TS177 - SUBSTATION BATTERY DUPLICATION

Business case 2017/18 – 2018/19

Prepared by Asset Strategy and Planning

September 2017

Endeavour Energy

REVIEW AND APPROVAL SCHEDULE

Responsibility	Position	Name	Signature	Date
Authored	Network Investment Program Engineer	Sanath de Fonseka		22/09/17
Reviewed	Senior Renewal Project Development Engineer	Jonathan Cook		22/09/17
Reviewed	Network Investment Planning Manager	Manoraj Jayasekara		22/09/17
Endorsed	Acting Manager Asset Strategy and Planning	Manoraj Jayasekara		22/09/17

CONTENTS

1.0 EXECUTIVE SUMMARY

The purpose of this business case is to seek endorsement for a revised program to address the risks associated with the failure of the DC systems in zone substations (which are equipped with only a single DC system) in Endeavour Energy's network. It also seeks approval for the funding for the initial stage of the revised program in FY18 and FY19.

Distribution Network Service Providers are required by the National Electricity Rules to provide protection systems to ensure that faults of all types on their sub-transmission and distribution systems are disconnected in a safe and timely manner. Therefore the loss of the DC supply in a zone substation which causes the loss of operability of the network protection systems poses significant risks. A Statement of Asset Need from Asset Standards & Design identified that on average, DC outages of zone substations with only a single DC supply in Endeavour Energy's network occur approximately once every year and over the last five years the average duration of the loss of DC supply has been 12 hours. During this outage period, any fault on the distribution network fed by the substation would not be disconnected by protection systems presenting significant safety risk for the public and a significant risk of destructive failure of both the faulted distribution feeder and the power transformers and switchgear in the zone substation.

29 of the Company's 164 zone substations have duplicated battery and DC systems. The remaining zone substations have only a single DC system (or no DC system in the case of very small rural substations).

The previous business case [1] for this program considered two approaches to reduce the risks associated with the failure of the DC systems in zone substations which have a single DC supply and initiated a program of works including:

- The installation of a second battery bank and DC system at six zone substations which supplied particularly high risk customers including major public hospitals; and
- At all other sites, the installation of an independent alarming system so that the system operators are made aware of loss of DC incidents and can respond to immediately de-energise the zone substation from the supplying transmission substation and initiate corrective action to address the situation.

This business case was approved in July 2016. However, since that time, a re-focussing on network reliability led to the conclusion that while the independent alarming system effectively addressed the safety risks presented by the loss of supply in a substation, it also reduced the reliability outcomes for customers by ensuring that every "loss of DC" incident would result in an outage of the substation.

Accordingly, it was resolved that the alarms are an interim solution only and that ultimately all zone substations (which currently have DC systems) should be equipped with a duplicated DC system. Therefore, the proposal in this business case includes all zone substations to progressively have duplicate batteries installed in a programmed manner based on their customer numbers and their value of customer reliability (VCR) risk priority. The first stage of the program includes the installation of duplicate DC systems in 20 high risk substations during FY18 and FY19. The cost of this work is $2.3 million. A contingency amount of $0.2 million to allow for unforeseen complications due to working in aged substation sites is also proposed. The cost of the complete 10 year program, including previously approved works, is estimated to be $15.8 million (in real FY18 terms).

Accordingly, it is recommended that:

- The strategy of progressively duplicating battery systems in zone substations as detailed in this document be endorsed;

- A capital expenditure of $2.3 million to install dual battery systems at 20 high priority zone substations over the period of FY18 – FY19 as detailed in this business case be approved; and
- A contingency amount of $0.2 million be approved.

The total project estimate is $2.5 million including $2.3 million for base costs and $0.2 million for contingency.

2.0 INTRODUCTION

2.1 PURPOSE

This business case seeks endorsement for a revised program to address the risks associated with the failure of the DC systems in zone substations (which are equipped with only a single DC system) in Endeavour Energy's network and seeks approval for the funding for the initial stage of the revised program in FY18 and FY19.

The original program and associated business case was developed in response to a Statement of Asset Need (SAN) provided by Asset Standards and Design which identified significant risks to public safety and network assets due to loss of DC supply to Endeavour Energy's zone substations and also proposed the duplication of battery banks in the zone substations as a solution to address the identified risks. Refer to Appendix A for further detail of the SAN.

2.2 BACKGROUND

2.2.1 BATTERY SYSTEMS

The function of battery systems in substations is to provide DC power to protection and SCADA systems. It is important that a substation battery system is reliable to avoid situations when the substation cannot clear faults due to loss of DC supply to the protection relays and circuit breakers and cannot report the situation to the control room due to the loss of the DC supply to the substation SCADA system.

Endeavour Energy is required to provide protection systems to ensure that a fault of any type on its sub-transmission or distribution system is disconnected in a safe and timely manner under the National Electricity Rules. Uncleared faults result in safety risks to the public as well as electricity workers and damage to network assets.

It is also important that the substation SCADA system remains operational so that operations staff can respond effectively to substation fires, faults and other incidents.

Endeavour Energy has 253 120V battery banks in service at 201 sub-transmission and zone substations and switching stations throughout its network. Each site (apart the small rural sites that have no station DC system installed) is equipped with either a single or a duplicated DC system. Table 1 shows the volume of each of these.

TABLE 1 - 120V BATTERIES IN ENDEAVOUR ENERGY SUBSTATIONS AND SWITCHING STATIONS

Asset	Dual DC system	Single DC system	No DC system	Total sites	Total batteries
Zone Substations	29	132	3	164	190
Switching Stations	5	6	2	13	16
Transmission Substations	23	1[1]	0	24	47
Totals	**57**	**139**	**5**	**201**	**253**

2.2.2 ASSETS AT RISK

Within Endeavour Energy's network generally all transmission substations and 132kV zone substations are equipped with duplicated DC systems and therefore are exposed to a greatly reduced risk of loss of DC supply.

[1] Illford TS has a single DC system and shares that with Ilford Hall ZS. Therefore Ilford Hall ZS is listed as having no DC.

Ilford TS is the only transmission substation with a single DC supply. Further, the two small remote rural zone substations of Bylong and Meadow Flat are equipped with auto-reclosers in place of protection relays and circuit breakers and therefore do not need, and are not equipped with, 120V DC supplies.

There are six switching stations in Endeavour Energy's network that have single 120V DC systems. However, failure of the protection systems at these sites to clear faults will result in an upstream transmission substation clearing the fault. Therefore, while there is a risk of losing a sub-transmission feeder supply to downstream substations, there is no risk of loss of supply to customers or safety risk. Therefore, the risks associated with loss of DC at these sites are low and subsequently switching stations are excluded from this program.

Zone substations with single DC supplies are most at risk because protection failures on the secondary side of the power transformer(s) will not be reliably cleared by upstream protection because of the impedance of the transformer(s).

Accordingly, zone substations with single DC supplies will be the focus of this program and project.

