Protection Relay Replacements

Business Case

19 January 2024

energex

Part of Energy Queensland

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DOCUMENT VERSION

Version Number	Change Detail	Date	Updated by
Draft v0.1	Draft	22/05/2023	Senior Asset Strategy Engineer
Draft v0.2	Initial Release	31/05/2023	A/Senior Asset Strategy Engineer
V1.0	Finalised	23/11/2023	Manager Asset Strategy

RELATED DOCUMENTS

Document Date	Document Name	Document Type
JAN 2024	Asset Management Plan - Protection Relays	PDF
MAR 2023	Maintenance driven Protection Relay replacement priorities & spares strategy	PDF
NOV 2023	Protection Relay Weibull Model	Excel
OCT 2023	Lines Defect Classification Manual	PDF
V3	Substation Defect Classification Manual	PDF
AUG 2023	Maintenance Activity Frequency (MAF) – Release 2	PDF

1 SUMMARY

Title	Protection Relay Replacements
DNSP	Energex
Expenditure category	☒ Replacement ☐ Augmentation ☐ Connections ☐ Tools and Equipment ☐ ICT ☐ Property ☐ Fleet
Identified need	☐ Legislation ☒ Regulatory compliance ☒ Reliability ☐ CECV ☒ Safety ☒ Environment ☒ Financial ☐ Other The purpose of this document is to outline the proposed volumes of replacement and expenditure associated with protection relays owned by Energex during the regulatory period 2025-30, in accordance with the lifecycle management strategies detailed in the Asset Management Plan for Protection Relays. This business case provides the asset limitation and volume forecast outputs based on age and known problems. To meet the challenges of Energex retiring its problematic and ageing relay population; relay replacements are generally undertaken opportunistically with other projects at a site, or specified projects where particular problematic relays are required to be replaced. With limited spares capability, the cost of unplanned relay replacements after failure will be significant and prolong Energex's exposure to network safety, reliability, and financial risks.
Expenditure	(see table below)
Optimal timing and NPV analysis	Within the framework of the Network Planning Process, an assessment is conducted for the limitations associated with each Protection Relay. Subsequently, individual projects are initiated, and an assessment undertaken to determine the optimal timing for their replacement. This procedure involves performing Net Present Value (NPV) analysis, risk assessment, and consolidating activities with other network assets in suboptimal condition at a designated timing. Energex ensures prudency and efficiency, ultimately curbing the financial impact on our customers and the broader community. Attachment 5.2.01 SCS Capex model – January 2024 outlines our overall investments for the 2025-2030 period, which will include protection relays. Business cases for those investments are available on request.

Expenditure:

Year	2025/26	2026/27	2027/28	2028/29	2029/30	Total
$m, direct 2022-23	8.6	13.8	12.9	12.3	9.3	**56.9**
Quantity	28	86	186	65	406	**771**

2 PURPOSE AND SCOPE

The purpose of this business case is to outline asset limitations for replacement of protection relays in accordance with the lifecycle management strategies detailed in the Asset Management Plan and the EQL Maintenance Driven Relay Replacement Priorities and Spares Strategy. This business case provides asset limitations summary in terms of condition and failure risks/impact in terms of performance and cost to demonstrate prudency and efficiency.

This business case should be read in conjunction with the following documents:

- **Asset Management Plan Protection Relays:** Contains detailed information on the asset class, populations, risks, asset management objectives, performance history, influencing factors, and the lifecycle management strategies.
- **EQL Maintenance Driven Relay Replacement Priorities & Spares Strategy**: Outlines the strategy to prioritise relay replacements based on historical failures and defects encountered historically and spares capability. Relay make/model, quantities and replacement priorities are provided in this strategy document to enable a replacement program of dedicated protection replacement projects; and opportunistic replacements in conjunction with other CAPEX works in substations.

Protection relay failure and defect trends since July 2021 are outlined in Section 3.3 of this business case.

3 BACKGROUND

Protection relays exist to protect important assets and infrastructure on the electric network by detecting faults or abnormal conditions and sending a triggering response to circuit breaking equipment. These devices vary in their core function, offering schemes such as overcurrent and differential detection, as well as their physical and electrical properties.

