Jemena Electricity Networks (Vic) Ltd

Replace North Heidelberg (NH) Zone Substation Aged Relays

1.

Business Case

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Replace North Heidelberg (NH) Zone Substation Aged Relays

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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 JEN 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 JEN stakeholders and approval from the relevant delegated financial authority.

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1. EXECUTIVE SUMMARY

Synopsis

- Purpose of this project is to mitigate risks of asset damage and health and safety risks, and to maintain reliability and security of supply of standard control services from North Heidelberg (**NH**) zone substation to more than 19,480 customers
- This project proposes replacement of relays to mitigate the risks associated with deteriorating 66 kV line protection, 66 kV bus protection, 22 kV bus protection relays and transformer protection relays at NH. This project also proposes fibre communication support between the new 66 kV line protection relays and also removal of decommissioned copper supervisory cables.
- The project is planned to be completed in 2026, at an estimated cost of $2,654k (total project cost, real $2019).

1.1 BUSINESS NEED

This business case relates to mitigation of risks associated with deteriorating protection relays at the North Heidelberg (**NH**) zone substation.

This project is necessary to:

- Maintain the performance of the protection asset class in accordance with accepted practices world-wide and JEN's asset management policies, given the critical role of protection relays in managing fault clearance in electricity network;
- Mitigate health and safety risks to personnel to As Low As Reasonably Practicable (**ALARP**) in line with JEN Group Risk Management Manual (JAA MA 0050);
- Mitigate risk of asset damage; and
- Maintain reliability of electricity supply to over 19,500 customers being served from NH zone substation

The project is planned to be completed in 2026, at an estimated cost of $2,654k (total project cost, real $2019).

1.2 RECOMMENDATIONS

The proposed investment's Option 3 is recommended to be endorsed. This option consists of replacement of deteriorating protection equipment at NH, in the year 2026, at an estimated cost of $2,654k (total project cost, real $2019).

This option is preferred based on following considerations:

- It recognises the critical role of protection relays in keeping the electricity network safe by timely clearance of network faults;
- It facilitates managing the health and safety risks to personnel, associated with deteriorating protection system assets, to As Low As Reasonably Practicable;

- It enables protecting the assets such as 66 kV bus, 22 kV bus and 66/22 kV power transformers from damage due to network faults;
- It ensures maintaining the reliability of electricity supply to over 19,500 customers;
- It enables JEN to maintain supply of standard control services (**SCS**) from North Heidelberg (**NH**) zone substation;
- It is technically prudent and addresses the risks identified above, 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 [1] and asset condition
- It is in accordance with JEN's Secondary Plant Asset Class Strategy[2] and JEN's broader corporate objectives; and
- It maximises the positive net benefit across the options considered, and represents the economically efficient option

1.3 REGULATORY CONSIDERATIONS

There are no specific legal obligations that the protection infrastructure at NH is expected to breach. 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 obligations associated with its protection and control 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 9A – Aug 2018), 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;*

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

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

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.*

1.4 FINANCIAL INFORMATION

1.4.1 FORECAST EXPENDITURE AND BUDGET SUMMARY

This business case proposes a total investment of $2,654k (total project cost, real $2019) and requires JEN Leadership Team – Executive General Managers, Zinfra MD,& DMDs appointed by Shareholders (Band C) approval under the SGSPAA DFA Manual, Annex 3.

The business case is prepared in relation to regulatory submission for the period 2021-2026.

This project is required to be commissioned by 2026.

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	2,252
Overhead Recovery	402
Total Budget Value	**2,654**

2. BACKGROUND

2.1 BUSINESS AND SOCIO ECONOMIC CONTEXT

North Heidelberg (**NH**) consists of two 20/30MVA and one 20/33 MVA transformers providing a total nameplate rating of 93MVA. NH supplies the areas of Heidelberg, North Heidelberg, Rosanna, Macleod, Yallambie and Viewbank. There are 10-off 22kV feeders supplying electricity to more than 19,480 customers in areas of North Heidelberg.

2.2 ASSET RISK (OR OPPORTUNITY) ANALYSIS

2.2.1 SHORT DESCRIPTION OF THE AFFECTED JEN ASSETS

Current useful life of electromechanical relays is 40 years and that of analogue and digital relays is 20 years.[3] The asset useful lives are based on good industry practice and the specific JEN experiences, and represent the lives of assets at which end-of-life replacement will be considered.