3.0 DC SYSTEM FAILURE INCIDENTS

3.1 DC FAILURE INCIDENTS

Endeavour Energy has experienced six loss of DC supply incidents at zone substations over the last five years. The details of these incidents are included in the previous SAN included in Appendix A and the previous business case for program TS177 [1].

3.2 LOSS OF DC RISK

With 135 zone substations with single DC supplies and on average 1.2 failures per year, there is a 0.009 probability of any one substation losing supply each year. Given the variable nature of this data, a nominal 1% probability of any zone substation with a single DC supply, losing DC during any one year has been used in this business case to assess the risks associated with loss of DC supply.

4.0 RENEWAL NEED

4.1 GENERAL

Risk factors taken into account when considering a strategy for managing battery systems include:

- Safety
- Reliability;
- Bushfire;
- Damage to plant.

4.1.1 SAFETY RISK

There is a safety risk to electricity workers or members of the public in the event of a fault in the distribution network or the substation that could lead to an explosive failure.

4.1.2 RELIABILITY

Events in which DC supply to a substation is lost due to equipment failure require repair works to restore the DC supply. The current organisational procedures require supply to the substation to be shut off during this time for the safety of the staff working on the DC systems and members of the public. This results in an impact to reliability.

4.1.3 BUSHFIRE RISK

Bushfires can be initiated as a result of faults caused by animals, conductors clashing during high wind, and branches falling across lines etc. If protection systems are not operating during these events the risk of arcing and melted metal from the conductor or burning material falling to the ground and igniting a bushfire are substantially increased. Likewise the risk of fallen conductor initiating a fire increases with the duration of it lying on the ground alive.

4.1.4 DAMAGE TO PLANT

Loss of DC systems and an uncleared fault can lead to the explosive failure and or damage to equipment in the distribution network.

4.2 COMPLIANCE

Endeavour Energy is required by the National Electricity Rules to provide protection to ensure that faults are cleared in a safe manner. Refer to the SAN in Appendix A for further detail about compliance requirements.

4.3 RISK ASSESSMENT

Table 2 is based on the Company's risk assessment procedure, Board Policy 2.0.5 [2] and assesses the principal risks presented by losing DC supply at substations.

TABLE 2 - RISK ASSESSMENT

Event	Likeli-hood	Impact	Risk rating	Consequence and Comments	Proposed Treatment	Expected risk after Treatment
DC outage at a substation with single DC supply	Likely (B)	Moderate (3)	**High (B3)**	Substation will be shut down and customers lose power. Major impact to company reputation.	Install duplicate DC system.	Low (E3)
Undetected DC outage of substation due to technician error	Likely (B)	Moderate (3)	**High (B3)**	Non-compliance with National Electricity Rules resulting in investigation into company procedures.	Install duplicate DC system or DC alarm system	Low (E3)
DC equipment failure causing DC outage at substation	Possible (C)	Minor (2)	Medium (C2)	Zone substation outage during works to repair.	Install duplicate DC system if the cost is justified by the value of customer reliability	Low (E2)
Explosive failure due to DC systems outage at substation	Rare (E)	Major (4)	Medium (E4)	Extensive damage to the substation and parts of the distribution network and possible death or injury to personnel or members of the public (if in vicinity). Loss of supply from the substation for an extended period	Install duplicate DC system or DC alarm system	Low (E2)

4.4 CONCLUSION

Given the occurrence of zone substations losing DC supply and the risks associated with these events, it was concluded in the first stage of this program that options for providing redundancy or implementing more appropriate response measures should be assessed further and implemented.

5.0 PROPOSED STRATEGY

5.1 PREVIOUS APPROACH

In the previous business case [1] two approaches were employed to reduce the risks associated with the failure of the DC systems in zone substations which have a single DC supply:

1. In selected zone substations a second battery bank, charger and DC system was installed; and
2. In all other sites, an alarm which monitors the substation DC panel and notifies the control room when DC volts are lost (independently of the station SCADA system) were proposed to be installed.

Whist this approach effectively addressed the safety implications of undetected loss of DC supply, except in the case of the six substations where duplicate DC systems were scheduled for installation, it will effectively lead to a decrease in customer reliability. At the time, this was considered a reasonable trade-off between cost and risk. However, with a renewed focus on customer reliability, this business case re-examines the case for fully duplicating the substation DC systems and in so doing reducing the risk of a loss of DC event occurring to negligible levels, to as low as reasonably possible (ALARP).

5.2 PROPOSED STRATEGY

Under the revised proposal in this business case it is recommended that all zone substations (and Ilford Transmission Substation) which currently have a single DC system will progressively have a second DC system implemented. It is further proposed that substations will be prioritised for duplication of their DC systems based on their customer number and magnitude of their *value of customer reliability* (VCR) risk costs [3].

It is further proposed that the installation of DC monitoring alarms, currently being implemented under the previous business case, will continue in order to manage the safety and equipment damage risk until the second DC system has been implemented at all substations. The additional alarms are ultimately not required at substations with duplicated DC systems and therefore, the alarm program should be re-phased to coordinate with the proposed DC duplication works proposed to avoid unnecessary works and costs where possible.

5.3 ESTIMATED COSTS

Newer substations that contain a duplicated DC panel and DC busbars (Type A substations) require less wiring works than older substations that are fitted with only single DC busbars (Type B substations). Therefore the costs of duplication are less in Type A substations compared to Type B. The average estimated costs of the two types are shown in TABLE 3 below.

TABLE 3 - ESTIMATED UNIT COSTS

Option details	Type A substation cost ($)	Type B substation cost ($)
Battery & charger	25,000	25,000
Isolation links	2,500	2,500
Battery enclosure/vents	20,000	20,000
DC panel (paralleling switch, voltage transducer to SCADA, positive/negative earth fault indicator)	3,000	3,000
Connection/wiring	8,500	33,000
Design	8,000	12,000
Civil works/trays/labelling	11,000	16,000

Option details	Type A substation cost ($)	Type B substation cost ($)
Change-over	3,000	3,000
Testing	3,200	3,200
Project definition	400	400
Project management	3,200	6,000
Totals (rounded to nearest $1,000)	**88,000**	**124,000**

5.4 PROPOSED PROGRAM

The battery duplication works under this program should be carried out on a substation basis. Each substation requires analysis of arrangements to ensure that all secondary dual DC systems are installed appropriately to provide primary and backup DC systems.

As noted above, the revised strategy for addressing the supply reliability risk associated with single battery system failures is to install duplicated systems in all zone substations (and Ilford TS) over time. A concept level view of this program is shown in TABLE 4 below. Approximately 40% of the substations in the program are Type A and 60% Type B which gives a weighted average duplication cost of $110,000 per site with the remaining 123 substations spread over a nominal 10 year period. Costs for program year one are actual estimates whereas costs from year two onwards use average values. The complete program, including the previously approved battery duplication and alarm works, totals $15.8 million. All costs are in real 2017/18 terms.

