Jemena Electricity Networks (Vic) Ltd

Address Risk of Deteriorating Protection Relays at North Essendon (NS) Zone Substation

2025 Business Case

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Address Risk of Deteriorating Protection Relays at North Essendon (NS) Zone Substation

Authorisation

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Rev No	Date	Description of changes	Author
1.0	11/04/2019	First Issue	Senior Protection and DC System Engineer

Owning Functional Area

Business Function Owner:	Asset Strategy Electrical

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

- Purpose of this project is to mitigate risks of asset damage, health and safety risks, and to maintain reliability and security of supply of standard control services from North Essendon (**NS**) zone substation to more than 11,880 customers
- This project proposes replacement of relays to mitigate the risks associated with deteriorating 11 kV feeder protection, 11 kV bus protection relays and Master Earth Fault (MEF) relay at NS.
- The project is planned to be completed in 2026, at an estimated cost of $2,253k (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 Essendon (**NS**) zone substation.

This project is necessary to:

- Maintain the performance of the protection asset class in accordance with accepted practices world-wide and Jemena'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 Jemena Group Risk Management Manual (JAA MA 0050);
- Mitigate risk of asset damage; and
- Maintain reliability of electricity supply to 11,880 customers being served from NS zone substation

The project is planned to be completed in 2026, at an estimated cost of $2,253k (total project cost, real $2019).

1.2 RECOMMENDATION

The proposed investment's Option 3 is recommended to be endorsed. This option consists of replacement of deteriorating protection equipment at NS, in the year 2026, at an estimated cost of $2,253k (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 from damage due to network faults;

- It ensures maintaining the reliability of electricity supply to 11,880 customers;
- It enables Jemena to maintain supply of standard control services (**SCS**) from North Essendon (**NS**) 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 NS 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;*
> >
> > *b. to minimise the risks associated with the failure or reduced performance of assets; and*

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

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

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 $2,253k (total project cost, real $2019) and requires Jemena Managing Director's (Band B) approval under the SGSPAA DFA Manual, Annex 3.

This project is included in the approved budget for CY25.

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

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	1901
Overhead recovery	352
Total Budget Value	**2,253**

2. BACKGROUND

2.1 BUSINESS AND SOCIO ECONOMIC CONTEXT

North Essendon (**NS**) consists of three 12/18 MVA transformers providing a total nameplate rating of 36 MVA, operating at 22/11 kV with three 11kV buses. NS supplies the areas of North Essendon, Strathmore, Moonee Ponds and Ascot Vale. There are 12-off 11 kV feeders supplying electricity to more than 11,880 customers in areas of North Essendon. Two of these feeders are Citipower feeders.

Each 11kV feeder is protected by a feeder management relay (located at NS). Their primary purpose is to detect electrical faults on the feeder and isolate the fault by tripping the 11 kV feeder circuit breaker (also located at NS).These relays enable JEN to comply with NER S5.1.9 (identified above), providing primary protection to JEN's assets and people (Note: backup protection is provided by 11 kV Bus protection).

Major customers include Moonee Valley Racecourse, DFO, Essendon Airport, ATO and several commercial complexes.

2.2 ASSET RISK (OR OPPORTUNITY) ANALYSIS

2.2.1 SHORT DESCRIPTION OF THE AFFECTED JEMENA 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 Jemena experiences, and represent the lives of assets at which end-of-life replacement will be considered.

Major issues at NS are as follows:

- majority of relays under discussion here are numerical 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 NS. 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 mis-operation - 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".*

[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

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 NS are impacting Jemena'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 NS is provided below.

2.2.2 RISK ASSESSMENT

A Risk Assessment has been carried out following Jemena's Networks Projects Business Cases Risks Budgeting and Assessment Guidelines document JEN GU 2502. This risk assessment highlights the current issues at NS 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.

Refer Appendix B.

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's (**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 NS.

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

2.2.2.1 Degradation of reliability of supply, risk of asset damage and health & safety risk due to failure of SR760 type feeder protection relays.

The GE SR series SR760 relays have been used on the JEN network to protect feeders The older GE SR series relays have a history of failure due to faulty power supply modules and input/output modules (I/O modules). The failure of the power supply module is caused by the age-related breakdown of the electronic components within these modules, in particular the capacitors. Since 2005, a total of 21 of the GE SR series relays have failed across JEN. Other utilities have also identified issues with these relays.[6]

Feeder protection relays are required to protect the feeder and to operate during a fault on that feeder; during this, the supply is lost to the customers connected to that feeder. When a feeder protection relay fails to operate during a fault, the back-up protection (bus bar 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 feeder fault, the backup protection will result in loss of supply to all customers supplied by that bus, rather than just those customers supplied by the faulted feeder.

