/14	Average
System 1	4.85	-	-	4.85
System 2	4.07	2.41	7.01	4.50
System 3	6.35	6.93	2.42	5.23
Total	15.27	14.00	14.15	14.58

The Mullumbimby converter fire means that there is no information available from System 1 for FY 2012/13 or 2013/14. The Totals shown in the table for FY 2012/13 and FY 2013/14 uses the average of the adjusted cable faults on Systems 2 and 3 as a proxy for System 1 (4.67 in FY 2012/13 and 4.72 in FY 2013/14). The estimated average value of 14.58 (based on the System 1 value of 4.85) over the three year period provides an indication of the level at which the upward trend identified in Figure 2 will flatten out.

This average points to the realisation that the number of cable faults going into and throughout the next regulatory period will be well in excess of three cable faults per year (as determined by the AER) and even higher than 7.5 cable faults per year (acknowledged as a possibility by the AER)[6].

Inclusion of FY 2014/15 data in the analysis

Table 4 did not include data for FY2014/15. At the time of writing only 5 months of data was available and it is unreliable to use this data because less cable faults occur in July to October than November to April, as shown in Figure 8.

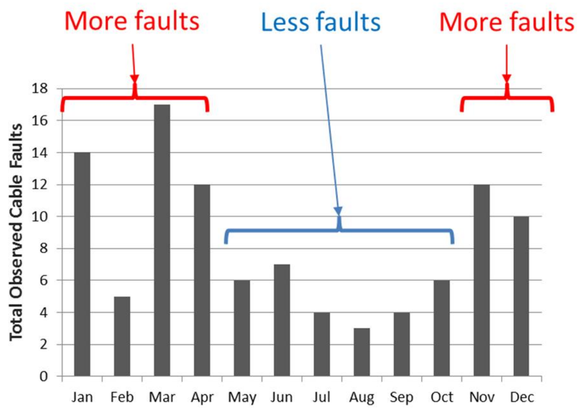

Figure 8: Observed cable faults plotted per month

Figure 8 reveals that historically less cable faults occur in May to October and more cable faults occur in November to April.

[6] Refer to Note 33 on page 7-19 of Attachment 7 in the AER draft Determination (also quoted above).

Historically less than a third of observed cable faults have occurred in the 5 months from July to November compared to the full year. It is also acknowledged that Figure 8 includes cable faults occurring before the large sections of cable were replaced. The level of uncertainty around appropriate adjustments when partial year data is available would introduce an unacceptable level of uncertainty in any estimate of historic cable fault trend. As such the partial data from July 2014 onwards have not been included.

Analysis based on monthly data points (12 month 'rolling window' average)

To complete this analysis we present the 12 month average of cable fault data for each System calculated using a rolling average rather than on an annual basis. This calculation is performed in exactly the same manner as the Financial Year analysis presented above[7]. The results are shown in Figure 9.

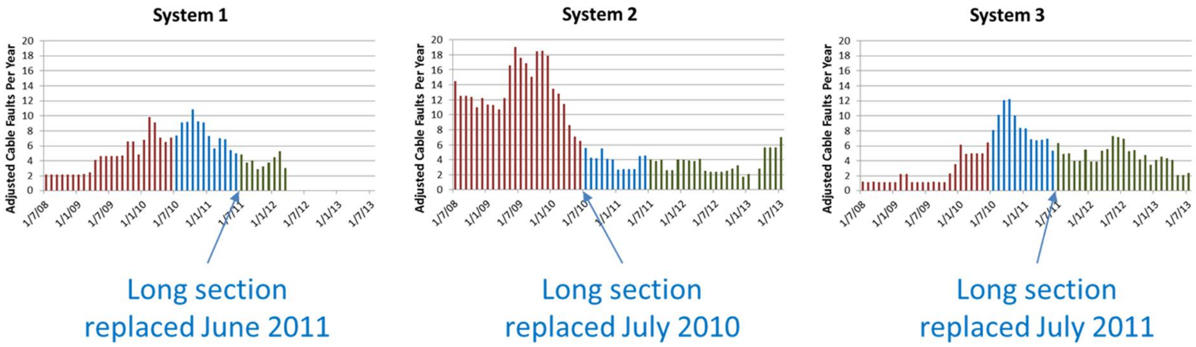

Figure 9: Adjusted cable faults calculated monthly[8]