TABLE 4 – PROPOSED BATTERY DUPLICATION PROGRAM ($ REAL 2017/18)

Program year	Financial year	Substation	Cost estimate ($M)
Currently approved	2017 - 2019	6 substations supplying major hospitals – Westmead, West Wollongong, Homepride, Kingswood, Leabons Lane + alarm installation at 125 sites	2.2
1	2019	20 substations with highest VCR risk	2.3
2	2020	13 substations in risk priority order	1.4
3	2021	13 substations in risk priority order	1.4
4	2022	12 substations in risk priority order	1.3
5	2023	12 substations in risk priority order	1.3
6	2024	12 substations in risk priority order	1.3
7	2025	12 substations in risk priority order	1.3
8	2026	12 substations in risk priority order	1.3
9	2027	12 substations in risk priority order	1.3
10	2028	5 substations in risk priority order	0.6
Program total			**15.8**

5.5 DUAL BATTERY SYSTEMS

On the basis of the above it is proposed that a program be developed to install dual battery systems at 20 zone substations from FY18 to FY19.

The 20 zone substations have been selected based on the customer risk profile as evidenced by number of customers and VCR costs. Table 3 below shows the sites in priority order with details of the impact of loss of supply at each site. VCR is calculated based on a nominal three

hour outage after a loss of DC incident, with a 1% probability of occurrence in any one year and the present cost of that risk over a 15 year period. Refer Appendix B for further detail of the calculation of VCR risk.

It is proposed that the replacement works at these sites generally include:

- Installation of a second DC busbar in the DC panel or in a separate panel;
- Installation of a changeover switch between the two DC busbars;
- Installation of a second battery bank and charger and connection to the DC panel; and
- Connection of relays and trip coils to the second DC busbar to create a duplicated DC system.

TABLE 5 – ZONE SUBSTATION RISK RANKING

Zone substation	Number of customer connections	Peak load (MVA)	Average load (MVA)	Typical VCR risk cost per outage ($ pa)	VCR risk cost PV (S)
Minto	15,838	65.6	30.2	36,200	382,200
Bow Bowing	5,250	46.7	28.7	34,400	363,200
Campbelltown	9,429	54.5	23.4	28,000	295,900
Narellan	15,306	75.8	22.5	27,100	285,400
Werrington	10,515	38.4	18.8	22,600	238,400
West Liverpool 11kV	9,211	37.9	18.0	21,600	228,200
Cranebrook	5,705	26.5	16.2	19,400	204,500
Canley Vale	14,806	28.0	12.9	15,500	163,500
Holroyd	16,494	31.8	12.8	15,300	161,400
Kentlyn	13,846	38.8	12.7	15,200	160,800
Shellharbour	11,555	27.3	12.6	15,100	159,600
Ulladulla	13,031	28.6	12.2	14,700	154,800
Macquarie fields	10,380	28.3	11.8	14,100	148,900
Dapto	13,399	32.9	11.6	14,000	147,300
Claremont meadows	8,957	28.8	11.3	13,500	142,900
Hinchinbrook	11,499	27.3	11.1	13,300	140,200
Casula	8,960	33.1	10.6	12,700	133,900
Katoomba	8,841	18.8	10.3	12,300	130,100
Nowra	8,780	26.2	10.3	12,300	130,100
Lennox	10,441	18.6	10.2	12,200	129,200

Primary and backup protection relays and trip coils should be connected to alternate DC systems. At sites without duplicate distribution feeder protection the feeder protection relays/coils and the busbar protection relays/coils should be connected to alternative batteries. This will ensure that primary and backup protection systems will not be both affected by a single DC system fault.

5.5.1 DC MONITORING SYSTEMS

The previous business case for this program proposed DC monitoring system installed in 125 zone substations which includes 20 zone substations proposed in this business case for dual battery systems.

It is proposed that the DC monitoring works for these 20 zone substations, if not already complete or in advanced stage of development, be reprioritised to the lowest level following the

approval of this business case. Once the battery duplication works are committed through a formal program of works the DC monitoring works can be removed from these substations.

It is further proposed that the remaining zone substations with single DC supplies and Ilford TS have DC monitoring systems installed according to the current project plan and timeframe. This will ensure that the safety risk and the equipment damage risks at these sites are managed until the dual battery systems have been implemented.

6.0 BUSINESS CASE PROJECT DETAILS

6.1 GENERAL

The project includes work to install dual DC systems at the 20 zone substations.

The exact timing for the works at each substation is not critical and the program may be adjusted to suit logistical requirements providing the works are completed within the overall specified timeframe of 2018/19.

6.2 PROJECT SCOPE OF WORKS

The proposed works at the 20 zone substations generally include:

- Installation of a second DC busbar in the DC panel or separate panel;
- Installation of a changeover switch between the two DC busbars;
- Installation of a second battery bank and charger and connection to the DC panel; and
- Connection of relays and trip coils to the second DC busbar to create a duplicated DC system.

6.3 RISK MANAGEMENT DURING IMPLEMENTATION

A system of work with an end to end process focus on risk is to be developed to manage, during the implementation of this program, the risk of inadvertent human error causing system interruptions thereby causing loss of supply to customers.

6.4 PROJECT ESTIMATE

Below provides a summary of the estimated cost for each of the 20 sites included in this business case. Costs are in real 2017/18 terms.

The cost estimates have been developed by Asset Standards and Design on a site specific basis apart from Bow Bowing, Canley Vale, Cranebrook, Narellan and Werrington zone substations for which average costs for their particular type of substation have been applied.

TABLE 6 – COST ESTIMATES ($REAL 2017/18)

Zone substation	Substation type (A = ready for duplication) (B = Additional civil and wiring works required)	Cost estimate ($)
Minto	B	126,000
Bow Bowing	B	124,000
Campbelltown	B	123,000
Narellan	B	124,000
Werrington	B	124,000
West Liverpool 11kV	B	126,000
Cranebrook	B	124,000
Canley Vale	A	84,000
Holroyd	A	84,000

Zone substation	Substation type (A = ready for duplication) (B = Additional civil and wiring works required)	Cost estimate ($)
Kentlyn	B	126,000
Shellharbour	B	125,000
Ulladulla	B	123,000
Macquarie fields	B	126,000
Dapto	A	88,000
Claremont meadows	A	84,000
Hinchinbrook	A	90,000
Casula	A	88,000
Katoomba	B	119,000
Nowra	B	123,000
Lennox	B	119,000
Total		**2,250,000**
Total (to nearest $0.1M)		**2,300,000**

The cost estimate for the program spread across the 2017/18 and 2018/19 years is shown in Table 7 below. The project estimate totals $2.3 million in real terms and in nominal terms. Refer to Appendix C for further detail of the cost estimates and Appendix D for images of typical battery installations in zone substations.