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 22kV no 2-3 bus was lost affecting 14,522 customers. **This equates to an S-factor impact of $1.1M**.

All feeder protection relays at NS are type SR760. This relay has failed once during last 12 years at NS site, as detailed below:

- **Feeder NS9 Date:** 2nd April 2006, **Cause:** Power supply failure in relay

Further, there have been close to 20 instances of failure of feeder protection relay type SR760 in JEN since 2005.

Refer Appendix C for details of SR760 type relay failures in JEN.

Refer Appendix D for the description of time and temperature related failure of these relays.

An example of failure of SR760 relays: on 16 January 2014, there was a fault on feeder ST34; the feeder protection relay failed to operate; the back-up bus protection operated to clear the fault. Consequently, supply to all feeders on the 22kV No 3 bus was lost affecting 9,038 customers.

Continuing use of SR760 type relays at NS is likely to worsen the reliability of supply to customers.

[6] Asset Management Plan – Protection, Power and Water Corporation, Attachment 14.12

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

2.2.2.2 Unexpected behaviour of SR760 type relay

There has been an instance where the unexpected behaviour of feeder protection relay type SR760 has been cause of generation of spurious alarms in SCADA.

Consequence:

The consequence of the above unexpected relay behaviour is the impact on the reliability of supply of electricity to customers on respective feeder, and additional OPEX costs in investigating the root cause of such relay abnormal behaviour. As an example, on 4 May 2014, the feeder protection relay feeder SBY32 generated an "Unsuccessful Auto Reclose" alarm which appeared on SCADA alarm screen. The investigation into cause of this alarm required taking an outage on the feeder and expending of resources of both Jemena and the supplier. Lastly, the alarm was found to be spurious, which raised questions about the integrity of this relay type.

2.2.2.3 Degradation of reliability of supply, risk of asset damage and health and safety risk due to relays without failure monitoring (risk of hidden failures)

Background:

The Master Earth Fault relay model 2C136 at NS is close to end of useful life. These relays do not have self-monitoring or alarming feature resulting in potentially hidden failures with consequences. This relay provides a trip permissive to all feeder protection relays. If this relay fails, the feeder protection relays will not operate during an earth fault.

Consequence:

If this relay fails, the failure will remain hidden.

There is a possibility that this protection relay may have failed without knowledge of operating personnel, thus putting the substation assets at risk of damage in the event of a fault, and also impacting the safety of personnel.

In a publication of the Institution of Electrical and Electronics Engineers (**IEEE**) entitled **Working Group C-6, System Protection Subcommittee, IEEE PES Power System Relaying Committee Final Report on Wide Area Protection and Emergency Control**[7]**,** the importance of undetected relay failures is highlighted in these words: *"It has been observed that of all the reported cases of major system blackouts (wide area disturbances) in North America, about 70% of the cases have relay system contributing to the initiation or evolution of the disturbance. On closer examination, it became clear that one of the major components of relay system misoperations is the presence of relays which have failed during service, and their failure is not known. Consequently, there is no alarm, and no repairs or replacements are possible. These hidden failures are different from straight relay misoperations, or failures which lead to an immediate trip. The hidden failures remain undetected (and substantially undetectable), until the power system becomes stressed, leading to an operating condition which exposes the hidden relay failures".*

The MEF relay can have hidden failures that may either cause non-operation in the event of a fault or operate under load and non-fault conditions. In either event, consequences can cause supply disruption.

[7] Institute of Electrical and Electronics Engineers (IEEE) report entitled Working Group C-6, System Protection Subcommittee IEEE PES Power System Relaying Committee Final Report - Wide Area Protection and Emergency Control – (section on Relay Hidden Failures)

If MEF relay fails and there is an earth fault, the feeder protection relays will not operate. Consequently the fault will be cleared by Back up earth fault scheme thus impacting all customers connected to that bus.

These issues impact Jemena'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.

2.2.2.4 Worsening of security of supply, risk of asset damage and health & safety risk due to deteriorating and aged relays

The high impedance bus protection relays type Siemens/Reyrolle 7SG1211 and the bus overcurrent relays type GE SR735 at NS are beyond their service life and are deteriorating.