Amongst a range of issues with protection infrastructure as elaborated below, the major issues at NH are as follows:

- majority of relays under discussion here are electromechanical type and approaching end of useful life,
- there have been a number of instances of relay failures, thus:
  - undermining safety of personnel,
  - increasing risk of asset damage due to faults being not cleared in a timely manner and
  - impacting reliability of electricity supply to customers,

This section enumerates the issues and related risks with regard to the current state of the protection relays at NH. In accordance with the North American Electric Reliability Council (**NERC**)'s Protection System Maintenance Technical Reference[4], *"Protective relays have been described as silent sentinels, and do not generally demonstrate their performance until a fault or other power system problem requires that they operate to protect power system elements…A misoperation - a false operation of a protection system or a failure of the protection system to operate when needed - can result in equipment damage, personnel hazards, and wide area disturbances or unnecessary customer outages".*

The above statement of NERC emphasizes the main role of protection system in protecting the assets from damage and ensuring safety of personnel during a fault situation. These aspects are closely meshed with reliability and integrity of systems.

A range of issues at NH are impacting JEN's ability to meet or maintain the reliability and security of supply of the Standard Control Services (**SCS**) as stipulated in the NER.

Description of the current issues related to protection relays at NH is provided below.

3 JEN Network Assets Useful Lives Procedure (ELE PR 0012)

4 North American Electric Reliability Council (NERC)'s Protection System Maintenance - A Technical Reference (September 13, 2007) - Prepared by the System Protection and Controls Task Force of the NERC Planning Committee

2.2.2 RISK ASSESSMENT

A Project Risk Assessment has been carried out following JEN's Networks Projects Business Cases Risks Budgeting and Assessment Guidelines document JEN GU 2502. This risk assessment highlights the current issues at NH zone substation and the risks to JEN business emanating from these risks, as well as initiation of the proposed project capital expenditure as an action to mitigate these risks.

Protection failure can lead to following consequences:

- Increased health and safety risk to personnel
- Risk of asset damage due to prolonged fault clearance and higher energy let through (I^2t) causing stress to assets
- Impact on reliability of electricity supply

Consequences of both primary and back-up protection failures can be costly, as evidenced by the recent protection scheme failures at Morwell Terminal Station where on 4 April 2014 failures of both protection schemes on a line during a fault on the line led to loss of supply to 80,000 customers in Gippsland.

Energy Safe Victoria (**ESV's**) Morwell Terminal Station Incident Final Report summary excerpt reads[5]:

> *"ESV understands that this event will affect the service component of AusNet Services' transmission STPIS with a total marginal impact likely to be in excess of $1M. The associated costs of repair and reconstruction are also likely to be significant.(… 1865 route meters of 66kV conductor… pole top assemblies on poles 2, 3, 4, and 5…replacement of a 22kV gas switch…)*
>
> *ESV's investigation confirmed… The probability of the sequence of events that occurred on 4 April, where both of the primary protection schemes failed to operate, is considered low but not impossible".*

This incident demonstrates the severity of consequences of protection schemes failing to operate, when required under network fault conditions.

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

This section describes the issues and related risks with regard to the current state of the protection relays under discussion at NH.

2.2.2.1 Degradation of reliability of supply, risk of asset damage and health and safety risk due to a number of relays being electromechanical type and without failure monitoring and without spares

Many of the relays at NH are the oldest generation - that is electromechanical type. These relays have long been discontinued by manufacturers. There are no spares available for these relays. These relays are being used for protection of 66 kV lines, transformers and buses at NH.

Background:

Electro-mechanical relays are the oldest relay technology. They comprise moving parts, springs and magnets that degrade their characteristics over time, affecting the relay performance.

[5] Energy Safe Victoria's (ESV) Morwell Terminal Station Final Report (August 2014) – Regulatory Regime section

These relays do not provide diagnostics or health monitoring; hence, a failure may remain hidden.

Relays retired from service at other stations are kept as spares, and parts cannibalized to maintain in-service relays, so that there are some relays at NH that as well as being old, have been refurbished with older parts. The spare relay stocks are now exhausted such that further electro-mechanical relay failures there is no exact spare and the whole protection scheme would need to be modified.

