Jemena Electricity Networks (Vic) Ltd

Replacement of Batteries and Chargers at JEN Zone Substations

2021-2025 Business Case

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Replacement of Batteries and Chargers at JEN Zone Substations

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PREFACE

The intent of this business case document is to provide self-supportive, rigorous documentation to substantiate the need and prudency of an investment for both Jemena and its customers. The business case should assist in determining the strengths and weaknesses of a proposal, in comparison with its alternatives, in a systematic and objective manner. The business case seeks endorsement and funding for the project from the appropriate Jemena stakeholders and approval from the relevant delegated financial authority.

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1. EXECUTIVE SUMMARY

Synopsis

- The purpose of this project is to address issues and risks associated with the deteriorating battery banks and chargers at various zone substations within JEN, and to maintain reliability and security of supply of Standard Control Services from these sites.
- The capital expenditure proposal is to replace the deteriorating DC systems at these zone substations in 2021-2025.
- This represents the most efficient and prudent among the credible options.
- Project completion at different sites is required at different stages in the period 2021-2025 at an estimated capital cost of $3,539k (total project cost, real $2019).

1.1 BUSINESS NEED

This business case is for a capital expenditure proposal aimed at maintaining the reliability and security of supply of Standard Control Services (SCS) in accordance with the provisions of the National Electricity Rules (NER), by mitigating the risks associated with deteriorating battery banks and chargers at following sites:

- Battery replacement - Pascoe Vale(PV), Sydenham (SHM), NT (Newport), Nilsen Electrical Industries (NEI), Somerton (ST) , Tottenham (TH) , Visyboard Coolaroo (VCO), Yarraville (YVE), Broadmeadows South (BMS), Tullamarine (TMA), East Preston (EPN)
- Charger replacement – NT (Newport), Tottenham (TH), Visyboard Coolaroo (VCO), Nilsen Electrical Industries (NEI)

In addition, essential spare DC distribution boards will be procured and some remediation works at existing battery rooms will be carried out to comply with Australian Standards, as per following.

- Battery room remediation works - Pascoe Vale(PV), Sydenham (SHM), NT (Newport), Nilsen Electrical Industries (NEI), Somerton (ST) , Tottenham (TH), Visyboard Coolaroo (VCO), North Heidelberg (NH)
- Spare DC distribution boards – 240V, 110V, 50V and 24V

There is an increasing probability of failure of battery banks and chargers at these sites.

This project is necessary to mitigate risks related to the condition of battery banks and chargers as above and to address the following:

- Maintain reliability of electricity supply to customers served from the zone substations described above;
- Manage risk to personnel to As Low as Reasonably Practicable (ALARP) level, by maintaining availability of DC systems at above zone substations; and
- More generally to maintain the performance of the DC system asset class.

This project proposes to replace existing battery banks and chargers as above.

The most efficient option has been chosen from a life cycle perspective. The costs are what would be incurred by an efficient and knowledgeable network operator.

The cost of this project is estimated to be $3,539k (total project cost, real $2019). It would be completed in 2025.

1.2 RECOMMENDATION

It is recommended that Option 3 be adopted, which consists of replacement of battery banks and chargers at a number of JEN sites enumerated above (refer Appendix A). In addition essential spare DC distribution boards will be procured and some remediation works at existing battery rooms will be carried out to comply with Australian Standards.

Three feasible options have been considered and the recommended option (Option 3) meets Jemena's business objectives and the applicable legal and regulatory requirements. This Option is preferred as it:

- Reduces likelihood of equipment failure, which will reduce the likelihood of supply interruption to customers;
- Is technically prudent and addresses the points listed above in section 1.1;
- Reduces the possibility that JEN would be found to have breached its general obligation associated with good asset management;
- Is aligned with JEN's DC supply systems asset class strategy and JEN's broader corporate objectives; and
- Maximises the positive net benefit across the options considered, and as such, represents the economically efficient option.

The cost of this option is estimated to be $3,539k (total project cost, real $2019). and this project is scheduled to be completed in the period 2021-2025.

1.3 REGULATORY CONSIDERATIONS

There are no specific legal obligations that the DC systems infrastructure at JEN zone substations is expected to breach over the period considered in this document.

However, the occurrence of serious incidents due to the issues discussed here increase the possibility that JEN could be found in breach of its broader obligation associated with its protection systems and its requirement to apply good asset management. In this regard, the two most significant obligations are:

National Electricity Rules (Version 66), section 5.1.9 Protection systems and fault clearance times

> *C. Subject to clauses S5.1.9(k) and S5.1.9(l), 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 in accordance with clause S5.1.9(e) or clause S5.1.9(f).*

Victorian Electricity Distribution Code (Version 7 – May 2012), section 3.1 Good asset management

> A distributor must use best endeavours to:

A. *assess and record the nature, location, condition and performance of its distribution system assets;*

B. *develop and implement plans for the acquisition, creation, maintenance, operation, refurbishment, repair and disposal of its distribution system assets and plans for the establishment and augmentation of transmission connections:*

   a. *to comply with the laws and other performance obligations which apply to the provision of distribution services including those contained in this Code;*

   b. *to minimise the risks associated with the failure or reduced performance of assets; and*

   c. *in a way which minimises costs to customers taking into account distribution losses; and*

C. *Develop, test or simulate and implement contingency plans (including where relevant plans to strengthen the security of supply) to deal with events which have a low probability of occurring, but are realistic and would have a substantial impact on customers.*

Note the reliability and operability of all protection and control systems directly hinges on availability of DC supply system.