Consequence:

Consequence of having relays in the network, which are beyond service life and deteriorating is that in case of failure of these relays, significant resources may be required in a short time at an ad-hoc basis, for providing replacement protection schemes using relays of a different type.

Note, although not uncommon, it is a credible scenario that both X & Y protection schemes may fail to operate at the same time. For example, at AusNet Services' Morwell Terminal Station (**MWTS**) both X & Y protection schemes failed to operate on 4 April 2014 leading to loss of supply to 80,000 customers in Gippsland[8].

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

2.2.2.5 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:

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

[8] Energy Safe Victoria's (ESV) Morwell Terminal Station Final Report (August 2014)

On that day, had the feeder protection failed to clear this fault, there could have been more fatalities and Jemena 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[9], 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.

Besides above, there is a need to remediate the deteriorating roofs of the old control building / 11kV switchroom.

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 feeder protection relay type SR760	Reliability of supply of SCS impacted (Loss of supply to at least 5,107 customers).
Abnormal operation of relay	Additional operational costs in troubleshooting and replacing
Aged and deteriorating relays	Reliability of supply of SCS impacted
Possibility of both X & Y protection schemes failure	Security of supply of SCS impacted
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 2026 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 $0.27M per annum;
- age and condition of relays infrastructure has deteriorated to a point where Jemena's ability to deliver SCS may be impacted;
- this project will enable Jemena in keeping the risks arising from deteriorated and ageing assets to below ALARP level

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

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 NS
- 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 3. 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:

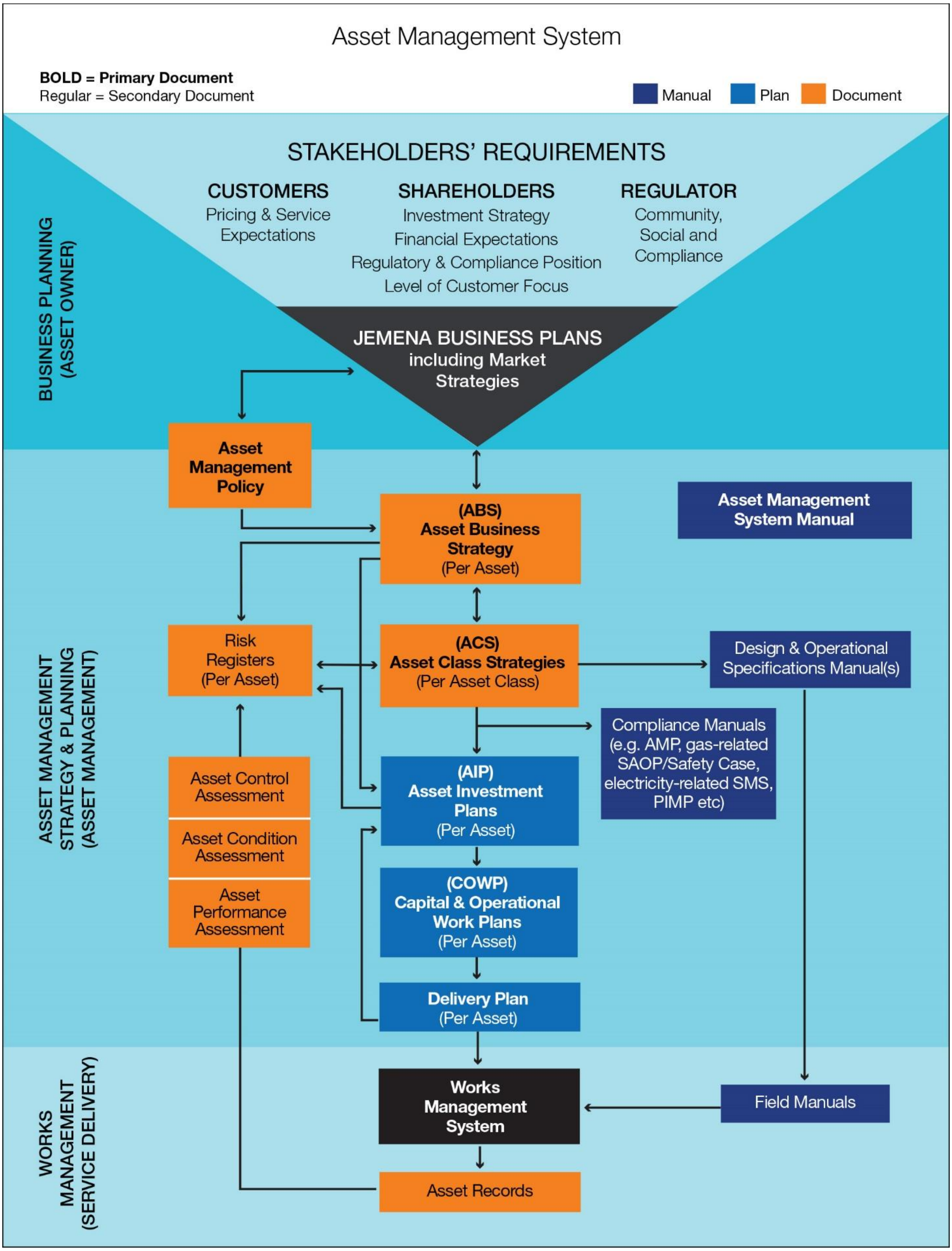
1. Efficiently and safely deliver affordable and reliable energy;
2. Make the customer experience easier and more valuable through digital and performance improvements; and
3. Modernise the grid to prepare for a connected future.