Consequence:

Electromechanical relays do not have failure monitoring; hence a relay failure may remain hidden, thus increasing the risk of fault not being cleared. These relays do not provide fault diagnostics such as disturbance records and distance to fault information; this results in increased time in troubleshooting, fault location and fault investigations. Further, increasing lack of spares directly impacts the availability of protection schemes having electromechanical relays.

These issues impact JEN's ability to meet the obligations under Section 5.1.9 of the NER, notably the obligation related to clearance of faults. Further, this exacerbates health and safety risk and increases possibility of asset damage due to faults not being cleared in a timely manner.

Given the large number of electromechanical relays in installed base at NH, the continuance of these relays in the network is impacting the reliability of supply to customers, health and safety risk and asset damage risk.

2.2.2.2 Degradation of reliability of supply, risk of asset damage and health & safety risk due to SPAJ type relay failures

Currently, No 2 66 kV bus and all three 22 kV buses are being protected by SPAJ type. There have been a number of failures with this relay in various JEN sites.

Refer Appendix B for details of SPAJ type relay failures in JEN.

Consequence:

Bus protection relays are required to protect the bus and to operate during a fault on that bus; during this, the supply is lost to the feeders/customers connected to that bus. When a 22 kV bus protection relay fails to operate during a fault, the back-up protection (transformer protection) operates to clear the fault. Similarly, when a 66 kV bus protection relay fails to operate during a fault, the back-up protection (line protection) operates to clear the fault.

Relying on backup protection to clear the fault has following sub-optimal consequences:

- **Increased possibility of serious injury or fatality** – Back-up protection is designed to take longer time to clear the fault, and consequently, the fault and fault current remain on the network for longer period. Therefore, there is a greater possibility that assets carrying the higher fault current could cause serious injury or fatality to JEN personnel and general public.
- **Increased possibility of asset damage** – Due to the longer time taken by the backup protection to clear the fault, there is a greater possibility that assets carrying this higher fault current may be stressed, damaged and may have impact on design life.
- **Increased customer outages** - The number of customers that will lose supply will increase because the backup protection isolates a wider section of the network. In the case of a 22 kV bus fault, the backup protection will result in loss of supply to all customers supplied by the transformer, rather than just those customers supplied by the faulted bus.

As an example, on 28th February 2013, there was a fault on feeder AW6; the feeder protection relay failed to operate; the back-up bus protection operated to clear the fault. Consequently, supply to all feeders on the 22 kV no 2-3 bus was lost affecting 14,522 customers. **This equates to an S-factor impact of $1.1M**. Note AW6 and NH have same SPAJ140 type of relay.

Manufacturer's advice on the cause of the SPAJ140C relay failures is "Internal Relay Failure due to the power supply cards" which has been further suggested to be on account of following possible factors:

- Un-steady power supply to relay
- Typical ageing of equipment

The SPAJ140C relay stock available in warehouse is "retired relay stock" of almost same age profile, which also is prone to similar relay failures. It is therefore not prudent to replace the failed relays using this "retired relay stock".

Considering that all 22 kV bus protection relays at NH is composed of SPAJ140C type relays, continuance of these relays in the network is likely to impact the reliability of supply to customers.

This issue impacts JEN's ability to meet the obligations under Section 5.1.9 of the NER, notably the obligation related to clearance of faults.

2.2.2.3 Impact on security of supply, risk of asset damage and health & safety risk due to deteriorating supervisory cables

The 66 kV NH-NEI/TTS line protection scheme is dependent upon supervisory cables which have reached end of their useful life. The useful life of supervisory cables is 50 years in accordance with JEN Asset Class Strategy documents. The supervisory cables carry pilot wire trips as well as remote trips between NH and remote end (TTS). These cables are known to fail catastrophically at end of useful life. Due to their deteriorating condition of the cables, they are progressively being phased out and replaced by fibre optic cables. Pilot wire relays used on the NH-NEI/TTS line cannot operate on fibre optic cables and must be replaced with current differential relays that use digital signalling.

Consequence:

Supervisory cables form part of an inter-relay communication technology which is obsolete and is being phased out by various utilities. Copper supervisory cables suffering time-related failures and are being progressively replaced by fibre optic cables. Supervisory cable failure not only compromises the 66 kV line protection but also interrupts the remote trip signalling from transformer protection to remote end circuit breakers, which can lead to prolonged fault clearance times and possible consequential damage to assets.