1.4 FINANCIAL INFORMATION

1.4.1 FORECAST EXPENDITURE AND BUDGET SUMMARY

This business case proposes a total investment of $3,539k (total project cost, real $2019) and requires Managing Director (Band B) approval under the SGSPAA DFA Manual, Annex 3.

The business case is prepared in relation to regulatory submission for the period 2021-2025.

This project is required to be completed in the period 2021-2025.

Summary of financial analysis of the recommended option (Option 3) is provided below.

Table 1-1: Project Budget Information

Budget Value	Total ($'000s, $2019)
CAPEX Budget	2,989
Overheads	550
Total Budget Value	**3,539**

2. BACKGROUND

2.1 BUSINESS AND SOCIO ECONOMIC CONTEXT

Jemena Electricity Network supplies electricity to more than 350,000 customers. The number of customers served from the JEN sites where the DC systems are being considered for replacement are as follows:

- Pascoe Vale(PV) – 20,720
- Sydenham (SHM) - 15,271
- Somerton (ST) – 18,237
- NT (Newport) – 12,817
- Yarraville (YVE) - 6,273
- East Preston (EPN) – 5,989
- Broadmeadows South (BMS), - 4,159
- Tottenham (TH) – 2,946
- Tullamarine (TMA) – 1,647

2.2 ASSET RISK (OR OPPORTUNITY) ANALYSIS

2.2.1 SHORT DESCRIPTION OF THE AFFECTED JEMENA ASSETS

This business case concerns the replacement of the following DC system assets, which would have reached the end of their design life in the period 2021-2025 and whose condition is deteriorating:

- 25 battery banks at Pascoe Vale(PV), Sydenham (SHM), NT (Newport), Nilsen Electrical Industries (NEI), Somerton (ST) , Tottenham (TH) , Visyboard Coolaroo (VCO), Yarraville (YVE), Broadmeadows South (BMS), Tullamarine (TMA), East Preston (EPN)
- 7 battery chargers at NT,TH, VCO & NEI sites.

The battery banks at SHM,NT,NEI,VCO,ST and TH are flooded lead acid type, while those at PV, YVE, BMS, TMA and EPN are valve regulated lead acid (VRLA) type.

Most of the existing flooded batteries are of Hoppecke make OGI typewhile some batteries are also of Battery Energy make Enerlyte type. All VRLA batteries are of Century Yuasa make UXH 125-6 type. Most chargers are of Brodribb make and constant output voltage type.

The battery chargers at ST, TH, NEI & VCO are conventional type.

Note, battery banks and chargers at SHM,NT,NEI,VCO,ST,TH and PV are single redundant configuration, whereas those at newer installations such as YVE,BMS,TMA & EPN are dual redundant configurations.

Refer to Appendix A for details of the above mentioned batteries and chargers.

2.2.2 FUNCTIONS OF DC SUPPLY SYSTEM

DC supply systems consist of battery bank and charger. DC supply systems are one of the most critical assets in a substation. They enable the following functions:

- closing and opening (switching) operation of all high voltage circuit breakers in zone substations, both locally and remotely
- providing auxiliary supply for protection and control of various assets
- providing auxiliary supply for metering, SCADA and communication equipment
- providing auxiliary supply for local indications and alarms
- providing auxiliary supply for control room emergency lighting
- providing auxiliary supply to miscellaneous systems including smoke detectors and security systems

Failure of DC supply system would necessitate shutting down of the site and transferring of all loads from that site to other sites, if practicable. It may also result in damage to assets and injury to personnel, if a network fault was not cleared during the period when DC supply system is not available.

DC systems are one of the most critical equipment at a substation. This is highlighted in a paper titled "Auxiliary DC Control Power System Design for Substations" published by Institute of Electrical and Electronics Engineers (**IEEE**) at the 2007 60th Annual Conference for Protective Relay Engineers[1] wherein it is stated that *"The most critical component of a protection, control, and monitoring system is the auxiliary DC control power system. Failure of the DC control power can render fault detection devices unable to detect faults, breakers unable to trip for faults, local and remote indication to become inoperable, etc*."

Notably, most of the DC systems on JEN (except at newer sites such as Yarraville, Broadmeadows South, Tullamarine Airport etc) are legacy design standard based single battery banks and single chargers; this lack of redundancy affects availability of the DC system. Single systems do not provide redundancy and thus impact system availability. This further underlines the need to keep the DC system assets in satisfactory condition.

Jemena's ability to maintain the reliability and security of supply of **SCS** as required under National Electricity Rules, are likely to be impacted due to following issues with the DC system assets:

Batteries

- There is a risk of failure of batteries due to irreversible temperature related thermal degradation or age related deterioration at various zone substation sites.
- There have been instances of batteries failing in JEN and at other Distribution Network Service Provider (**DNSP**)'s sites

[1] IEEE's 2007 60th Annual Conference for Protective Relay Engineers

- In the event of failure or unavailability of single battery bank, JEN site would become inoperable impacting supply of electricity to large number of customers.
- In JEN, most of the older DC systems are single systems consisting of single battery bank and single chargers; this lack of redundancy affects availability of DC system. In newer installations beginning from Yarraville (YVE), dual redundant DC supply systems are being installed.