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

Figure 2-2 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: 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. Note that all expected option costs include overheads.

3.2.1 OPTION 1: DO NOTHING

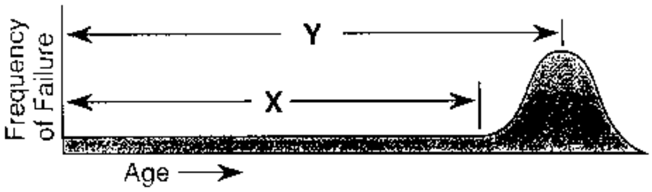
Option 1 represents Do Nothing scenario - that is, maintaining the status quo.

3.2.1.1 Scope, costs & timelines

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 NS 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 5,107 customers could be lost, if a feeder protection relay did not operate during a feeder 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 NS zone substation. In addition, relays of similar make and model as at NS 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:

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

- failure of Master Earth Fault protection relay to isolate fault leads to operation of back-up protection which leads to loss of supply to all customers connected to a bus (expected supply restoration time considered as 1 hour)

- Health and safety risk – possible loss of life based on Value of a Statistical Life (VSL)[10]

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

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:

- **Numerical and analogue (static) relays:**

  Numerical and electronic relays consist of electronic and microprocessor based components and practically no maintenance can be carried out at this component level. However, during maintenance some components (e.g. relay output contacts) can be checked for failures. Note such failures are not possible to be flagged under self-diagnostics or alarming in older relays. Thus increased maintenance when a relay type is known to have reliability issues can verify the relays' operability at one point in time, there is little guarantee that a component failure will not occur within a short time.

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

- 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.

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,

[10] *https://www.dpmc.gov.au/sites/default/files/.../Working_paper_2_Peter_Abelson.rtf*

The Health of Nations – The Value of a Statistical Life, 2008 (Australian Safety and Compensation Council) which may marginally reduce the probability of failure of protection relays (it has been assumed that probability of failure marginally improves from 50% for Do Nothing option to 45%).

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

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

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

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

Financial evaluation for this option was carried out following the methodology of Options 1 & 2 and considering the mitigated impact on STPIS due to planned & proactive asset replacement.

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

Table 3-1: Summary of Options and their technical feasibility

Option #	Description of Option	Whether technically feasible or not (Yes/No)	Whether selected for further evaluation (Yes/No)
1	Base Case – Do Nothing	Yes	Yes
2	Increase maintenance	Yes	Yes
3	Planned and proactive relays replacement	Yes	Yes

On the basis of above, options 1, 2 & 3 were considered for further evaluation.

This project will be completed in 2026.

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 3-2: 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 SR760 type relays failures	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
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.

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 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

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 Bulk replacement using conventional technology
Total Expected costs	0	0	2,253
Total Expected market benefits	Status quo	70	1,395
Net market benefits	NA	70	-858
Option ranking	2	1	3

Based on the above economic analysis, Option 3 is the recommended option.

5. RECOMMENDATION

This business case proposes adopting Option 3 among the available options. This option consists of replacement of ageing and deteriorating protection relay infrastructure at the Essendon (NS) Zone Substation with new modern equivalents, at a total investment of $2,253k (total project value, real $2019), and requires Jemena Managing Director's (Band B) approval under the SGSPAA DFA Manual, Annex 3.

This option would address all the issues identified in previous sections and has a positive impact on safety, reliability and security of supply to customers. This option is considered prudent, has a positive net present value and is the preferred option.