Protection relays are categorised into three separate groups based on their construction, as described below. These categories give an indication of expected lifespan of the asset, as the unique components within each has differing degradation characteristics and limit the reliability of the device proportionately.

Based on industry best practice and past observations, the associated life expectancies of the different relay classifications are listed:

- Electromechanical relays – 45 years
- Static relays – 25 years
- Microprocessor relays – 20 years

3.1 Asset Population

There are approximately 18,000 Protection relays in Energex as shown Figure 1. Relay types electromechanical, static and microprocessor relays with different design and service life varying significantly from 20 years to 45 years. Varying technology and useful service life makes the management of the spares and replacement programs a very complex and challenging task due to compatibility issues caused by generational gaps with other equipment and protection systems.

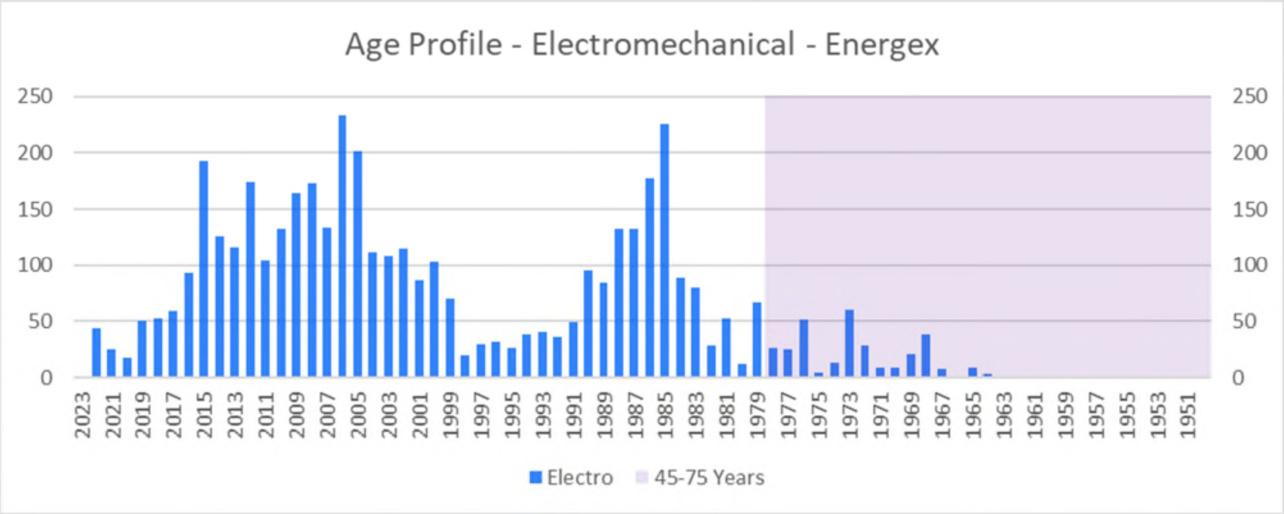


Figure 1 : Age Profile – Electromechanical

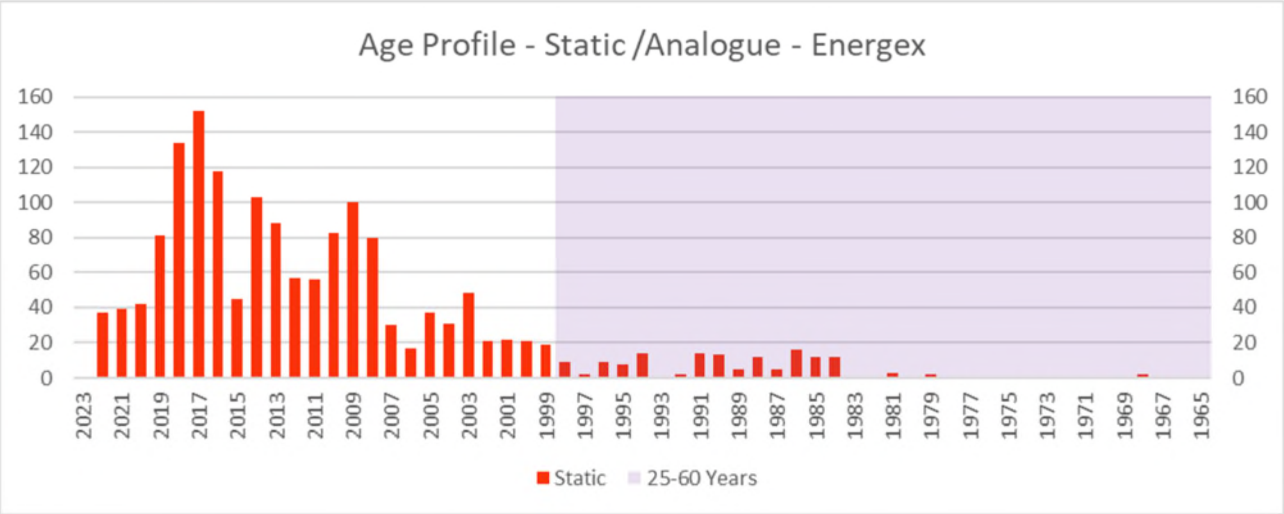