As an example of cable failure, the supervisory cables 217/218 on HB-TSTS line failed this year. This resulted in loss of 66 kV X line protection scheme and connected transformer X remote trip scheme. Consequently, the reliability of 66 kV supply from TSTS to HB zone substation was compromised. There was also an increase in the risk of prolonged fault clearance times from remote end and possible damage to assets there.

2.2.2.4 Safety risks to people due to failing protection relays

Purpose of protection systems is to protect assets and minimise risk of injury to people to ALARP, by effectively clearing network faults, and maintain reliability of supply to customers. Failure to do so may lead to serious risk to operating personnel and the public due to possibility of following:

2. electrocution from direct contact with energised conductors
3. hazardous step and touch potentials

4. start of fire from downed conductors or conductors contacting dry vegetation during high winds and high temperature conditions

The issue of personnel safety is linked to JEN's obligations under Section 3.1 of the Electricity Distribution Code "*to minimise the risks associated with the failure or reduced performance of assets".*

In 2013, a contractor working on a scaffold came into contact with conductor of feeder BY13 in Braybrook area. Feeder protection for BY13 correctly detected this fault and isolated the fault by tripping BY13 CB. However, this was not enough to save the life of the person who came into contact with the feeder conductor, because the technology available at this stage and requirement of supply reliability limits feeder protection's capability to operate faster.

On that day, had the feeder protection failed to clear this fault, there could have been more fatalities and JEN could possibly have been found liable for the loss of life because the primary protection failed to clear the fault. This event amply demonstrates how critical it is to maintain the protection systems in sound condition at all times.

In a report prepared by the Institute of Electrical and Electronics Engineers (**IEEE**) entitled Redundancy Considerations for Protective Relaying Systems[6], the purpose of protection relays has been accentuated as follows:

"Because protective relaying provides no profit and is only required for infrequent and random abnormal operation of the power system, it can be described as insurance that prevents damage to the main grid equipment while minimizing outage time".

Due to the critical aspect of protection systems in minimizing asset damage and also keeping personnel safety to ALARP level, protection relays are not run to failure and reasonable steps are proactively taken to keep the protection system in sound health at all times.

[6] Institute of Electrical and Electronics Engineers (IEEE) - IEEE PSRC, WG I 19 - Redundancy Considerations for Protective Relaying Systems

The table below provides a summary of above outlined issues and their consequences:

Table 2-1: Summary of issues and consequences

ISSUE	Consequence
Old generation relays in network	Reliability of supply of SCS impacted
Failure of bus protection relay type SPAJ	Reliability of supply of SCS impacted (Loss of supply to at least 9,000 customers).
Abnormal operation of relay	Additional operational costs in troubleshooting and replacing
Aged and deteriorating relays	Reliability of supply of SCS impacted
Risk of failure of ageing supervisory cables	Reliability of supply of SCS impacted Possible damage to assets at BD due to prolongation of fault clearance times from remote end
Prolonged fault clearance time due to protection relay failure	Longer fault clearance times leading to increased risk of damage to assets due to high energy let through (I2t)
Health and safety risks due to failing and deteriorating relays	Safety of personnel impacted

There is a business requirement to address above issues of deteriorating condition of relays infrastructure.

The project is planned in the year 2025 based on following considerations:

- due to the condition of the ageing and deteriorating assets, the estimate of financial impact of consequences on account of S factor impact is of the order of $0.65M per annum;
- age and condition of relays infrastructure has deteriorated to a point where JEN's ability to deliver SCS may be impacted;
- this project will enable JEN in keeping the risks arising from deteriorated and ageing assets to below ALARP level

The optimal timing for the commencement of the project is 2025.

2.3 PROJECT OBJECTIVES AND ASSESSMENT CRITERIA

Project objectives

This project seeks to meet the key objective of maintaining the standard control services as set out in the NER.