Appendix A
Project Scope and Delivery Information

A1. HIGH LEVEL SCOPE

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

a) Replace 11kV Feeder protection, control & monitoring relays: quantity 12-off

b) Replace No 1, No 2 and No 3 11kV bus ‘X’ High Impedance Bus protection relays: quantity 3-off

c) Replace No 1, No 2 and No 3 11kV bus ‘Y’ Bus Overcurrent protection relays: quantity 3-off

d) Replace Master Earth Fault (MEF) protection relay: quantity 1-off

A2. PROJECT COST ESTIMATE

Estimated cost of this project is 2,253k (total project value, real $2019) including overheads.

Appendix B
Network Risk Assessment Summary

B1. NETWORK RISK ASSESSMENT SUMMARY

JEN Asset Specific (Strategic) Risk Assessment

Click here for INSTRUCTIONS

Normal View

Print View

Context statement: Project Name: NS Relay Replacement Project

Participants: Diptiman Yadav

Workshop Date: 12/09/18

(Setup page for printing)

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	Development (Network)	Asset Management	Operational (JEN)	Failure of assets	**Risk** associated with the failure of protection relay having an impact on network reliability and JEN assets. Potential for an adverse impact to large number of customers (worst case scenario 5042 customers on No2 11kV Bus). **Eg:** Operation of 11kV bus protection for the failure of feeder protection during a fault on the feeder.	Feeder Relay failure due to age. There have been several failures of feeder protection relays type SR760. These include NS13 relay failure on 18/1/13.	AS-E	• Periodic maintenance (8 years) • Reactive replacement	Fair	Severe	Possible	Significant	Initiate a project to address deteriorating, failing and aged relays replacement at NS.	Diptiman Yadav	20/12/25	In progress			Severe	Rare	Moderate
2	Development (Network)	Asset Management	Operational (JEN)	Failure of assets	**Risk** associated with the failure of protection relay having an impact on network reliability and JEN assets. Potential for an adverse impact to large number of customers (worst case scenario 5042 customers on No2 11kV Bus). **Eg:** Mal-operation of 11kV bus protection leading to loss of supply to all customers on a 11kV Bus	Bus Protection Relays failure due to age.	AS-E	• Periodic maintenance (8 years) • Reactive replacement	Fair	Severe	Unlikely	Moderate	Initiate a project to address deteriorating, failing and aged relays replacement at NS.	Diptiman Yadav	20/12/25	In progress			Severe	Rare	Moderate
3	Development (Network)	Asset Management	Operational (JEN)	Failure of assets	**Risk** associated with the failure of protection relay having an impact on network reliability and JEN assets. Potential for an adverse impact to large number of customers (worst case scenario 5042 customers on No2 11kV Bus). **Eg:** Operation of 11kV bus protection for the failure of MEF relay leading to failure of feeder protection to clear an earth fault	MEF Relay failure due to age.	AS-E	• Periodic maintenance (8 years) • Reactive replacement	Fair	Severe	Unlikely	Moderate	Initiate a project to address deteriorating, failing and aged relays replacement at NS.	Diptiman Yadav	20/12/25	In progress			Severe	Rare	Moderate

Appendix C
Failure history of SR760 type feeder protection relays

C1. FAILURE HISTORY OF SR760 TYPE RELAYS

Date	Zone Substation	Description	Relay	Protection Description
28-Nov-05	YTS	YTS8	GE SR760	Feeder Protection
28-Nov-05	YTS	YTS4	GE SR760	Feeder Protection
14-Dec-05	YTS	YTS3	GE SR760	Feeder Protection
18-Dec-05	YTS	YTS6	GE SR760	Feeder Protection
21-Dec-05	YTS	YTS2	GE SR760	Feeder Protection
08-Feb-06	YTS	YTS10	GE SR760	Feeder Protection
30-Mar-06	AW	AW14	GE SR760	Feeder Protection
01-Apr-06	SBY	SBY31	GE SR760	Feeder Protection
02-Apr-06	NS	NS No.2 Bus	GE SR760	No2 22kV Bus Protection
11-May-06	SBY	SBY11	GE SR760	Feeder Protection
27-Nov-06	AW	AW11	GE SR760	Feeder Protection
16-Mar-07	AW	AW14	GE SR760	Feeder Protection
17-May-07	AW	AW11	GE SR760	Feeder Protection
28-Jun-12	BY	BY11	GE SR760	Feeder Protection
29-Jun-12	BY	BY11	GE SR760	Feeder Protection
21-Aug-12	YTS	No.4 Tx	GE SR737	No.4 Trans HT OL
18-Jan-13	NS	NS13	GE SR760	Feeder Protection
18-Mar-13	BY	BY15	GE SR760	Feeder Protection
20-Jan-14	ST	ST34	GE SR760	Feeder Protection