Figure 2 : Age Profile - Static/Analogue

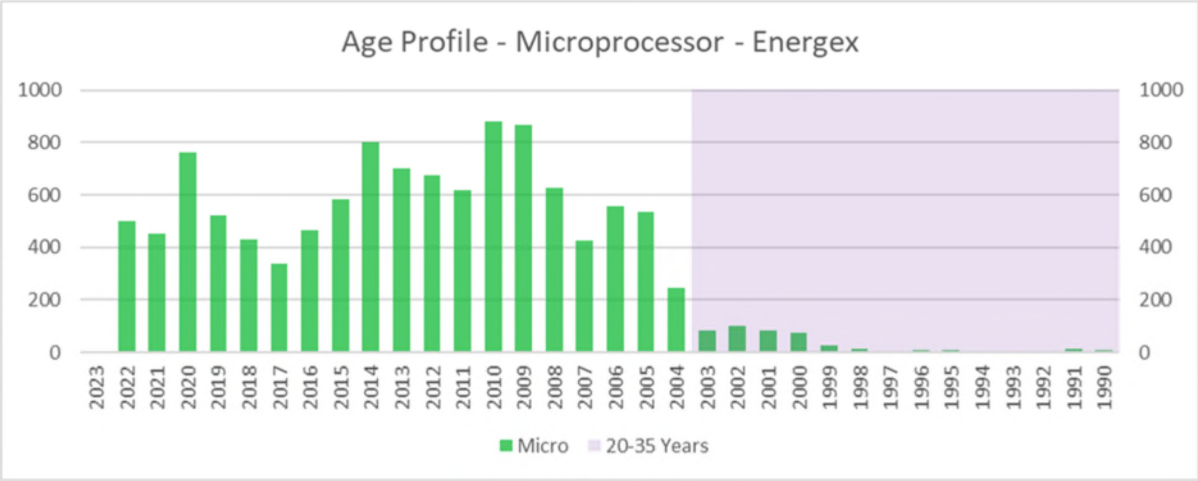


Figure 3: Age Profile - Microprocessor

3.2 Asset Management Overview

Energex adopts a number of strategies in managing the asset. These include:

- **Preventative maintenance**: which is performed in accordance with the inspection and Maintenance Standard Tasks with maintenance intervals outlined in the Maintenance Activity Frequency.
- **Corrective Maintenance:** undertaken when inspection and condition monitoring classify defects as outlined in the Lines Defect Classification Manual and Substation Defect Classification Manuals.
- **Proactive Replacement:** is the management strategy used in conjunction with Condition Based Risk Management to replace problematic assets.

3.3 Asset Performance

Figure 4 illustrates the unassisted relay failures from 2018/19 to 2022/23. A relay is considered to have failed when it is no longer able to fulfill its primary function of detecting and isolating power system faults. Most failures were observed in microprocessor relays, accounting for nearly 86% of failures. This can be attributed to the growing use of microprocessor relays and their relatively short lifespan.