Chargers:

- There is a risk of failure of chargers due to age related deterioration of components
- There have been numerous instances of charger failures at JEN sites and at other Distribution Network Service Provider (DNSP)'s sites.
- If a charger fails, the JEN site can only remain in service for a limited time, after which the site has to be shutdown, unless corrective timely steps are taken to restore DC system.

Failure of charger or battery directly impacts the integrity of DC systems, which can lead to loss of protection and control systems, potentially resulting in loss of supply to customers, widespread damage to assets and injury to personnel.

Refer to Appendix C for a snapshot of recent failures of batteries and chargers in JEN and at sites of other Distribution Network Service Providers (DNSPs) in Victoria.

It is noteworthy that most of these failures occurred while the age of the equipment was within their design life.

All the battery banks and chargers proposed for replacement in this business case would have reached end of design life.

2.2.3 RISK ASSESSMENT

A qualitative risk assessment was carried out in accordance with Jemena's risk assessment guideline and the outcome of this is placed in Appendix B The purpose of this risk assessment is to evaluate the risks to JEN business in the event of failure of DC supply system assets.

The issues discussed here and the proposed solutions are part of JEN broader DC systems strategy. These matters are discussed in JEM AM Electricity Secondary Plant Asset Class Strategy (ELE AM PL 0062).

This section describes the risks associated with the DC system assets, the outcomes if the risks are realised and the factors that affect the probability of the outcome occurring.

2.2.3.1 Deterioration and Failure mode of Battery Banks

Lead-acid batteries suffer from performance degradation over time due to accumulative effects of the irreversible electrochemical reactions. Further, the useful life of batteries is severely impacted by operating temperatures. In accordance with IEEE Standard 450-2002, batteries follow a Thermal Degradation Curve which is based on a widely accepted rule of thumb for lead-acid battery ageing, in accordance the Arrhenius equation. For example, the battery life is reduced by 50% for every 8 degree C increase in operating temperature above 25 deg C. Battery manufacturers corroborate this interdependence between increase in temperature and battery life.[2] As per the Bureau of Meteorology records, in Melbourne, the highest daily temperatures recorded during summer months (December to February) over the last 3 years (2013-2015) were in the range ~33 to ~ 44 deg C.[3] which are well above 25 deg C. Such high temperatures lead to loss of battery life.

Further the Ampere-hour capacity of batteries reduces with age, due to various factors such as frequent charging /discharging, float charge voltage variation etc which means the capacity of battery to supply the loads for required period of time reduces as the batteries age.

More recently, during 2013, there were battery failures at Somerton Switching Station (SSS), North Essendon (NS), Fairfield (FF) & Footscray West (FW) zone substation sites of JEN. Notably, most of these battery failures occurred before the expiry of their design life.

Further, there was an incident of a battery failure at the site of another distribution utility in Victoria recently. This incident required emergency mobilisation of a spare battery bank mounted on a trailer, in order to keep the zone substation in service. It is noteworthy again that this battery had failed before the end of its design life.

Refer to Appendix C for a snapshot of recent battery failures in JEN and at other DNSPs' sites.

Consequence

As highlighted above in IEEE 2007 60th Annual Conference for Protective Relay Engineers, failure of battery bank at a substation has following consequences:

- the switching of primary plant cannot be performed, i.e. circuit breakers cannot be opened or closed; this situation means that if a network fault occurred during this time, it would not be cleared due to the circuit breaker not being able to perform tripping duty; in order to prevent this from happening, the zone substation may have to be shutdown with subsequent transferring of loads to other adjacent zone substations, if possible; this scenario would likely lead to loss of supply of electricity to customers
- Injury to personnel may occur if a network fault occurred during this time and if preventive steps were not taken to shut down the electrical system
- Protection and control schemes become inoperative due to non-operability of circuit-breakers as described above, thus exposing the network assets to widespread damage, and exposing personnel to serious injuries, if a network fault occurred during this period (since the fault may remain uncleared for a prolonged period leading to asset damage and injuries to people).

As an example: a serious failure occurred at Albury zone substation in September 1989 when a corroded battery connection resulted in the failure of both the primary and back up protection schemes to clear a system fault. The time taken to finally isolate the fault was very long and two power transformers within the zone substation caught fire and were subsequently destroyed. There was extensive damage to the zone substation primary assets and the cost of damage was of the order of several millions of dollars.

Another consequence of an ageing and deteriorating battery is that due to reduction in the ampere-hour capacity of battery with time, there is a risk that the battery may become incapable of providing the required duty cycle of loads and as a result, loads may have to be transferred to other sites (this may not be practicable during peak load times, e.g. summer critical periods) thus impacting the reliability of electricity supply to customers.

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2 Battery manufacturer Hoppecke's Installation, commissioning and operating instructions for vented stationary lead-acid batteries Section 7.9 (Temperature Influence on battery performance and lifetime)

3 Source: Bureau of Meteorology, Daily Max Temperatures recorded at Melbourne Airport Weather Station no 86282

As per Australian Standard AS2676.2 Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings Part 2: Sealed cells, "*Physical characteristics, such as age, are often deciding factors for complete battery or individual cell replacement*". A similar suggestion is made in AS2676.1 for flooded batteries. Thus age is a critical factor leading to performance degradation of batteries and is the principal criterion for planning replacement of batteries.

The above issues highlight the criticality of the requirement for replacement of batteries not later than the end of their design life.

2.2.4 DETERIORATION AND FAILURE MODES OF CHARGERS

There is risk of failure of chargers due to age related deterioration of components (e.g. electrolytic capacitors).