Appendix D
Failure Information on SR760 Relays Collected from Relay Manufacturer (GE)

D1. FAILURE INFORMATION ON SR760 TYPE RELAYS

Information presented below was gathered from CSE Uniserve and from various other sources. Across Australia, GE relays are distributed by CSE Uniserve. They also provide technical support for all GE protection relays.

Accelerated Lifetime Testing Data:

GE has conducted extensive testing on the SR760 relay by performing Accelerated Lifetime Testing (**ALT**) which provides a tested assessment of lifetime expectation. ALT testing is a methodology to stress relays in a controlled way to provide indication of lifetime expectation.

In summary the following conclusions can be drawn from the ALT testing conducted:

a) A minimum 13 year life can be expected based on a continuous 40 degree Celsius environment.

b) A 36 year life can be expected based on a continuous 25 degree Celsius environment.

c) It must be noted that the actual running temperature of internal components may be high as 20^{o}C above the ambient temperature.

    a. According to Bureau of Meteorology (**BOM**), average daily ambient temperature in Melbourne is 15^{o}C. Therefore, the operating temperature of a relay installation in Melbourne is around 35^{o}C (15^{o}C+20^{o}C=35^{o}C).

SR Series relay Power Supply Module:

d) Due to the well know power supply issue associated with SR series relay, GE has made changes to the power supply module to improve the performance.

e) Relays with firmware version 5.0 and above are shipped with the improved power supply module.

f) Power supply module on the SR platform cannot be replaced. Entire relay will have to be replaced to get the improved power supply module.

Environmental Factors Affecting Relay Life:

Typically the power supply in any relay including the SR760 is the component that generally limits the overall life of the relay. The life of electrolytic capacitors used in power supplies is generally affected by two main factors:

1. Ambient operating temperature

2. Ripple current (DC power supply to relay)

The table below shows the effect of ambient temperature and ripple current on the life expectancy of electrolytic capacitor (and of the relay).

The power supply in digital relays are sensitive to high temperatures. Power supply failure is often attributed to electrolytic capacitor failure due to overheating.[6] This is a severe relay component failure because without the power supply, the relays will no longer function.

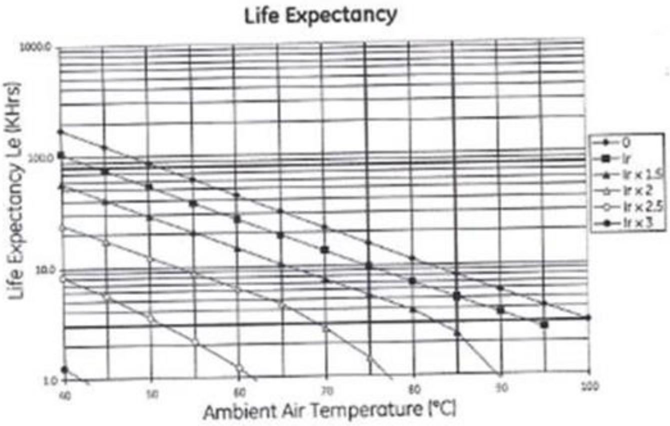


Figure 10[7]
Capacitor Life Expectancy vs Temperature and Ripple Current (Ir).

Over time, capacitors lose their capacitance, a condition that is significantly accelerated when overheated.[6] As a rule of thumb, capacitor life will approximately halve with every 10°C increase in running temperature. As such, a capacitor rated for 5000 hours at 105°C will have an estimated application life of 25 years when running at 60°C, dropping to 12.5 years when running at 70°C. This is of particular concern for relays operated at high temperatures, as the actual running temperature of internal components may be as high as 20°C above the ambient temperature.

The graph [Figure 10] shows the negative effects of increasing ambient air temperature and increasing ripple current have on the life expectancy of a capacitor.

High operating temperatures can also effect the relay display. LCDs, and more specifically the liquid crystal material within the display chamber, can be permanently damaged in extreme temperatures. The result will be a loss of display resolution, discoloration, and display dead spots. (see Figure 8)