Energex primarily focuses on addressing problematic relays. These relays are deemed high risk due to inherent issues such as mal operation.

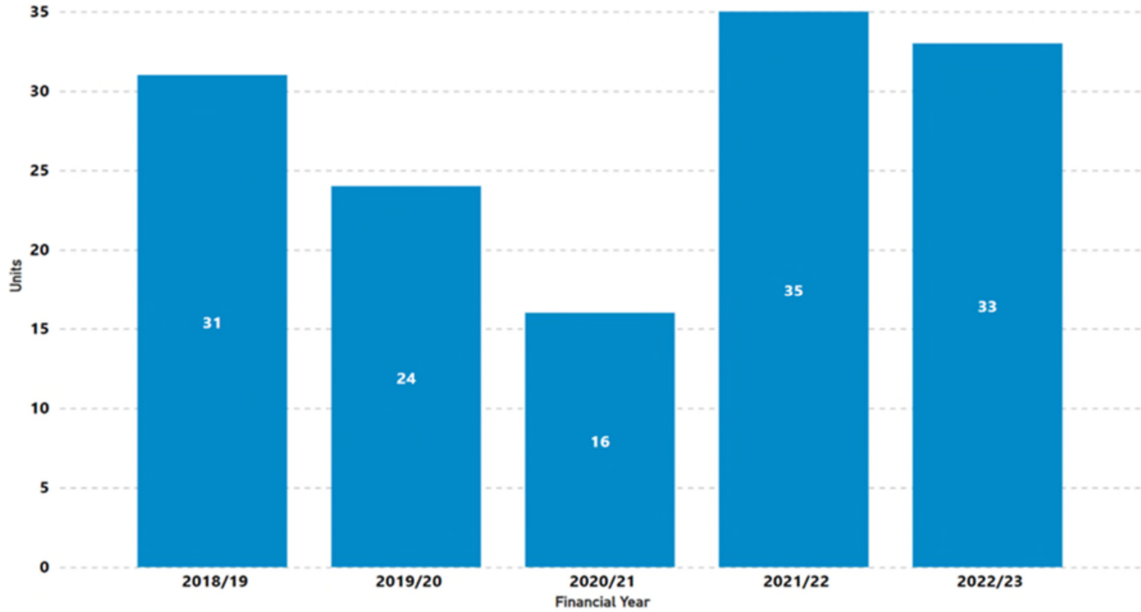


Figure 4: Unassisted Protection Relays Failures

Figure 5 illustrates the unassisted relay failures from 2018/19 to 2022/23. A protection relay is classified as defective when one or more of its components do not perform as expected, but the relay can still carry out its basic function of detecting and isolating power system faults.

Approximately 72% of the defects were identified in microprocessor relays. Defects varied in nature, ranging from failures in communication cards to issues like water ingress or vermin damage.

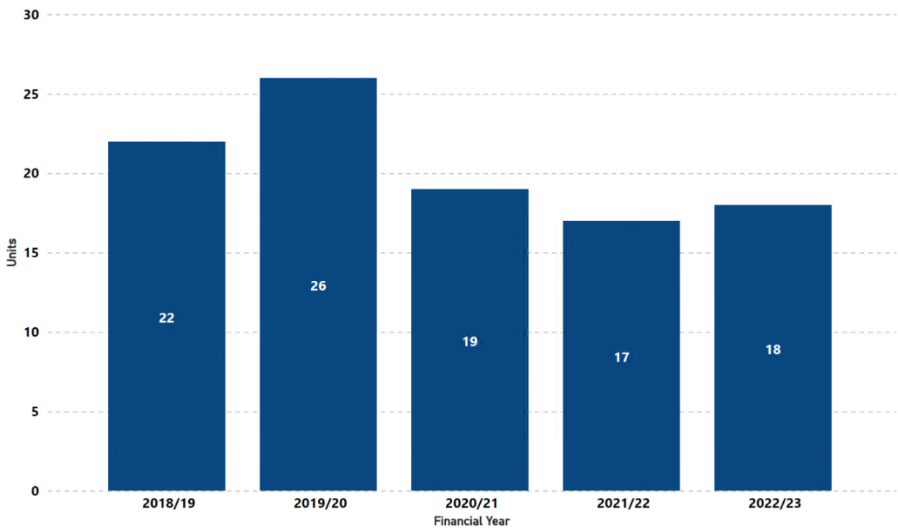


Figure 5: Protection Relays Defects

3.4 Risk Evaluation

The risk is calculated as per equation in Figure 6.