TABLE 7 - PROJECT EXPENDITURE SPREAD

Item	Estimated expenditure		
	2017/18	2018/19	Totals
Dual DC battery systems	0.4	1.9	2.3
Project total ($, real 17/18)	**0.4**	**1.9**	**2.3**
Project total ($, nominal)	**0.4**	**1.9**	**2.3**

6.5 CONTINGENCY

A specific contingency amount has been estimate for each substation based on the age of site and likelihood of unforseen obstructions and subsequent delays, the likelihood of finding asbestos and the complications when installing the wiring for the duplicated battery. Across all of the 20 sites this provision averages 9% of the project costs which amounts to $0.2 million. TABLE 8 summarises the proposed contingency requirements.

TABLE 8 – CONTINGENCY PROVISION

Project item	Contingency detail	Contingency amount ($M)
Duplicated DC wiring	Unforeseen obstructions causing delays and requiring re-design work	0.1
Civil works	Unforseen complications arising from working in aged substations including asbestos	0.1
Total provision		**0.2**

6.6 PROJECT FUNDING

This project falls within SARP program TS177 – *Substation Battery Duplication*. The program summary in the PIP is shown in Table 9 below and reflects the risk level and priority of the program.

TABLE 9 – PIP SUMMARY

PIP element	PIP rating
Project ID	TS177
Weighted ranking	4,200
Percentage	33.8%

PIP8.5 has a provision of $3.5 million for program TS177 over the period of 2017/18 - 2018/19. However, a substantial portion of this funding will be used by the cashflow of the previous 2016/17 business case for TS177. As a result, additional funding will be required for the works proposed under this business case. This will be provided for the 2017/18 year via the PIP change control process and a provision will be made in the next release of the PIP for the funding required in 2018/19.

The estimated expenditure, including contingency for this program is shown in Table 10 below.

TABLE 10 – PROJECT EXPENDITURE SPREAD ($ NOMINAL)

Estimated Cost ($ nominal)	2017/18	2018/19	Total
PIP 8.5 Gate 1 approval amount	1.0	2.5	**3.5**
Funding reserved for the initial stage of program TS177 (20167/17 business case and project definition T-1641)	1.3	0.7	**2.0**
Project TS177 base costs for this business case ($ nominal)	0.4	1.9	**2.3**
Contingency (9% of base costs)		0.2	**0.2**
Total project cost for this business case ($)	**0.4**	**2.1**	**2.5**

7.0 RECOMMENDATIONS

It is recommended that:

- A capital expenditure of $2.3 million to install dual battery systems at 20 zone substations over the period of 2017/18 – 2018/19 as detailed in this business case be approved;
- A contingency sum of $0.2 million, representing 9% of the project estimated cost to cover unforseen events be approved.

The complete project estimate, including the base costs and the contingency sum totals $2.5 million.

8.0 APPENDICES

APPENDIX A - STATEMENT OF ASSET NEED

APPENDIX B – VCR RISK DETAILS

APPENDIX C – COST ESTIMATES

APPENDIX D - IMAGES OF TYPICAL BATTERY INSTALLATIONS

9.0 REFERENCES

[1] “Substation Battery Duplication Project TS177 2016/17 - 2018/19,” July 2016.
[2] “Board Policy 2.0.5 – Risk Management,” 2015.
[3] Australian Energy Marker Operator, “Value of Customer Reliability Review,” 2014.

This page intentionally blank

APPENDIX A - STATEMENT OF ASSET NEED

Memorandum

To	Network Investment Planning Manager	File no	TSE14059
From	Network Substations Manager (Colin Crisafulli)	Date	05-Mar-15
Subject	Statement of Asset Need: Dual 120V Battery Supplies in Substations – Asset Prioritisation		
Copies	Protection Manager; Secondary Systems Development Manager; Maintenance Manager		

Purpose

To formally establish the high-level need in accordance with GAM 0006 to initiate a broader asset management review and expenditure program to improve the redundancy of 120V DC battery systems, chargers, supply to trip coils and protection systems in zone substations, transmission substations and switching stations based on the identified need detailed below.

Background

Endeavour Energy's traditional substation practice had been to install single battery systems in zone substations. This practice has changed over time and up until July-14 had still been in place for all substations other than transmission substations and 132kV zone substations in excess of 20MVA firm capacity.

As of Aug-14 in development of the new Equipment Technical Specification (ETS 0085), this practice was reviewed for suitability. It was identified that single battery supply criteria was not in alignment with good industry practice and a general compliance review. Similarly, based on some recent and historical issues, a position to move to dual batteries was further reinforced and supported by a quantitative risk cost benefit assessment.

Single battery incidents

Endeavour Energy in the last 5 years has suffered 5 known single battery failure incidents (other issues are expected to have occurred but not been necessarily reported), namely:

2015 St Marys ZS: the single battery discharged. On the 27th of January 2015 a DC_Supply Abnormal alarm was generated at St Marys. On the 30th of January field staff found the substation batteries at 30V and the charger tripped off. At this point the cause of the charger trip has not been determined. System Control did not action the DC alarm for 2.5 days. Recommendations from this event included more tailored alarming and highlight alarm response to System Operators.

2014 Moorebank ZS: the single battery failed as a result of a faulty 33kV out-of-service GCN circuit-breaker coil remaining energising (movement failure) when closed as part of works involving protection staff performing a relay replacement. A decision was made to turn off the substation since the battery had depleted (50V) until recharged with a loss of roughly 5,600 customers for 29 mins (~10MWh based loads prior).

2013 Bulli ZS: substation staff accidently cut the main protection positive wire of the battery supply. The site was without all protection systems for around 24 hours until protection technicians raised the alarm when they arrived on site the following day.

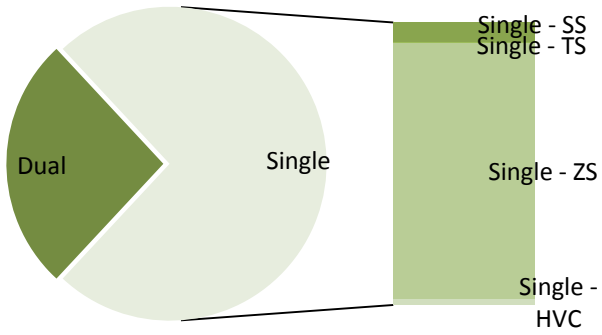
2012 Nowra ZS: the new battery charger failed and the site remained without healthy battery for us to 24 hours. Staff were on site at the time rectifying the problem in a substation without protection systems.

2011 Narellan ZS: maintenance staff accidently pulled the main battery fuse by accident. The site lost all protection and SCADA for an hour until it was realised and rectified follow suspicion by the system operator.