Age related components degradation within chargers is also likely to impact charger performance. e.g. increased AC ripple content in DC output.

Further, spares are not available for the older chargers, which impacts availability of chargers after a component failure.

There have been a number of instances of battery charger failures at Jemena's sites and at the sites of another Distribution Network Service Providers (DNSP) which has similar type of chargers in their installed base. The causes of failure have been varied, such as charger malfunctioning and tripping on AC thermal overload, DC Low and not resetting, laminations of power transformer coming off loose.

A large number of these failures occurred while the chargers were within the design life.

Consequence

When a charger fails, battery banks have a limited carryover time to supply DC loads, and even this battery capacity reduces with ageing; there is a risk that within a few hours of charger failure, batteries may get fully discharged. As described in previous sections, this will make the circuit breaker switching and protection & control systems ineffective at zone substation. Consequently, network faults may continue to remain uncleared causing serious damage to equipment, shortening of useful life of assets and injuries to people, if the fault occurred during this period.

Another aspect of ageing of chargers is that the AC ripple content in the DC output of chargers is known to increase with ageing, caused by degradation of components like electrolytic capacitors. The high ripple content in DC supply is a well-known cause of failure of sensitive protection and control equipment (e.g. modern numerical relays). Also, the high ripple content causes damage to batteries due to additional battery temperature rise, leading to shortening of useful life.

Thus, failure of battery chargers can render the protection and control systems ineffective..

Jemena have started capturing the failure statistics of equipment in SAP only recently. There have been instances of charger failures at a number of JEN sites, and Jemena is also aware of charger failures at sites of other DNSPs over the years.

Refer to Appendix C for a snapshot of these recent charger failures at JEN sites and those of another DNSP.

From above, it is evident that there is increased risk of battery and charger failure due to various factors as the equipment reaches the end of its design life. Also the impact of such failure is high.

2.3 PROJECT OBJECTIVES AND ASSESSMENT CRITERIA

This project consists of replacement of DC system assets and in doing so, it seeks to meet the key objective of maintaining the SCS as set out in the National Electricity Rules (NER).

The proposed capital expenditure will meet the following objectives, as set forth in NER 6.5.7 (3) sub clauses (iii) and (iv):

iii) Maintain the quality, reliability and security of supply of standard control services

This capital expenditure will ensure maintenance of reliability and security of supply of SCS by mitigating the issues outlined above.

iv) Maintain the reliability and security of the distribution system through the supply of standard control services

This project aims to maintain the reliability and security of the distribution system by mitigating the issues outlined above

The assessment criteria by which the project will be assessed against are the extent to which each of the identified options addresses the issues, as described in Section 2.2. Valid options that address the critical issues described therein are then analysed from both net present value and network risk perspective, in order to determine the preferred option.

2.4 CONSISTENCY WITH JEMENA STRATEGY AND PLANS

JEN's focus is to improve its competitiveness and adaptability in the following ways:

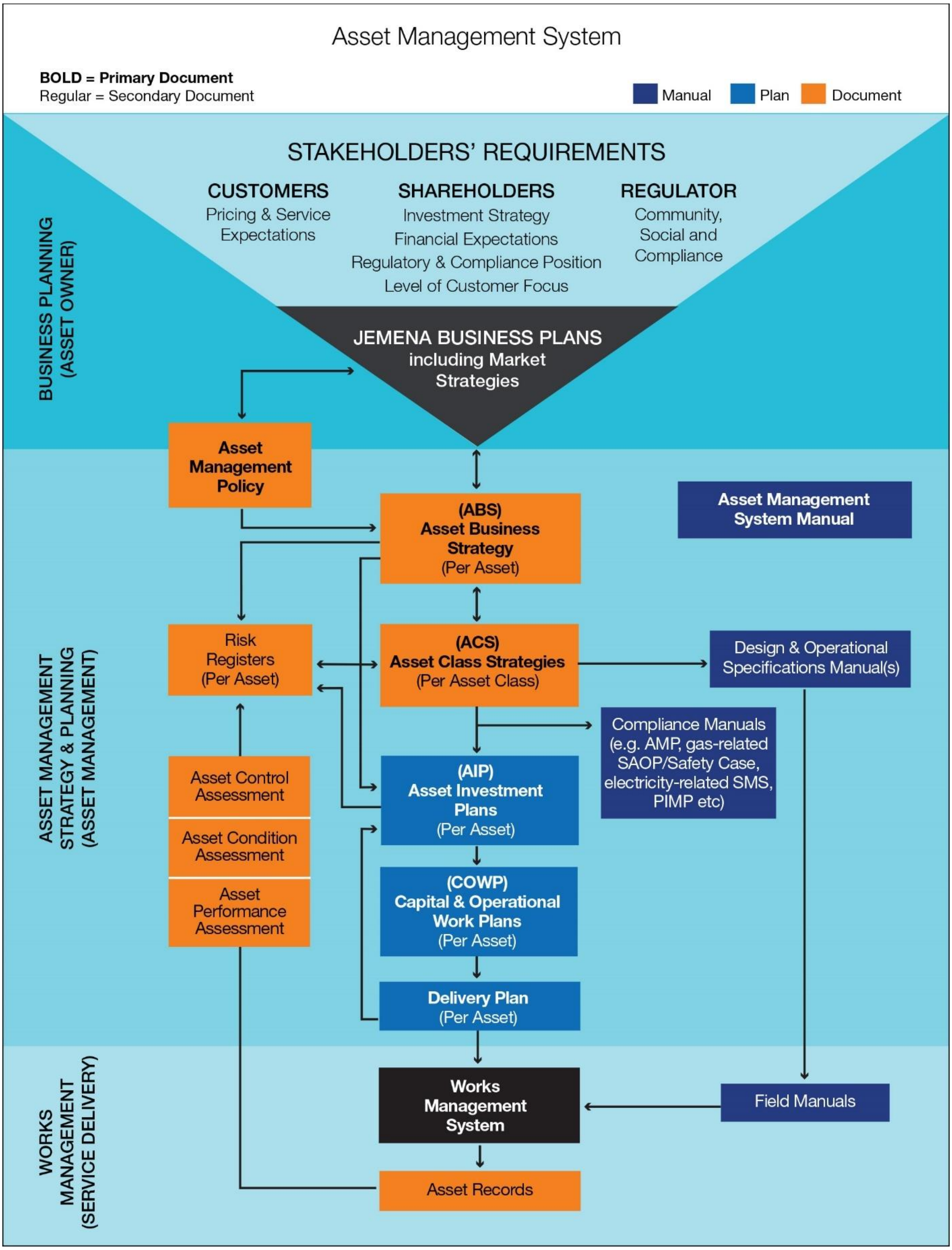
1. Efficiently and safely deliver affordable and reliable energy;
2. Make the customer experience easier and more valuable through digital and performance improvements; and
3. Modernise the grid to prepare for a connected future.