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

- Mitigate risks associated with asset damage due to deteriorating condition of protection relay infrastructure at NH
- Mitigate health and safety risks to personnel
- Maintain the quality, reliability and security of supply of standard control services
- Maintain the reliability and security of the distribution system through the supply of standard control services

In summary, this project aims to mitigate risk of asset damage, health and safety risks to personnel and to maintain the reliability and security of the distribution system by mitigating the issues outlined above

Assessment criteria

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 JEN STRATEGY AND PLANS

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

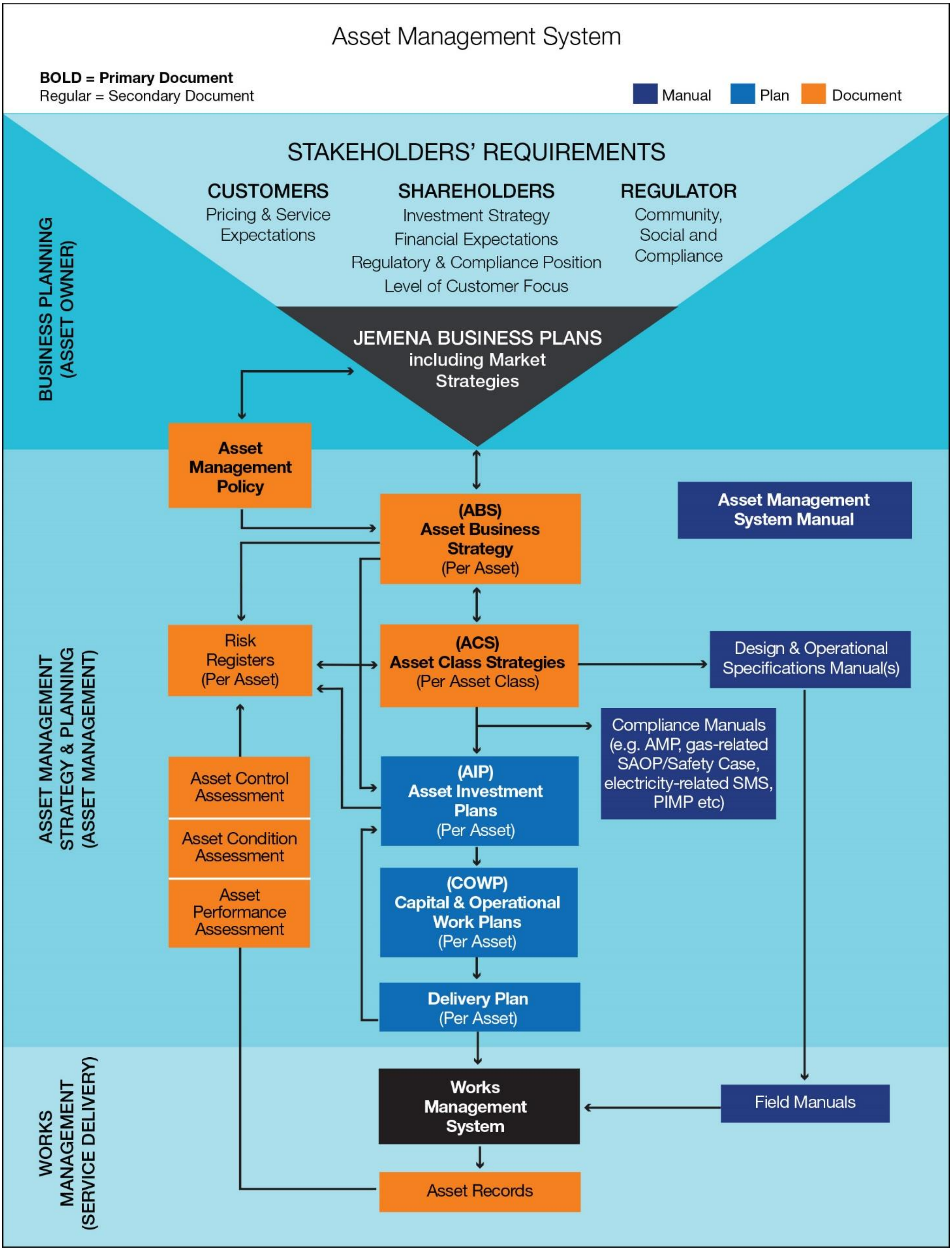
1. Efficiently and safely deliver affordable and reliable energy;
2. Make the customer experience easier and more valuable through digital and performance improvements; and
3. Modernise the grid to prepare for a connected future.

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

Figure 2-1 outlines the JEN 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 JEN 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 JEN 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: Do Nothing
- Option 2: Increase maintenance
- Option 3: Proactive relays replacement

These options are discussed in more detail below.