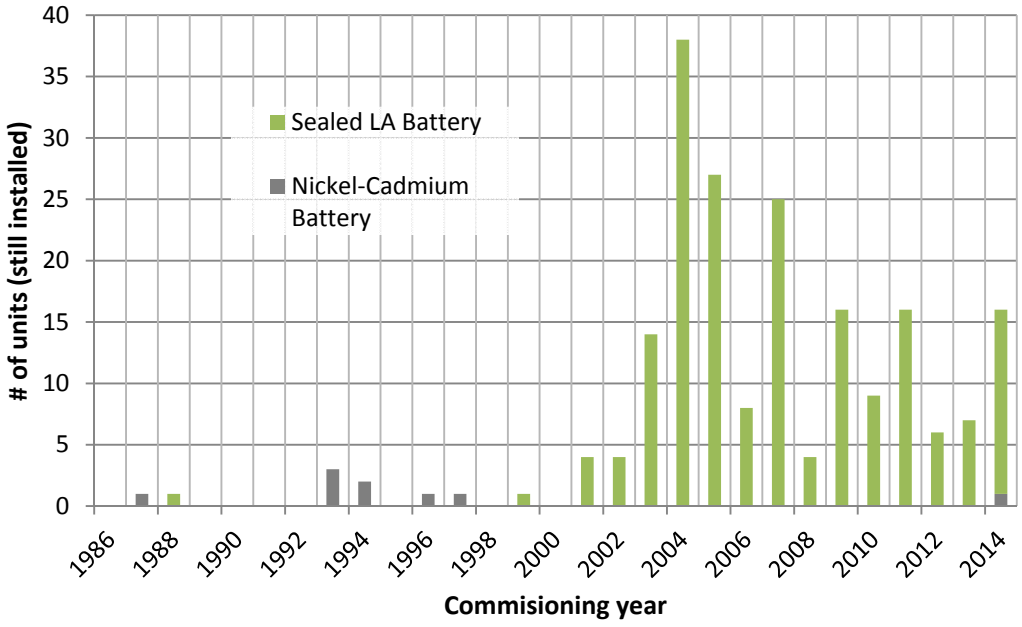
A high-profile and publicised case (attached) resulting in catastrophic failure as a result of single battery system failure from **1989** occurred at **Albury ZS** (NSW). During a lightning storm a fault developed and the battery system had failed prior. Two 30MVA transformers failed catastrophically along with the feeder affected and as a result power restrictions applied for days following given the site had only a single 30MVA transformer remaining. The substation was surrounded by residential properties with reports suggesting persons needed to flee in fear of the 'huge' fire that engulfed the substation.

Battery condition and age characteristics

Roughly 145 sites (including 133 zone substations and 1 transmission substation [Ilford]) have single 120V battery supplies. The breakup is as below.



The majority of 120V batteries in substations are now sealed lead-acid with a minimal number of remaining nickel-cadmium in the network. The average age of batteries is 8.5 years with a significant spike of new commissioning's in 2004.



Additional issues

A recent test was conducted at East Richmond ZS to review the scenario of a faulty battery to determine whether the battery charger would provide sufficient strength to provide a trip. All DC to the substation was lost within 200ms and as such there was no trip output contacts that operated, let alone tripping breakers. This highlighted the lack of ability of the charger to perform tripping functions directly.

Inspections of various sites have taken place to review the performance and failure rate of Battery Systems. The concerns are highly dependent on the environment which impacts on aging (temperature and moisture). As an example, the photos below show a comparison between North Parramatta 120V Battery Systems (2 of) 2002 commissioned SLA, one in an air conditioned room and the other not. The image below shows the post growth, and when the positive terminals begin to lift as shown, the double O-ring construction allows the cell (electrolyte and gas) to remain sealed until it eventually gives way resulting in a failed cell.

The air conditioned part of the room showed little deterioration which was confirmed with test records. The example shows the environmental impact on the aging of batteries and creation of common mode failures.

Further compounding this risk presently, proposed changes to minor overhaul of lead acid sealed/valve regulated for 12/24V batteries changed from 0.25 year to 0.5 year; Routine maintenance for high current discharge test of station batteries has been changed from 1 year to 2.5 years (High current discharge test is only required for batteries which supply 11kV & 33kV switchgear which use solenoid). Station failure risk due to single battery failure may not have been appropriately considered in the RCM analysis which will be highlighted for review.

Compliance

National Electricity Rules

The national electricity rules provide a regulatory framework for NEM participants with the force of law under the *National Electricity (NSW) Law* (as at 19 December 2013).

The National Electricity Rules S5.1.9 says *"… a Network Service Provider must provide sufficient primary protection systems and back-up protection systems (including breaker fail protection systems) to ensure that a fault of any fault type anywhere on its transmission system or distribution system is automatically disconnected …"*

A protection system is defined as: *"A system, which includes equipment, used to protect a Registered Participant's facilities from damage due to an electrical or mechanical fault or due to certain conditions of the power system."*

Industry Practice

In NSW both Ausgrid and Essential Energy install 2 battery banks in all new substations as a result of the above legislative requirement. Both utilities also retrofit 2 banks in older substations either as a targeted program, or when renewal opportunities present themselves.

Risk Cost Benefit Analysis

Risk quantification

An estimated quantification of the value of the risk is included below including a comparison quantification of the economic and damage impact cause by the Albury incident in 2014 dollars. This quantification is based on, annual fault rates (not including successful reclose), AEMO published value of customer reliability weighted by the economic value of the load (i.e. industrial or residential), the time, customers and load affected, the likelihood of cumulative and subsequent damage to network equipment, possible response time, the type and potential damage bill of network equipment installed and the risk to safety in the event of an single battery failure occurrence and downstream uncleared fault.

It is apparent of the estimate that the position of rural substations, response time and exposure to more frequent faults (overhead) heightens the risk in these locations although the cost of network equipment damage would be lower. The estimate also highlights the economic cost of switching off Moorebank ZS as a precaution exceeded the cost of the risk exposed.

		direct costs:				risk cost								
Site	date	reliability	damage	economic	direct costs	Fault rate (p.a.)	risk duration (mins)	risk liklihood	safety risk liklihood	damage liklihood	damage	economic / feliability	safety	risk cost
Moorebank	2014	$ 162,996	$ -	$ 493,518	$ 656,513	11.5	30	0.066%	0.010%	0.046%	$ 7,347	$ 15,007	$ 409	$ 22,762
Bulli	2013	$ -	$ -	$ -	$ -	19.0	1440	5.202%	0.485%	3.381%	$ 304,312	$ 771,958	$ 19,878	$ 1,096,147
Nowra	2012	$ -	$ -	$ -	$ -	28.1	1440	7.693%	0.662%	5.001%	$ 400,055	$ 1,519,353	$ 27,127	$ 1,946,534
Narellan	2011	$ -	$ -	$ -	$ -	6.1	60	0.070%	0.010%	0.049%	$ 7,307	$ 20,176	$ 427	$ 27,909
Albury	1989	$ 2,511,013	$ 5,081,171	$ 9,765,981	$17,358,165	-	-	-	-	-	-	-	-	-

The annual cost of this risk exposure to Endeavour Energy is estimated to be $773,000 annually. This equates to an average likelihood of an incident similar to Albury occurring, based on history, of roughly 1% p.a. or 1 in 100 years. However it is noted that the Nowra incident is estimated to have had a 7.7% risk of uncleared fault with 5% overall estimated risk of catastrophic equipment failure as a consequence.

At 4% discount rate, realising this benefit through risk controls would account to **$17.3M** over 50 years. Note, unknown details of other battery issues suggest the value of this risk may exceed **$25M** NPV.