This project is based on guidelines and principles enshrined in the JEM AM Secondary Plant Asset Class Strategy.

Figure 2-1 outlines the Jemena Asset Management System and where the Asset Management Plan (AMP) is positioned within it. The AMP covers the creation, maintenance and disposal of assets including investment planned to augment network capacity to meet increasing demand and to replace degraded assets to maintain reliability of supply to meet Jemena Business Plan requirements.

This strategic framework facilitates the planning and identification of business needs that require network investment documented via business cases.

Figure 2–1: The Jemena Asset Management System



3. CREDIBLE OPTIONS

This section discusses how credible options are identified and developed. The credible options are considered for their commercial and technical feasibility, abilities to address the identified needs, deliverability, economic and financial benefits, as well as legal and regulatory implications.

3.1 IDENTIFYING CREDIBLE OPTIONS

The following feasible options were considered to address the business need, problem or opportunity:

- Option 1: Continue current regime of routine maintenance and like-for-like replacement on failure
- Option 2: Increase routine maintenance
- Option 3: Planned replacement of chargers and batteries

These options are discussed in more detail below.

Replacing battery banks and chargers upon failure has not been considered as an option, due to the long lead time of the equipment and also due to the fact there is no DC system redundancy at most of JEN zone substation sites.

3.1.1 OPTION 1 – DO NOTHING

Option 1 represents a continuation of the existing regime for these DC system assets, without any further actions.

3.1.2 OPTION 2 – INCREASE MAINTENANCE

Option 2 represents a change to the existing maintenance regime for these equipment, with the aim of reducing the likelihood of failure. The change will involve increasing the frequency of equipment maintenance from once in 6 months to once every 2 months.

3.1.3 OPTION 3 – PLANNED REPLACEMENT

Option 3 involves the proactive and planned replacement of the DC system assets based predominantly on age and condition.

All three options have been considered for further financial analysis evaluation.

No non-network options could be identified for addressing the issues discussed herein above, which could be considered efficient and prudent credible option.

3.2 DEVELOPING CREDIBLE OPTIONS COSTS & BENEFITS

The credible options are discussed in the following sub-sections. Note that all expected option costs include overheads.

3.2.1 OPTION 1: DO NOTHING

Option 1 represents Do Nothing scenario. That is, maintaining the status quo.

3.2.1.1 Scope, costs & timelines

As such, this option consists of following:

- Continuing the current routine maintenance regime which is performed every 6 months for batteries and every 12 months for chargers
- Replacing the equipment once a fault is detected, using spares.

The only advantage of this option is that it represents the lowest upfront cost option to JEN, in terms of routine maintenance and the expected capital cost of replacement.

However, this option does not address any issues related to chargers and batteries as described above. All battery banks and chargers proposed to be replaced have outlived their design life and are prone to failure. This option of “Do Nothing” will not address any of these issues and associated risks discussed above in section 2.2.

Under this option, the current risks will thus remain unmitigated and increase further as the equipment continues to age.

3.2.1.2 Assumptions and forecasts

Financial evaluation for this option was carried out by considering the case of DC system failure at PV zone substation. Loss of electricity supply to all 20,720 customers for a period of 2 hours, with a 50% probability of failure of DC systems was considered and the impact on STPIS was taken.

The protection and control infrastructure was assumed to have a regulatory standard life of 10 years, and a tax asset life of 10 years.

3.2.2 OPTION 2: INCREASE MAINTENANCE

Option 2 represents increasing the frequency of routine maintenance from once every 6 months to once every 2 months

3.2.2.1 Scope, Costs & timelines

This option consists of increasing the frequency of routine maintenance from once every 6 months to once every 2 months. It is considered that under Option 2, although there is no material impact on the design life of the DC systems, there is a possibility of some obvious defects being known in course of increased inspection and maintenance of assets, which may marginally reduce the probability of failure of DC system.