3.1.1 OPTION 1 – DO NOTHING

Option 1 represents a continuation of the existing regime for maintenance and replacement upon failure of these secondary 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 8 years to once every year.

3.1.3 OPTION 3 – PLANNED AND PROACTIVE RELAY REPLACEMENT

Option 3 involves proactive and planned replacement of the protection and control infrastructure

3.2 DEVELOPING CREDIBLE OPTIONS COSTS & BENEFITS

The credible options are discussed in the following sub-sections.

3.2.1 OPTION 1: DO NOTHING

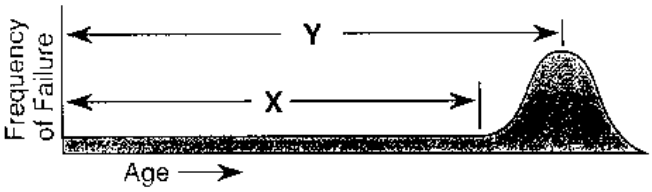
Option 1 represents Do Nothing scenario - that is, maintaining the status quo.

3.2.1.1 Scope, costs & timelines

Option 1 is the base case and represents the Do Nothing option, which means, continue the routine maintenance and replace relays upon failure, at the NH Zone Substation. Under this option, relay equipment will undergo routine maintenance every 8 years and will be replaced only when relay fault is detected.

Replacing relays upon failure poses risk of loss of electricity supply to customers, which is not acceptable (for example, supply to at least 9,000 customers could be lost, if a bus protection relay did not operate during a bus fault).

Probability of failure of protection relays follows Weibull distribution, as given below:



The failure rate of relays increases steeply as the relays reach end of useful life.

Protection relay failure has following consequences:

- damage to network assets;
- possible injury to personnel; and
- unnecessary network interruption to a large number of customers as discussed earlier

The current condition of the protection and control relays has already resulted in several failures at the NH zone substation. In addition, relays of similar make and model as at NH have also been failing at other zone substations across JEN. The likelihood of failure will continue to increase until a solution is implemented.

This option has following consequences:

- it is expected to continue to adversely impact JEN's ability to maintain delivering standard control services (**SCS**); and
- this option will continue to increase the risks of asset damage, health and safety risks to personnel and to affect network reliability performance and would compromise JEN's ability to meet the requirements of the Victoria Electricity Distribution Code

3.2.1.2 Assumptions and forecasts

Financial evaluation for this option was carried out by considering the following:

- Health and safety risk.
- Failure of bus protection relays to operate during network fault and impact on STPIS
  - failure of bus protection relay to isolate fault leads to operation of back-up protection which leads to loss of supply to all customers connected to the transformer (expected supply restoration time considered as 1 hour)
- Mal-operation of bus protection relays and impact on STPIS
  - Mal-operation of bus protection relay to isolate fault leads to loss of supply to all customers connected to a that bus (expected supply restoration time considered as 1 hour)

In above computations, it is assumed that the probability of failure of protection relays which have outlived their design life is 45%.

3.2.2 OPTION 2: INCREASE MAINTENANCE

3.2.2.1 Scope, Costs & timelines

Option 2 comprises an increase in the frequency of relay maintenance from once every 8 years as per current practice, to once every 12 months.

This option has been considered on the premise that an increased maintenance may bring to notice certain hidden failures in equipment and therefore bring about some reduction in probability of network faults not being cleared by protection equipment due to those failures.

The impact of increased maintenance on the reliability of various generations of relays is further elaborated below:

- **Electromechanical relays:**

  Electromechanical relays have springs, bearings and magnets that under maintenance can be adjusted to bring the relay to within calibration. Once calibrated, reliable operation for some time can be assumed, but if the limits of adjustment are reached then continued degradation will occur. If a type problem becomes known (spring corrosion) then increased maintenance can detect the problem before failure under network faults occur.

This option, however, has following consequences:

- Limitations of this option: (a) hidden failure of relay for maximum of 1 year period, (b) limited maintenance possibility
- An increase in maintenance activities within the existing control building would also increase the health and safety risks associated to the extent that these works will entail working in the constricted space and on or in vicinity of panels with asbestos. This represents a qualitative adverse impact on personnel health and safety.
- Ad hoc relay replacement would continue to occur upon failure. The installation of new relays into existing legacy design would be expensive, time consuming and in many cases may not be even practicable.
- It may provide some increase in the useful life of electromechanical relays; however, there is added risk of disturbing the old deteriorating operating mechanisms within these relays and thus introducing more issues in the relay circuits.