Figure 9 provides a useful presentation (and visual confirmation) of the results shown in Table 4 for validation purpose. Specifically for System 2 cable faults increase in the last financial year of the analysis while for System 3 they decrease. The figure shows that replacing a few larger sections of cable on each System have resulted in the number of cable faults remaining relatively flat. The figure does not show any downward trend in the number of cable faults since the trial replacements were undertaken.

We conclude this analysis by showing anticipated aggregated cable faults when the Mullumbimby converter fire is taken into consideration.

[7] That is, the number of cable faults occurring in a 12 month period is adjusted by the system availability over the same 12 month period.

[8] To remove ambiguity each calculation uses a full year of data looking forward from the date shown in the axis

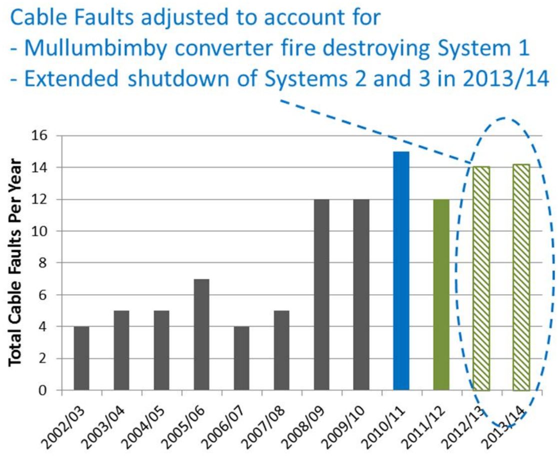

Figure 10: Total cable faults once adjustments are made for the Mullumbimby converter fire

Figure 10 highlights that the AER determination didn't consider the consequences of the Mullumbimby converter fire. There is no evidence that the total number of cable faults for all three Systems will decrease to three per year during the regulatory period, or in fact will be as low as 7.5 cable faults per year (acknowledged by the AER). Based on past performance Table 4 shows that once all three Systems become available cable faults are likely to be in excess of the three per year suggested by the AER.

Cable fault trends under different scenarios

This section projects the cable faults the Company would be exposed to under several scenarios.

- Scenario 1: Short section cable repairs (~5 metres of cable)
- Scenario 2: Longer sections of cable are replaced around a cable fault in a known trouble spot (~250 metres of cable)
- Scenario 3: Proactive cable replacement (as detailed in the Company business case)

Scenario 1 (Short section cable repairs)

Without the replacement of degraded sections of cable, fault clusters will not be addressed. The estimated number of cable faults will return to the trend shown prior to the trial replacement of longer sections of cable. Analysis shows faults will increase by an average of 1.05 faults per year. The results of this trend are shown in Figure 11:

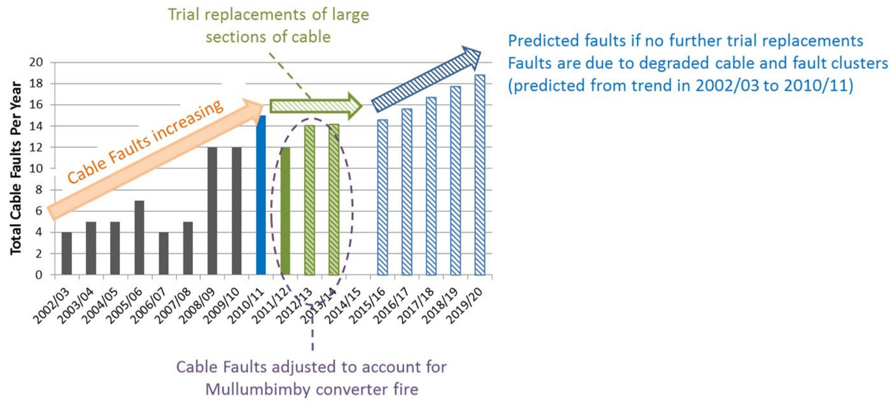

Figure 11: Estimated cable faults for Scenario 1 (reactive cable repairs)