Figure 6: Monetised Risk Calculation Per Category

Each consequence category follows the same calculations in Figure 6 to obtain the total monetised risk is as per below in Figure 7. Energex broadly considers five value streams for investment justifications regarding replacement of widespread assets. In Figure 7, only four of the value streams are considered; the 'Export' impact is not relevant for this study and will be excluded from the analysis.

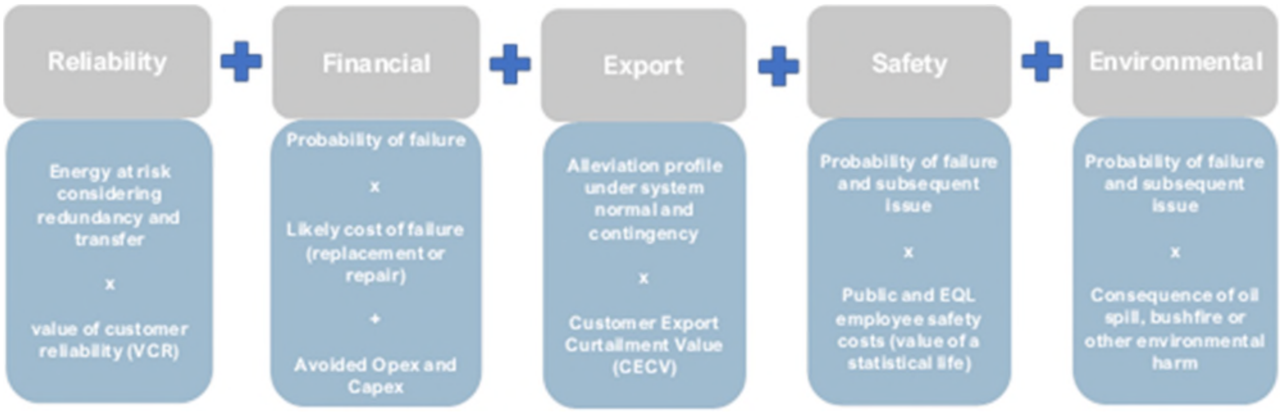


Figure 7: Total Risk Cost Calculation

3.4.1 Probability of Failure (PoF)

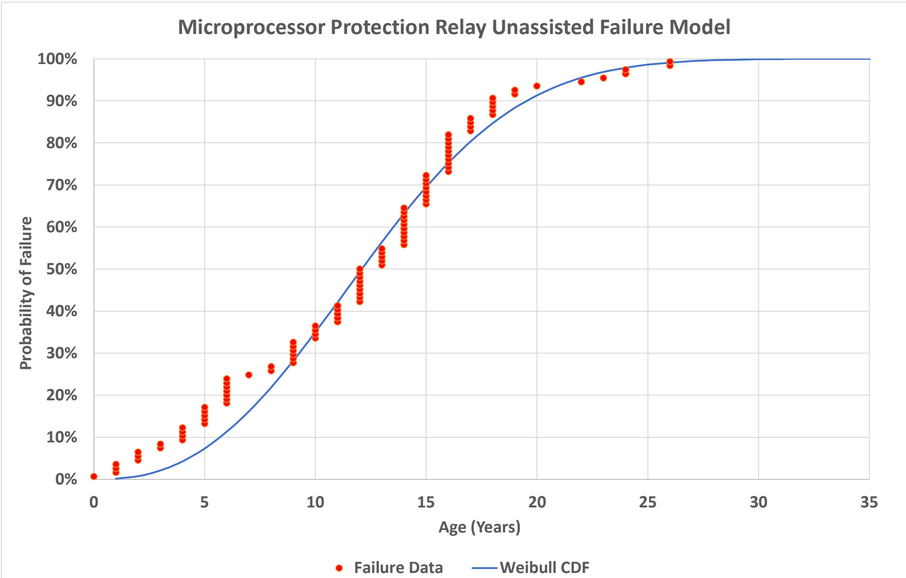
Due to the limited condition data available for the implementation of an Asset Health Index (AHI), the Weibull distribution model was utilised instead due to its flexibility and ability to model skewed data. The Statistical model Weibull Distribution has been developed for assets having only observed inspection and not having measured data to predict the PoF such as Protection relays, Low Voltage service cables, Pole Top Structures (Crossarm), distribution transformers and distribution switches to assist with the replacement management of ageing assets.