This option is technically feasible and hence, it has been considered for further evaluation.

3.2.2.2 Assumptions and forecasts

Financial evaluation for this option was carried out by considering the same failure scenarios and impacts as Option 1.

It is considered that under Option 2, although there is no material impact on the design life of the secondary system assets, there is a possibility of some obvious defects being known in course of increased maintenance, which may marginally reduce the probability of failure of protection relays (it has been assumed that probability of failure marginally improves from 45% for Do Nothing option to 40%).

3.2.3 OPTION 3: PLANNED & PROACTIVE RELAY REPLACEMENT

3.2.3.1 Scope, costs & timelines

Option 3 proposes the bulk replacement of all protection and control relays at the NH zone substation

This option has the consequence of capital investment; nevertheless this option provides following benefits:

- Risk of damage to network assets is minimised;
- Risk to personnel (associated with failure of secondary system assets) is minimised;
- Risk of supply interruption to customers is maintained and not worsened; and
- Reliability of supply of SCS is maintained.

The benefits in mitigating risks of asset damage, health and safety risks to personnel and in maintaining reliability of electricity supply to customers and maintaining personnel safety are primarily based on the reduction in likelihood of relay failure after replacement of ageing and deteriorating relays.

Further, planned replacement of the aged and deteriorating protection relays at NH also provides an opportunity to implement JEN secondary design standard, thus optimising the types of secondary system assets in JEN and bringing uniformity to the installed asset base. This would help in realising operational cost benefits (due to factors such as optimisation of spares) and would lead to further savings in cost of electricity supply to customers.

3.2.3.2 Assumptions and forecasts

The financial impacts emanating from above failure scenarios was considered working out the net present value (NPV), using the current financial evaluation template.

3.3 EFFECTIVENESS OF OPTIONS IN ADDRESSING THE ISSUES AND RISKS

Presented below is a summary of how effective each of the three options are in addressing the risks and issues identified before:

Table 3-1: Summary of selected options and their efficacy in addressing identified issues

DESCRIPTION OF ISSUES	EFFECTIVENESS OF OPTIONS IN ADDRESSING THE IDENTIFIED ISSUES		
	OPTION 1 Do Nothing	OPTION 2 Increase maintenance	OPTION 3 Planned and proactive relays replacement
Degradation of reliability of supply due to failure of SPAJ type relays	No	No	Yes
Worsening of security of supply due to obsolescence of relays	No	No	Yes
Degradation of security of supply due to aged duplicate protection schemes	No	Marginally	Yes
Deterioration of security of supply due to ageing supervisory cables	No	No	Yes

Prolonged fault clearance time due to protection relay failure - Longer fault clearance times leading to increased risk of damage to assets due to high energy let through (I2t)	No	No	Yes
Safety risks to people due to failing and deteriorating protection relays	No	No	Yes

4. OPTION EVALUATION

From above, it is noted that:

- Option 1 (Do Nothing) does not address the risks and issues related to secondary system assets failure; it does not require any costs (CAPEX or OPEX)
- Option 2 only marginally addresses the issues but does not mitigate the risks; it requires increased OPEX by way of increased maintenance
- Option 3 addresses all issues and mitigates the identified risks associated with ageing and deteriorating relays

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

4.1 ECONOMIC ANALYSIS

In line with the objective of the National Electricity Rules, JEN'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, JEN 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 augmentation 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

The basic global parameters used such as discount rate, WACC, depreciation, assessment periods and other assumed constants are included in this analysis.

Table 4-1: Economic Analysis Results Summary

Description ($'000, $2019)	Option 1 Do Nothing	Option 2 Increase Maintenance	Option 3 Planned and Proactive Replacement
Total Expected costs	0	0	2,654
Total Expected market benefits	-	312	1,947
Net market benefits	-	312	4,601
Option ranking	3	2	1

This identifies option 3 as the recommended solution.

5. RECOMMENDATION

The proposed Option 3 is recommended to be endorsed. This option consists of replacement of deteriorating protection and control equipment and the associated asset NH, in the period 2025-2026, at an estimated cost of $2,654k (total project cost, real $2019).