Scenario 2 (Longer section cable replacements around a cable fault in a known trouble spot)

The trial of strategic replacement of long sections of cable around some cable faults has been shown to address the cable fault clusters. While this repair strategy has successfully arrested the increasing number of cable faults, it has not decreased the number of cable faults. Table 4 shows the estimated number of cable faults (due to degraded cable) continuing at an average well in excess of the 7.5 cable faults per year (suggested by the AER). The results of this trend are shown in Figure 12).

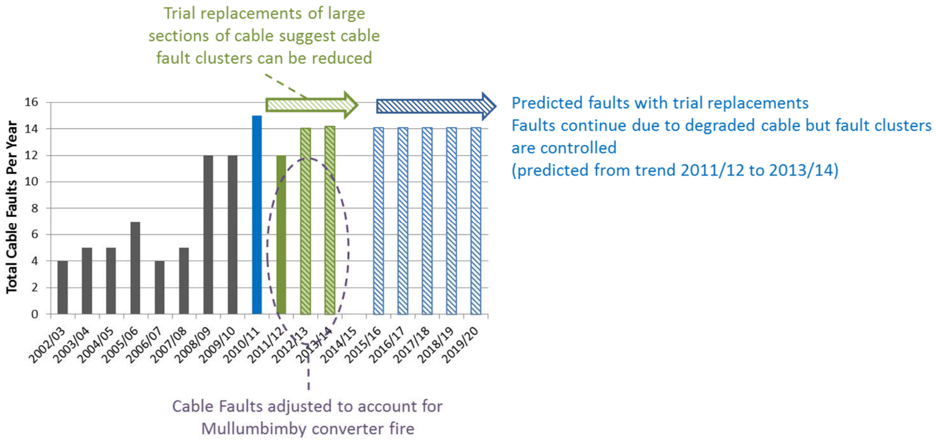

Figure 12: Estimated cable faults for Scenario 2 (continued strategic replacement of longer sections of cable)

Scenario 3 (proactive cable maintenance)

The Company business case outlines a program of work replacing 250 metre sections of cable 12 times each year. This proactive maintenance strategy requires analysis to identify sections of cable likely to have been degraded by earlier cable faults. Replacing degraded sections of cable before faults occur should reduce the number of unplanned cable faults. As the number of unplanned cable faults decreases this allows the company to undertake more planned cable replacements.

While the number of unplanned cable faults is likely to be high in the first year, the unplanned faults still provide an opportunity to replace degraded cable (for example a fault occurring on one cable can use the existing earthworks to replace a section of an adjacent cable). In future years the strategy is expected to result in less unplanned cable faults allowing an increased number of planned cable replacements.

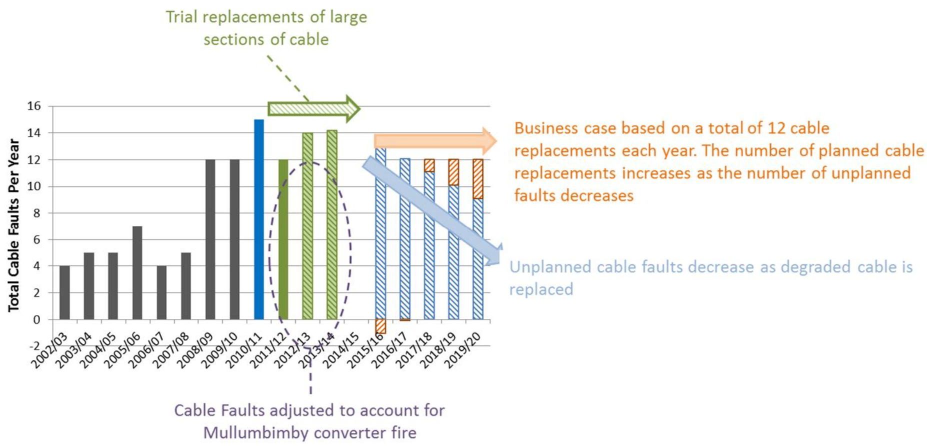

Figure 13: Scenario 3 proactively replaces 12 sections of cable each year

Figure 13 shows that there will be 12 cable replacements each year. The actual split between planned and unplanned cable replacements is somewhat irrelevant so the figure has simply assumed a small linear decrease in the number of unplanned faults over the next regulatory period to highlight the estimated trend due to the proactive strategy[9].