The Weibull distribution is one of the most widely used lifetime distributions in reliability engineering. It is a versatile distribution that can take on the characteristics of other types of distributions, based on the value of the shape parameter, Beta (β) and the scale parameter, Eta (η) refer Table 1. The function used to determine the probability of failure from a particular asset's time of failure is the Cumulative Distribution Function (CDF).

Shape parameter Eta defines the average period when 63.2% of asset population is expected to fail. The other parameter represents the failure rate behaviour. If Beta is less than 1, then the failure rate decreases with time; if Beta is greater than 1, then the failure rate increases with time. When Beta is equal to 1, the failure rate is constant. The resultant Weibull curve shown below for each relay technology type, besides static relays due to insufficient failures to produce a model, are show in Figure 8. The failure data modeled is based on failures that occurred between 2018-23.

Due to erroneous records of the manufactured dates associated with electromechanical relays, failures are unable to be modelled. However, based on the number of failures vs the total population, it is evident electromechanical relays are approaching their end-of-life wear-out period.

There are insufficient static relay failure and defect data to produce a Weibull model. It is evident that the majority of microprocessor relays are failing or becoming defective well before the expected life of 20 years. With majority of newer model installations being microprocessor relays, it can be seen there are a lot of infant mortality experienced as per Figure 8**.**



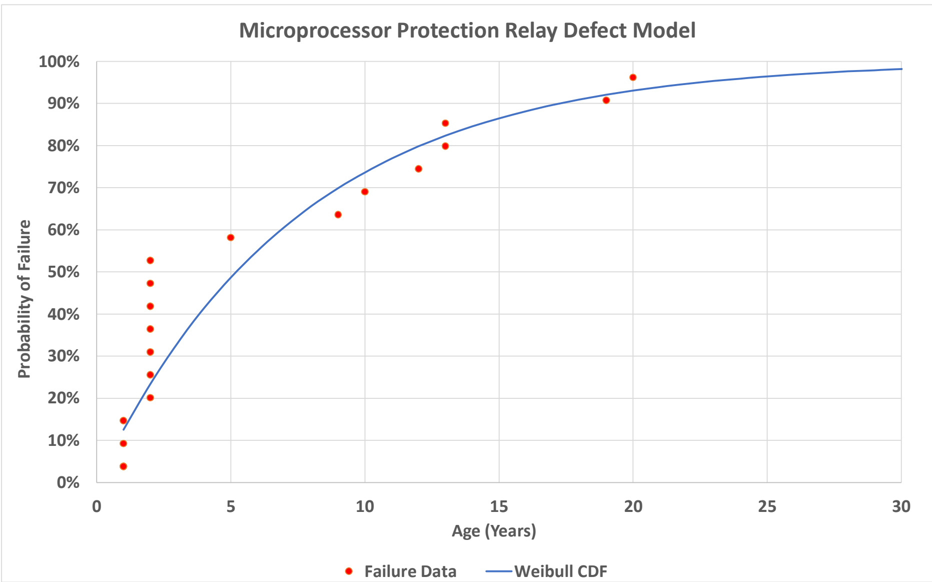


Figure 8: Microprocessor Failure and Defect Replacement against Weibull CDF Curve