This option has the following advantages:

- It has low capital costs
- Marginal reduction in probability of failure of assets

However, the disadvantages of this option are:

- Some maintenance can be done on flooded batteries (e.g. topping up of electrolyte). However these maintenance activities are unlikely to extend the life of assets. As mentioned above, age related and thermal degradation of DC system assets is largely irreversible and an increase in maintenance activity is unlikely to yield any extension in life span.
- Only minimal maintenance can be carried out on chargers, such as verifying and adjusting the operational parameters (e.g. float charge voltage). In some cases, the electrolytic capacitors can be replaced, if found cost-effective.
- Since most JEN DC systems consist of single battery bank and charger, there is limited flexibility in taking these assets out of service for maintenance and as such, an increase in maintenance activities on single systems may lead to a corresponding increase in the risk of inadvertently causing a loss of DC supply.
- It requires increase in OPEX due to more frequent maintenance

3.2.2.2 Assumptions and forecasts

Financial evaluation for this option was carried out by considering increasing the frequency of maintenance from once every 6 months to once every 2 months and taking the case of DC system failure at PV zone substation.

It is considered that under Option 2, although there is no material impact on the design life of the DC systems, there is a possibility of some obvious defects being known in course of increased maintenance, which may marginally reduce the probability of failure of DC system(from 50% for Do Nothing option to 45%).

Based on this, loss of electricity supply to all 20,720 customers for a period of 2 hours, with a 45% probability was considered and the impact on STPIS was taken.

The protection and control infrastructure was assumed to have a regulatory standard life of 10 years, and a tax asset life of 10 years.

3.2.3 OPTION 3: PLANNED & PROACTIVE RELAY REPLACEMENT

3.2.3.1 Scope, costs & timelines

This option consists of planned replacement of battery banks and chargers based on age and condition.

Total capital cost for this option is $3,539k . These cost estimates have been generated by Service & Projects via a cost element build up methodology utilising current rates, recent quotes/budgetary prices and estimated and actual costs with reference to recently completed similar projects.

All expected option cost estimates include overhead recoveries.

This project will be completed in 2021.

This option represents the highest capital cost investment option. However, this option addresses all the issues and associated risks identified in Section 2.2.

Planned replacement of assets provides additional benefits by way of lower construction risks (e.g. inadvertently causing loss of DC system) and lower costs, as compared to an unplanned ad-hoc replacement.

Proposed planned replacement of the aged and deteriorating DC system assets at the sites described above also provides an opportunity to implement JEN secondary design standard, thus optimising the types of DC system assets in JEN and bringing uniformity to the installed asset base. This would help in realising operational cost benefits and would lead to savings in cost of electricity supply to customers.

3.2.3.2 Assumptions and forecasts

The financial evaluation for this option was carried out by considering Service & Projects' projected spend during 2021.

The protection and control infrastructure was assumed to have a regulatory standard life of 10 years, and a tax asset life of 10 years.

4. OPTION EVALUATION

From above, it is noted that:

- Option 1 (Do Nothing) does not address the risks and issues related to DC system asset failure; it does not require any costs (CAPEX or OPEX)
- Option 2 only marginally reduces the probability of failure and therefore does not fully mitigate the risks ; further, it requires increased OPEX by way of increased maintenance
- Option 3 addresses all issues and mitigates the identified risks associated with failure of DC system assets; it requires CAPEX

In order to evaluate the options further, economic analysis was performed. Based on this, the preferred option is selected.

4.1 ECONOMIC ANALYSIS

In line with the objective of the National Electricity Rules, Jemena's investment decisions aim to maximise the present value of the net economic benefit to all those who produce, consume and transport electricity in the National Electricity Market.

To assess benefits against this objective, Jemena has undertaken a probabilistic cost-benefit assessment of options that considers the likelihood and severity of critical network outages. The methodology assesses the expected impact of network outages or asset failures on supply delivery, and combines this with the value that customers place on their supply reliability and compares the result with the costs required to reduce the likelihood and/or impact of these supply outages or asset failures. The table below presents a summary of the cost-benefit assessment undertaken for this project.

4.1.1 SUMMARY OF CREDIBLE OPTIONS' EXPECTED COSTS & MARKET BENEFITS

Expected costs and expected market benefits associated with each of the credible options used in the ensuing economic evaluations are summarised in the following tables.

Table 4-1: Economic Analysis Results Summary

Description ($'000s, $2019)	Option 1 Do Nothing	Option 2 Increase maintenance	Option 3 Planned replacement
Total Expected costs	0	0	3,539
Total Expected market benefits	Status quo	5,845	66,608
Net market benefits	N/A	5,845	63,069
Option ranking	3	2	1

On the basis of above economic analysis, Option 3 is the preferred option.

5. RECOMMENDATION

This business case proposes adopting Option 3 among the available options. This option consists of planned and proactive replacement of ageing and deteriorating batteries and chargers at JEN sites described above, at a total investment of $3,539k, and requires Managing Director (Band B) approval under the SGSPAA DFA Manual, Annex 3.

This option is preferred based on following considerations:

- It facilitates managing the health and safety risks to personnel, associated with deteriorating DC supply system assets, to As Low As Reasonably Practicable;
- It ensures maintaining the current performance level on reliability of electricity supply to customers being supplied from various sites stated in this business case;
- It enables Jemena to maintain supply of standard control services (**SCS**) from the sites stated herein as an efficient and knowledgeable network operator should;
- It is technically prudent and addresses the risks identified, and it reduces the possibility that JEN would be found to have breached its general obligations associated with good asset management;
- It is in line with JEN approach of considering end-of-life replacement of assets with due consideration to useful life [4] and asset condition; and
- It is in accordance with JEN's secondary plant asset class strategy[5] and JEN's broader corporate objectives.