Dual batteries cost

Battery systems in current dollars have been shown to cost:

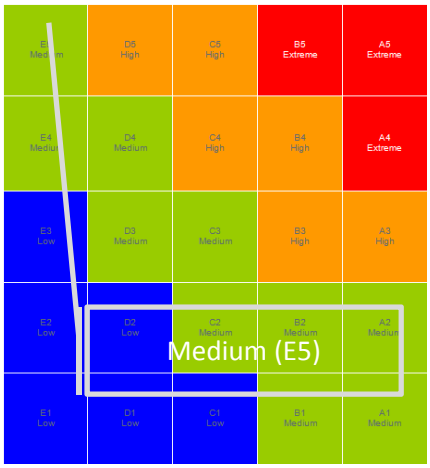
- 120V sealed valve regulated lead-acid:
  - 140Ah $10,000
  - 200Ah $13,000
  - 300Ah $20,000
- Installation ranges from $5,000 to $9,000
- Room (incremental) is $35,000 or AS 3011 enclosure / cupboard $5,000 – $12,000
- Additional wiring will vary, some sites are already configured for dual batteries and others will require more detailed wiring. Cost ranges are difficult to estimate given the variation but a round figure is $80,000. However, alignment of this business need with the proposed PS012 business case etc. will reduce the incremental cost.

This benefit is not fully realised at sites with only single protection systems and therefore such a program will need to be developed in close consultation with the proposed PS012 business case or alternatively some sites will require the dividing of various protection schemes between the dual battery systems to achieve maximum backup redundancy (i.e. feeder OC/EF protection on a separate battery to transformer LV OC/EF protection with lower Ampere-Hour requirements).

An incremental cost assessment, relative to a single battery substation has been applied across a range of sites including ongoing maintenance and replacement of batteries (14 years) utilising economies of scale and scope. The cost is calculated to be **$16M** NPV. The cost of implementation and management is less than the risk cost and therefore considered risk cost justified.

Semi-quantitative risk assessment (GRM 0003)

The likelihood of a substation failure due to uncleared faults as a result of Battery failure has been calculated to range between 1 in 50 and 1 in 100 years. The consequences in terms of economic / reliability impact, compliance and reputation however are Severe. Safety and environmental consequences are expected to be Moderate. This proposed program is expected to move the company risk position from Medium (E5) to Low (E3) using a semi-quantitative assessment in accordance with the company risk matrix (GRM 0003). A fully quantified risk assessment proves a positive risk case and therefore cost justification of redundancy.



Recommendation

Initiate a broader asset management review and expenditure program to improve the redundancy of battery systems, chargers, supply to trip coils and protection systems in zone substations, transmission substations and switching stations based on the identified need above. Risk prioritisation and considerations shall be based on:

- Cell environment (temperature and moisture risk assessment)
- Network fault frequency
- Operational flexibility and response time
- Alarming capability
- Cost assessment of failure (site conditions including fire risk assessment)
- Protection upgrade projects
- Existing battery ages
- Remote backup protection (i.e. switching stations with remote OC/EF/distance zone 2/3 protection)

Recommended by,

Colin Crisafulli
Network Substations Manager

This page intentionally blank

Following is summary of variables used and the basis of calculation of Value of Customer Reliability (VCR)

Base year for the calculation	FY18	The costs are represented in FY18 real terms
Consumer Price Index (**CPI**)	2.50%	
Value of Customer Reliability (**VCR**) $/kWh	40	AEMO VCR application guidelines have been used to choose this nominal value based on average customer mix.
Probability of loss of DC	1.0%	Nominal value has been chosen based on the historical failure rates
Duration of PV analysis	15	The duration has been chosen based on the average life of a batteries
Duratoin of loss of Battery (hours)	3	This is based on typical DC loss event with repair or offload substation and repair scenarios
Peak Demand		Peak demand based on Network Load History for FY17
Load Factor		Load factor based on Network Load History for FY17

Method of Calculation

Average demand	Peak demand X load factor
VCR ($/hr)	Average demand X value of customer reliability ($/kWh)
VCR risk cost ($/pa)	VCR ($/hr) X probability of loss of DC X duration of loss of DC (hours)
Present value of VCR risk	Excel function PV(CPI, duration of PV analysis (15 years), VCR risk cost ($/pa))

The Table below shows the present value of VCR risk cost for the substations identified for battery duplication in this business case

Substation	Peak Demand (kVA)	Load Factor	Average Demand (kVA)	VCR ($/hr)	VCR risk cost - typical outage ($/pa)	Present value of VCR risk
minto	65,558	0.46	30,189	1,207,579	36,227	$382,203
bow bowing	46,689	0.61	28,692	1,147,681	34,430	$363,245
campbelltown	54,454	0.43	23,371	934,821	28,045	$295,874
narellan	75,783	0.30	22,546	901,821	27,055	$285,429
werrington	38,407	0.49	18,834	753,340	22,600	$238,435
west liverpool 11kv	37,860	0.48	18,024	720,948	21,628	$228,183
cranebrook	26,481	0.61	16,155	646,217	19,387	$204,530
canley vale	28,028	0.46	12,911	516,445	15,493	$163,457
holroyd	31,810	0.40	12,752	510,062	15,302	$161,436
kentlyn	38,754	0.33	12,698	507,910	15,237	$160,755
shellharbour	27,301	0.46	12,605	504,185	15,126	$159,576
ulladulla	28,568	0.43	12,226	489,030	14,671	$154,780
macquarie fields	28,255	0.42	11,763	470,537	14,116	$148,926
dapto	32,878	0.35	11,634	465,371	13,961	$147,292
claremont meadows	28,846	0.39	11,287	451,484	13,545	$142,896
hinchinbrook	27,283	0.41	11,077	443,097	13,293	$140,242
casula	33,067	0.32	10,574	422,952	12,689	$133,866
katoomba	18,804	0.55	10,279	411,163	12,335	$130,134
nowra	26,243	0.39	10,276	411,055	12,332	$130,100
lennox	18,577	0.55	10,207	408,274	12,248	$129,220

This page intentionally blank

Battery Duplication at Minto ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Isolation Links	$ 2,500						$ 2,500
Ventilation	$ 20,000						$ 20,000
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 3,000						$ 3,000
Ladder / Tray System/ Cables	$ 4,500				15	$ 675	$ 4,500
Temporary DC Panel For Changeover *	$ 10,000				15	$ 214	$ 1,428.57
Connection/Wiring		160	2	$ 100	15	$ 4,800	$ 32,000
Design		120	1	$ 100	15	$ 1,800	$ 12,000
Civil		40	2	$ 100	20	$ 1,600	$ 8,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Removal of existing Equipment & Redirect electical circuit		20	2	$ 80	15	$ 480	$ 3,200
Project Definition		80	1	$ 100			$ 400
Project Management		150	1	$ 120			$ 6,000
Sub Total (To nearest $1k)							**$ 126,000**
Contingency (To nearest $1k)					**$**	**11,000**	
Grand Total (to nearest $1k)							***$ 137,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are seven sites for Central Region projects