This option is preferred based on following considerations:

- It recognises the critical role of protection relays in keeping the electricity network safe by timely clearance of network faults;
- It facilitates managing the health and safety risks to personnel, associated with deteriorating protection system assets, to As Low As Reasonably Practicable;
- It enables protecting the major assets such as power transformers; 66kV buses and 22kV buses etc from damage due to network faults;
- It ensures maintaining the current performance level on reliability of electricity supply to over 19,500 customers;
- It enables JEN to maintain supply of standard control services (**SCS**) from North Heidelberg (NH) zone substation as an efficient and knowledgeable 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 [7] and asset condition;
- It is in accordance with JEN's protection and control asset class strategy[8] and JEN's broader corporate objectives.

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

[8] Zone Substation Protection and Control Equipment Asset Class Strategy (JEN PL 0021)

Appendix A
Project Scope

A1. HIGH LEVEL SCOPE

Scope of Works for this business case consists of replacement of identified protection and control infrastructure and associated systems at NH zone substation and associated remote stations and includes the following:

High level summary of scope of works for this project is as follows:

- Replace Pilot wire scheme for 66kV NEI/TTS line
- Replace No 2 66kV bus protection relays
- Replace No 1 Transformer HT Overload protection relays
- Replace No 1, No 2 and No 3 bus protection relays
- Replace major SCADA and communication equipment and install new (RTU, MUX, GPS Clock): lot

A2. PROJECT COST ESTIMATE

The estimated cost is $2,654k (total project cost, real $2019) including overheads of $403k.

Appendix B
Failure history of SPAJ type feeder protection relays

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B1. FAILURE HISTORY OF SPAJ TYPE RELAYS

Date	Zone Substation	Description	Relay	Protection Description
14-Feb-06	AW	AW12	ABB SPAJ 140C	Feeder Protection
01-Jun-11	AW	AW7	ABB SPAJ 140C	Feeder Protection
06-Jun-12	AW	AW6	ABB SPAJ 140C	Feeder Protection
02-Jul-12	ST	ST No2 Cap Bank	ABB SPAJ 160C	Feeder Protection
23-Aug-12	**BD**	**BD10**	**ABB SPAJ 140C**	**Feeder Protection**
24-Aug-12	**BD**	**BD11**	**ABB SPAJ 140C**	**Feeder Protection**
27-Oct-12	**BD**	**BD06**	**ABB SPAJ 140C**	**Feeder Protection**
29-Mar-13	**BD**	**BD04**	**ABB SPAJ 140C**	**Feeder Protection**
28-Feb-13	AW	AW6	ABB SPAJ 140C	Feeder Protection

Appendix C
Network Risk Assessment

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C1. NETWORK RISK ASSESSMENT

JEN Asset Specific (Strategic) Risk Assessment

Click here for INSTRUCTIONS

Context statement: Project Name: Backup Earth Fault Relay (Stage 2) Replacement (Newport Zone Substation)

Participants: Anup Rana

Workshop Date: 03/04/2019

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S/No	Business Unit	Business Objective	Risk Type	Risk Title (Identified Risk)	Risk Description (Including Hazard Effect)	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)	Safety	Operational (JEN)	Failure of assets	Risk associated with the failure of protection relay having an impact on network relaibility and JEN assets.	1. Bus Protection Relays reached their end of design life. 2.Failure of bus proteciton relays operates could cause the TX incomer CB and 66kV BT CB to lock out	AS-E	1. Circuit Breaker maintenance regimes as per ACS.	Fair	Serious	Possible	Moderate	Initiate a project to replace deteriorating, failing and aged relays replacement at NH	Anup Rana	20/12/19	In progress			Serious	Rare	Low
2	Strategy (Network)	Asset Management	Operational (JEN)	Inadvertent impact on network reliability	Risk associated with the possible loss of co-ordinaiton due to electromechanical relays having reached end of their setting adjustment range. Impact on network reliability and JEN assets.	1. Protection Relays reached their end of design life.	AS-E	1. Circuit Breaker maintenance regimes as per ACS.	Fair	Serious	Possible	Moderate	Initiate a project to replace deteriorating, failing and aged relays replacement at NH	Anup Rana	20/12/19	In progress			Serious	Rare	Low