[4] JEN Network Asset Useful Lives Procedure (ELE PR 0012)

[5] JEM AM Electricity Secondary Plant Asset Class Strategy (ELE AM PL 0062)

Appendix A Project Scope and Delivery Information

A1. HIGH LEVEL SCOPE

Scope of Works for this business case consists of following:

YEAR	ZONE SUBSTATION	DESCRIPTION
2021	Pascoe Vale (PV)	Replace batteries: 110V, 2 strings (sealed type, Century Yuasa UXH125-6)
		Install new Battery Monitoring System for above batteries
		Remediate battery enclosure complying with Australian Standards for ventilation, eyewash, lighting, signage etc
	NT (Newport)	Replace batteries: 240V control (flooded lead-acid type, Hoppecke OGi)
		Replace batteries: 50V control (flooded lead-acid type, Hoppecke OGi)
		Replace battery chargers: 50V control
		Remediate battery room complying with Australian Standards for ventilation, eyewash, lighting, signage etc
	Visyboard Coolaroo (VCO)	Replace battery chargers: 120V control
		Replace battery chargers: 24V Clean
		Replace battery chargers: 24V Dirty
	Spares for DC supply system	Procure following spare DC Distribution Boards: • 240V DC Distribution Board • 110V DC Distribution Board • 50V DC Distribution Board • 24V DC Distribution Board
2022	Sydenham (SHM)	Replace batteries: 110V control (flooded lead-acid type, Hoppecke OGi)
		Replace batteries: 50V control (flooded lead-acid type, Hoppecke OGi)

YEAR	ZONE SUBSTATION	DESCRIPTION
		Replace batteries: 50V communications (flooded lead-acid type, Hoppecke OGi)
		Remediate battery room complying with Australian Standards for ventilation, eyewash, lighting, signage etc
2023	Somerton (ST)	Replace batteries: 250V control (flooded lead-acid type, Hoppecke OGi)
		Replace batteries: 50V control (flooded lead-acid type, Hoppecke OGi)
		Replace batteries: 50V communications (flooded lead-acid type, Hoppecke OGi)
		Remediate battery room complying with Australian Standards for ventilation, eyewash, lighting, signage etc
	Tottenham (TH)	Replace batteries: 240V control (flooded lead-acid type, Hoppecke OGi)
		Replace batteries: 50V control (flooded lead-acid type, Hoppecke OGi)
		Replace batteries: 50V communications (flooded lead-acid type, Hoppecke OGi)
		Replace battery chargers: 50V communications
		Remediate battery room complying with Australian Standards for ventilation, eyewash, lighting, signage etc
2024	Nilsen Electrical Industries (NEI)	Replace batteries: 120V control (flooded lead-acid type, Hoppecke OGi)
		Replace batteries: 24V control (flooded lead-acid type, Hoppecke OGi)
		Replace battery chargers: 120V control
		Replace battery chargers: 24V control
		Remediate battery room complying with Australian Standards for ventilation, eyewash, lighting, signage etc
	Visyboard Coolaroo (VCO)	Replace batteries: 120V control (flooded lead-acid type, Hoppecke OGi)

YEAR	ZONE SUBSTATION	DESCRIPTION
		Replace batteries: 24V Clean (flooded lead-acid type, Hoppecke OGi)
		Replace batteries: 24V Dirty (flooded lead-acid type, Hoppecke OGi)
		Remediate battery room complying with Australian Standards for ventilation, eyewash, lighting, signage etc
	Yarraville (YVE)	Replace batteries: X - 110V, 2 strings (sealed type, Century Yuasa UXH125-6)
		Replace batteries: Y - 110V, 2 strings (sealed type, Century Yuasa UXH125-6)
	North Heidelberg (NH)	Remediate battery room complying with Australian Standards for ventilation, eyewash, lighting, signage etc
2025	Broadmeadows South (BMS)	Replace batteries: X - 110V, 3 strings (sealed type, Century Yuasa UXH125-6)
		Replace batteries: Y - 110V, 3 strings (sealed type, Century Yuasa UXH125-6)
	Tullamarine (TMA)	Replace batteries: X - 110V, 3 strings (sealed type, Century Yuasa UXH125-6)
		Replace batteries: Y - 110V, 3 strings (sealed type, Century Yuasa UXH125-6)
	East Preston (EPN)	Replace batteries: X - 110V, 2 strings (sealed type, Century Yuasa UXH125-6)
		Replace batteries: Y - 110V, 2 strings (sealed type, Century Yuasa UXH125-6)

A2. PROJECT COST ESTIMATE

Estimated cost of this project is $3,539k including overheads.