Battery Duplication at Campbelltown ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Isolation Links	$ 2,500						$ 2,500
Ventilation	$ 20,000						$ 20,000
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 3,000						$ 3,000
Ladder / Tray System/ Cables	$ 4,500				15	$ 675	$ 4,500
Temporary DC Panel For Changeover *	$ 10,000				15	$ 214	$ 1,428.57
Connection/Wiring		160	2	$ 100	15	$ 4,800	$ 32,000
Design		120	1	$ 100	15	$ 1,800	$ 12,000
Civil		40	2	$ 100	20	$ 1,600	$ 8,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Project Definition		80	1	$ 100			$ 400
Project Management		150	1	$ 120			$ 6,000
Sub Total (To nearest $1k)							**$ 123,000**
Contingency (To nearest $1k) including vents					**$**	**10,000**	
Grand Total (to nearest $1k)							***$ 133,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are seven sites for Central Region projects

Battery Duplication at West Liverpool ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Isolation Links	$ 2,500						$ 2,500
Ventilation	$ 20,000						$ 20,000
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 3,000						$ 3,000
Ladder / Tray System/ Cables	$ 4,500				15	$ 675	$ 4,500
Temporary DC Panel For Changeover *	$ 10,000				15	$ 214	$ 1,428.57
Connection/Wiring		160	2	$ 100	15	$ 4,800	$ 32,000
Design		120	1	$ 100	15	$ 1,800	$ 12,000
Civil		40	2	$ 100	20	$ 1,600	$ 8,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Removal of existing Equipment		16	2	$ 80	15	$ 384	$ 2,560
Project Definition		80	1	$ 100			$ 400
Project Management		150	1	$ 120			$ 6,000
Sub Total (To nearest $1k)							**$ 126,000**
Contingency (To nearest $1k)					**$**	**11,000**	
Grand Total (to nearest $1k)							***$ 137,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are seven sites for Southern Region projec

Battery Redundancy at Holryd ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Isolation Links	$ 2,500						$ 2,500
Ventilation	$ 20,000						$ 20,000
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 3,000						$ 3,000
Ladder / Tray System/ Cables - Separate circuit	$ -				15	$ -	$ -
Temporary DC Panel For Changeover *	$ 10,000				15	$ 214	$ 1,428.57
Connection/Wiring		40	2	$ 100	15	$ 1,200	$ 8,000
Design		80	1	$ 100	15	$ 1,200	$ 8,000
Civil		20	2	$ 100	20	$ 800	$ 4,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Project Definition		80	1	$ 100			$ 400
Project Management		80	1	$ 120			$ 3,200
Sub Total (To nearest $1k)							**$ 84,000**
Contingency (To nearest $1k)					**$**	**5,000**	
Grand Total (to nearest $1k)							***$ 89,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are seven projects in total.

Battery Duplication at Kentyln ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Isolation Links	$ 2,500						$ 2,500
Ventilation	$ 20,000						$ 20,000
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 3,000						$ 3,000
Ladder / Tray System/ Cables	$ 4,500				15	$ 675	$ 4,500
Temporary DC Panel For Changeover *	$ 10,000				15	$ 214	$ 1,428.57
Connection/Wiring		160	2	$ 100	15	$ 4,800	$ 32,000
Design		120	1	$ 100	15	$ 1,800	$ 12,000
Civil		40	2	$ 100	20	$ 1,600	$ 8,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Removal of existing Equipment		16	2	$ 80	15	$ 384	$ 2,560
Project Definition		80	1	$ 100			$ 400
Project Management		150	1	$ 120			$ 6,000
Sub Total (To nearest $1k)							**$ 126,000**
Contingency (To nearest $1k)					**$**	**11,000**	
Grand Total (to nearest $1k)							***$ 137,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are seven sites for Central Region projects

Battery Duplication at Shellharbour ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Ventilation	$ 20,000						$ 20,000
Isolation Links	$ 2,500						$ 2,500
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 5,000						$ 5,000
Ladder / Tray System/ Cables	$ 4,500				15	$ 675	$ 4,500
Temporary DC Panel For Changeover *	$ 10,000				15	$ 167	$ 1,111.11
Connection/Wiring		160	2	$ 100	15	$ 4,800	$ 32,000
Design		120	1	$ 100	15	$ 1,800	$ 12,000
Civil		40	2	$ 100	20	$ 1,600	$ 8,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Project Definition		80	1	$ 100			$ 400
Project Management		150	1	$ 120			$ 6,000
Sub Total (To nearest $1k)							**$ 125,000**
Contingency (To nearest $1k)					**$**	**10,000**	
Grand Total (to nearest $1k)							***$ 135,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are nine sites for Southern Region project

Battery Duplication at Ulladulla ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Isolation Links	$ 2,500						$ 2,500
Ventilation	$ 20,000						$ 20,000
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 3,000						$ 3,000
Ladder / Tray System/ Cables	$ 4,500				15	$ 675	$ 4,500
Temporary DC Panel For Changeover *	$ 10,000				15	$ 167	$ 1,111.11
Connection/Wiring		160	2	$ 100	15	$ 4,800	$ 32,000
Design		120	1	$ 100	15	$ 1,800	$ 12,000
Civil		40	2	$ 100	20	$ 1,600	$ 8,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Project Definition		80	1	$ 100			$ 400
Project Management		150	1	$ 120			$ 6,000
Sub Total (To nearest $1k)							**$ 123,000**
Contingency (To nearest $1k) including New DC panel					**$**	**18,000**	
Grand Total (to nearest $1k)							***$ 141,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are nine sites for Southern Region project

Battery Duplication at Macquarie Fields ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Isolation Links	$ 2,500						$ 2,500
Ventilation	$ 20,000						$ 20,000
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 3,000						$ 3,000
Ladder / Tray System/ Cables	$ 4,500				15	$ 675	$ 4,500
Temporary DC Panel For Changeover *	$ 10,000				15	$ 214	$ 1,428.57
Connection/Wiring		160	2	$ 100	15	$ 4,800	$ 32,000
Design		120	1	$ 100	15	$ 1,800	$ 12,000
Civil		40	2	$ 100	20	$ 1,600	$ 8,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Removal of existing Equipment		16	2	$ 80	15	$ 384	$ 2,560
Project Definition		80	1	$ 100			$ 400
Project Management		150	1	$ 120			$ 6,000
Sub Total (To nearest $1k)							**$ 126,000**
Contingency (To nearest $1k)					**$**	**11,000**	
Grand Total (to nearest $1k)							***$ 137,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are seven sites for Central Region projects