Conclusion

The paper has reported the changes made in the Revised O&M model that have reduced the total operating expenditure from $15.121 million without escalation (in the May 2014 submission) to $11.098 million without escalation. The primary reason for this reduction is the Company's decision to treat the expenditure as CAPEX (therefore removing it from a calculation of OPEX).

In addition, a detailed analysis has been presented clearly showing that the number of cable faults experienced by the Company in the next regulatory period will be in excess of the three per year determined by the AER, and most likely to be in excess of 7.5.

Details of justification for cable replacement capital expenditure, and the staff required to support this work, have been transferred to the Company's Cable Replacement Program Business Case, as reported in the Revised Revenue Proposal.

[9] While the actual split between planned and unplanned cable replacements is largely irrelevant it is noted that as planned outages replace more degraded cable the number of cable faults (causing unplanned replacements) should show an overall decreasing trend.

Appendix

Analysis on an individual cable basis

It is acknowledged that detailed analysis should have considered the six cables separately. Instead the analysis presented in this paper has used the information made available to the AER during its determination. Purely for completeness the observed cable faults on the six cables are shown below.

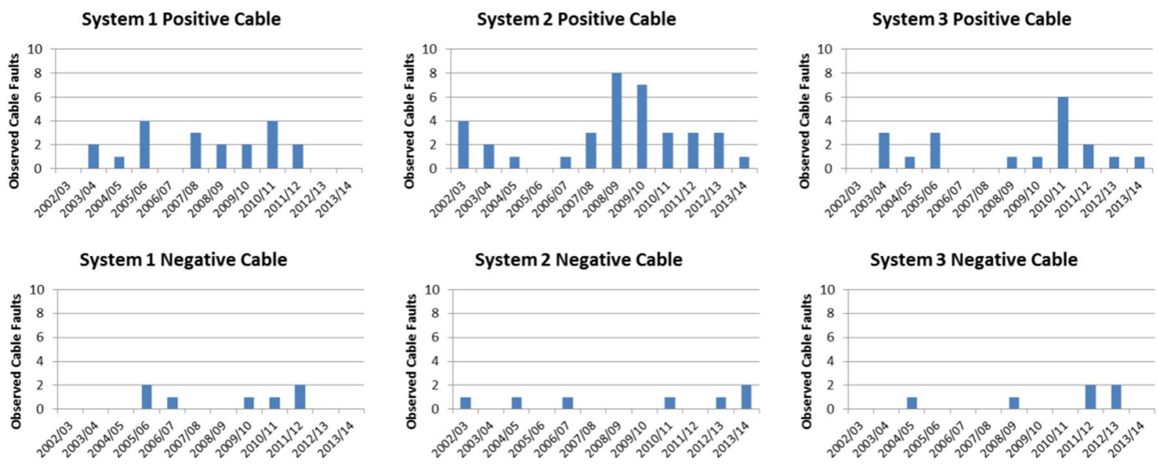

Figure 14: Observed Cable Faults per Cable

An immediate observation is that less faults have been reported on the negative cables. In fact this observation actually provides further confirmation of the reactive nature of cable maintenance being forced on the Company due to the high number of cable faults. Many of the faults prior to 2009 do not accurately record the affected cable and have therefore been arbitrarily assigned to the positive cable.

One of the roles identified for the reliability engineer was to ensure that appropriate information was being captured and entered into the Company's Fault Reporting Analysis and Corrective Action System (FRACAS). This detailed information is required to allow the reliability engineer to accurately identify areas where stress enhanced electro-chemical degradation of the cables has progressed to the point that cable replacement is required. This planning is vital to allow the Company to achieve a pro-active cable maintenance strategy.