Appendix B Network Risk Assessment Summary

B1. NETWORK RISK ASSESSMENT SUMMARY

JEN Asset Specific (Strategic) Risk Assessment

Click here for INSTRUCTIONS

Context statement: Project Name: Replace battery bank and chargers at various JEN zone substation sites in 2016,2017,2018 & 2019

Participants: Diptiman Yadav, Ken Lau, Justin Lai, Kopeeswaran Vaikundan, Michael Tame (Apologies - Alan Shu, Ranjan Vaidya,Raman Luthra)

Workshop Date: 16/10/14

S/No	Business Unit	Business Objective	Risk Type	Risk Title	Risk Description	Root Causes (Contributing Factors)	Risk Owner	Current Controls	Adequacy of Controls	Current Consequence	Current Likelihood	Current Risk Rating	Action Plans	Action Owner	Due Date	Status	Last Month	This Month	Target Consequence	Target Likelihood	Target Risk Rating
1	Strategy (Network)	Manage Risk	Financial	**Risk of impact on reliability of supply and asset damage due to failure of battery banks**	**If battery banks fail leading to a situation where there is no battery bank in service at site, the zone substation (ZSS) site is to be shutdown and loads are to be transferred.** There has been an instance at the site of another distribution utility where ZSS was shutdown due to failure of battery bank If existing DC supply at ZSS fails, power supply to all protection and control equipment may be lost. Consequently, both X & Y protection may fail and the assets may be severely damaged due to sustained / uncleared power system fault. Significant loss of reputation and significant stakeholder criticism	Aged and deteriorated battery banks at ZSS No redundancy(single battery bank) Example: Significant outage of primary and secondary plant and damage to assets occurred in 1989 at Albury ZSS. Faulty DC system led to loss of both both X & Y protection schemes, which resulted in a transformer catching fire and significant loss of property	Asset Strategy-Electrical	Routine inspection of flooded batteries at 6 months and VRLA batteries and chargers at 12 months interval	Fair	Major	Unlikely	**Significant**	Initiate a project for replacement of battery banks at zone substations	Diptiman Yadav	Project specific compeltion dates	Not Started		O	Major	Rare	**Moderate**
2	Strategy (Network)	Manage Risk	Financial	**Risk of impact on reliability of supply and asset damage due to failure of chargers**	If charger fails, battery banks may potentially get dischrged to a level, where zone substation site can not be operated, loads may have to be transferred and site may have to be shutdown If existing DC supply at ZSS fails, power supply to all protection and control equipment may be lost. Consequently, both X & Y protection may fail and the assets may be severely damaged due to sustained / uncleared power system fault.	Aged and deteriorated battery chargers at ZSS No redudancy (single chargers) Battery charger fail alarm not addressed in time Human error (e.g. inadvertent switching off of AC supply to charger)	Asset Strategy-Electrical	Periodic maintenance of chargers Battery charger fail alarm at SCADA Spare chargers	Adequate	Severe	Unlikely	**Moderate**	Initiate project to relace aged chargers	Diptiman Yadav	Project specific compeltion dates	Not Started		O	Severe	Rare	**Moderate**
3	Strategy (Network)	Safety & Environment	Health, Safety & Environment	**Risk of injury to staff, contractors and public due to failure of DC supply at a site**	If existing DC supplies are lost at a site,power supply to all protection and control equipment may be lost. Consequently, both X & Y protection may fail to clear a genuine fault on the network. This may lead to serious injury to staff, contractors and public.	Aged and deteriorated battery banks and chargers at ZSS No redundancy(single battery bank, single chargers) Example: Significant outage of primary and secondary plant and damage to assets occurred in 1989 at Albury ZSS. Faulty DC system led to loss of both both X & Y protection schemes, which resulted in a transformer catching fire and significant loss of property	Asset Strategy-Electrical	Routine inspection of flooded batteries at 6 months and VRLA batteries and chargers at 12 months interval	Fair	Major	Unlikely	**Significant**	Initiate a project to install charger fail alarm at various zone substations	Diptiman Yadav	Project specific compeltion dates	Not Started		O	Major	Rare	**Moderate**
4	Strategy (Network)	Community Reputation	Brand/ Reputation/ Stakeholders/ Customer Service	**Significant loss of reputation and significant stakeholder criticism**	If existing DC supplies are lost at a site,power supply to all protection and control equipment may be lost. Consequently, both X & Y protection may fail to clear a genuine fault on the network. This may lead to serious injury to staff, contractors and public.	Aged and deteriorated battery banks and chargers at ZSS No redundancy(single battery bank, single chargers) Example: Significant outage of primary and secondary plant and damage to assets occurred in 1989 at Albury ZSS. Faulty DC system led to loss of both both X & Y protection schemes, which resulted in a transformer catching fire and significant loss of property	Asset Strategy-Electrical	Routine inspection of flooded batteries at 6 months and VRLA batteries and chargers at 12 months interval	Fair	Major	Unlikely	**Significant**	Initiate a project to install charger fail alarm at various zone substations	Diptiman Yadav	Project specific compeltion dates	Not Started		O	Major	Rare	**Moderate**

Appendix C Failure history of batteries and chargers

C1. FAILURE HISTORY OF BATTERIES AND CHARGERS

Zone Substation	Equipment failure	Year of failure	Cause of failure	Whether failure occurred during design life
FW	Battery failure	2013	Battery failed to hold charge	Yes
SSS	Battery failure	Various failures 2007-2013	Battery failed to hold charge ; corrosion	Yes
NS	Battery failure	2013, 2014	Bulge in Battery case	Yes
FF	Battery failure	2013	Bulge in Battery case	Yes
CN	Battery failure	2017	Battery failed to hold charge	Yes
FE	Battery failure	2019	Battery failed to hold charge	No
Other DNSP	Battery failure	2014	Positive post growth; corrosion	Yes
NS	Charger failure	2014	Component failure	Yes
FF	Charger failure	2013	Component failure	Yes
PV	Charger failure	2014	Module failure, software issues	Yes
HB	Charger failure	2013	Module failure, software issues	Yes
Other DNSPs' sites	Charger failures	Various failures 2005 till date		Yes (in most cases)