Battery Duplication at Dapto ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Isolation Links	$ 2,500						$ 2,500
Ventilation	$ 20,000						$ 20,000
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 3,000						$ 3,000
Ladder / Tray System/ Cables					15	$ -	$ -
Temporary DC Panel For Changeover *	$ 10,000				15	$ 167	$ 1,111.11
Connection/Wiring		40	2	$ 100	15	$ 1,200	$ 8,000
Design		80	1	$ 100	15	$ 1,200	$ 8,000
Civil		40	2	$ 100	20	$ 1,600	$ 8,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Project Definition		80	1	$ 100			$ 400
Project Management		80	1	$ 120			$ 3,200
Sub Total (To nearest $1k)							**$ 88,000**
Contingency (To nearest $1k)					**$**	**5,000**	
Grand Total (to nearest $1k)							***$ 93,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are nine sites for Southern Region project

Battery Redundancy at Claremont Meadows ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Isolation Links	$ 2,500						$ 2,500
Ventilation	$ 20,000						$ 20,000
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 3,000						$ 3,000
Ladder / Tray System/ Cables - Separate circuit	$ -				15	$ -	$ -
Temporary DC Panel For Changeover *	$ 10,000				15	$ 214	$ 1,428.57
Connection/Wiring		40	2	$ 100	15	$ 1,200	$ 8,000
Design		80	1	$ 100	15	$ 1,200	$ 8,000
Civil		20	2	$ 100	20	$ 800	$ 4,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Project Definition		80	1	$ 100			$ 400
Project Management		80	1	$ 120			$ 3,200
Sub Total (To nearest $1k)							**$ 84,000**
Contingency (To nearest $1k)					**$**	**5,000**	
Grand Total (to nearest $1k)							***$ 89,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are six projects in total.

Battery Duplication at Hinchinbrook ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Isolation Links	$ 2,500						$ 2,500
Ventilation	$ 20,000						$ 20,000
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 3,000						$ 3,000
Ladder / Tray System/ Cables	$ -				15	$ -	$ -
Temporary DC Panel For Changeover *	$ 10,000				15	$ 214	$ 1,428.57
Connection/Wiring		40	2	$ 100	15	$ 1,200	$ 8,000
Design		80	1	$ 100	15	$ 1,200	$ 8,000
Civil		40	2	$ 100	20	$ 1,600	$ 8,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Removal of existing Equipment		16	2	$ 80	15	$ 384	$ 2,560
Project Definition		80	1	$ 100			$ 400
Project Management		80	1	$ 120			$ 3,200
Sub Total (To nearest $1k)							**$ 90,000**
Contingency (To nearest $1k)					**$**	**6,000**	
Grand Total (to nearest $1k)							***$ 96,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are seven sites for Central Region projects

Battery Duplication at Casula ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Isolation Links	$ 2,500						$ 2,500
Ventilation	$ 20,000						$ 20,000
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 3,000						$ 3,000
Ladder / Tray System/ Cables	$ -				15	$ -	$ -
Temporary DC Panel For Changeover *	$ 10,000				15	$ 214	$ 1,428.57
Connection/Wiring		40	2	$ 100	15	$ 1,200	$ 8,000
Design		80	1	$ 100	15	$ 1,200	$ 8,000
Civil		40	2	$ 100	20	$ 1,600	$ 8,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Project Definition		80	1	$ 100			$ 400
Project Management		80	1	$ 120			$ 3,200
Sub Total (To nearest $1k)							**$ 88,000**
Contingency (To nearest $1k)					**$**	**5,000**	
Grand Total (to nearest $1k)							***$ 93,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are seven sites for Central Region projects

Battery Redundancy at Katoomba ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Isolation Links	$ 2,500						$ 2,500
Ventilation	$ 20,000						$ 20,000
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 2,000						$ 2,000
Ladder / Tray System/ Cables - Separate circuit	$ 4,500				15	$ 675	$ 4,500
Temporary DC Panel For Changeover *	$ 10,000				15	$ 375	$ 2,500.00
Connection/Wiring		160	2	$ 100	15	$ 4,800	$ 32,000
Design		120	1	$ 100	15	$ 1,800	$ 12,000
Civil		20	2	$ 100	20	$ 800	$ 4,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Project Definition		80	1	$ 100			$ 400
Project Management		150	1	$ 120			$ 6,000
Sub Total (To nearest $1k)							**$ 119,000**
Contingency (To nearest $1k)					**$**	**10,000**	
Grand Total (to nearest $1k)							***$ 129,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are four projects in total.

Battery Duplication at Nowra ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Isolation Links	$ 2,500						$ 2,500
Ventilation	$ 20,000						$ 20,000
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 3,000						$ 3,000
Ladder / Tray System/ Cables	$ 4,500				15	$ 675	$ 4,500
Temporary DC Panel For Changeover *	$ 10,000				15	$ 167	$ 1,111.11
Connection/Wiring		160	2	$ 100	15	$ 4,800	$ 32,000
Design		120	1	$ 100	15	$ 1,800	$ 12,000
Civil		40	2	$ 100	20	$ 1,600	$ 8,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Project Definition		80	1	$ 100			$ 400
Project Management		150	1	$ 120			$ 6,000
Sub Total (To nearest $1k)							**$ 123,000**
Contingency (To nearest $1k)					**$**	**10,000**	
Grand Total (to nearest $1k)							***$ 133,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are nine sites for Southern Region project

Battery Redundancy at Lennox ZS

	Direct Charge	Labour			Contingency		
Item	**Unit Price**	**Hrs**	**No. Staff**	**Rate**	**%**	**Amount**	**Total**
Battery & Charger	$ 25,000						$ 25,000
Isolation Links	$ 2,500						$ 2,500
Ventilation	$ 20,000						$ 20,000
DC Panel - Paralelling Switch, Voltmeter, Voltage transducer to SCADA, Positive/Negative Earth fault indicator	$ 2,000						$ 2,000
Ladder / Tray System/ Cables - Separate circuit	$ 4,500				15	$ 675	$ 4,500
Temporary DC Panel For Changeover *	$ 10,000				15	$ 375	$ 2,500.00
Connection/Wiring		160	2	$ 100	15	$ 4,800	$ 32,000
Design		120	1	$ 100	15	$ 1,800	$ 12,000
Civil		20	2	$ 100	20	$ 800	$ 4,000
Installation of Ladder/ Tray System		16	2	$ 80	15	$ 384	$ 2,560
Install Temporary DC Panel for changeover		8	2	$ 100	15	$ 240	$ 1,600
Testing / SCADA/Commisioning		16	2	$ 100	15	$ 480	$ 3,200
Labelling	$ 500				15	$ 75	$ 500
Project Definition		80	1	$ 100			$ 400
Project Management		150	1	$ 120			$ 6,000
Sub Total (To nearest $1k)							**$ 119,000**
Contingency (To nearest $1k)					**$**	**10,000**	
Grand Total (to nearest $1k)							***$ 129,000***

* This cost can be shared over other projects which will require temporary DC panel for changeover. In this case, there are four projects in total.

APPENDIX D - IMAGES OF TYPICAL BATTERY INSTALLATIONS

Battery and charger at Claremont Meadows ZS

Battery and charger in enclosure at the refurbished Holroyd ZS