Type	Beta (β)	Eta (η)
Microprocessor Failures	2.5	14
Microprocessor Defects	2	12

Table 1: Microprocessor Weibull Beta (β) and Eta (η)

3.4.2 Consequence of Failure (CoF)

Consequences of an in-service failure have been assessed across four value streams and are relevant to this business case:

- **Reliability:** Represents the unserved energy following the in-service failure of protection relay. It is based on the assessment of the load at risk during three stages of failure: fault, initial switching and replacement time and also upon time gap duration with operation of the back-up protection; more delays mean wider damages and prolonged restoration time
- **Financial:** The financial cost is derived from an assessment of the likely replacement costs incurred by the failure of the asset. This cost can substantially increase for emergency replacements or replacement protection panels to suit new models of relays
- **Safety:** There is a risk of multiple serious injuries or fatality following a failure of a protection relay. Additionally, a protection failure could lead to widespread asset damage inside/outside of the substations causing significant public safety issues
- **Environmental:** There is a risk of environmental impact/contamination following a failure of a Protection relay in very specific circumstances if asset damages are widespread due to delays in operation of backup protection

3.4.3 Likelihood of Consequence (LoC)

The likelihood of consequence refers to the probability of a particular outcome or result occurring because of a given event or action. To estimate the likelihood of consequence, Energex has utilised a combination of historical performances and researched results.

Energex has analysed past events, incidents, and data to identify patterns and trends that can provide insights into the likelihood of similar outcomes occurring in the future. Additionally, Energex also has conducted extensive research to gather relevant information and data related to the respective risk criteria.

4 IDENTIFIED NEED

4.1 Problem Statement

Energex faces several significant challenges in the management of protection relays. The following factors contribute to these challenges:

- **Trending Specific Relays:** Due to the extensive variety of makes and models of relays used, it becomes increasingly difficult to track and analyse specific relay performance trends.
- **Lack of Common Failures:** Most relays exhibit unique failure patterns, making it challenging to identify common issues. Some failures pose higher risks than others, further complicating the management process.
- **Inaccurate and Incomplete Records:** The records pertaining to relays are often inaccurate and incomplete, hindering effective monitoring and maintenance.
- **Insufficient Strategic Spares:** There is a lack of strategic spare relays for those with higher failure rates or limited in-service population. This poses a risk in situations where emergency replacements are required.
- **Relays Operating Beyond Expected Life:** More than 39% of relays are operating beyond their life expectancy, increasing the likelihood of failures and potential disruptions.
- **Problematic Relays:** Approximately 9% are identified as problematic.

The proposed strategy prioritises relay replacement based on the level of risk they pose to the network, the public, and work crews in the event of failure. This is followed by age-based replacement, targeting relays operating beyond their expected end-of-life and relays with low populations. By implementing this approach, Energex aims to mitigate financial risks associated with emergency replacements and enhance the reliability and safety of the network.

4.2 Compliance

This business case is guided by the following legislation, regulations, rules and codes:

- Electricity Act 2002 (Qld)
- National Electricity Rules (NER)
- Electrical Safety Act 2002 (Qld)
- Electrical Safety Regulation 2013 (Qld)
- Queensland Electrical Safety Code of Practice 2020 – Works (ESCOP)
- Work Health & Safety Act 2011 (Qld)
- Work Health & Safety Regulation 2011 (Qld)

5 ASSET LIMITATION FORECAST SUMMARY

5.1 Problematic Relays

Problematic relays are classified by relays with high-risk failures and/or high failure rate. With majority of the problematic relays being microprocessor, a larger number of replacements are expected as per Table 2.

Replacement Technology Type	FY 2025/26	FY 2026/27	FY 2027/28	FY 2028/29	FY 2029/30	Total AER Period 2025-30
Electromechanical Relays	20	20	20	20	20	100
Static Relays	20	20	20	20	20	100
Microprocessor Relays	300	300	300	300	300	1500
Total	340	340	340	340	340	1700

Table 2: Problematic Forecasted Replacement Volume

5.2 Age Based Replacement

Table 3 shows the total number of relays that are approaching their expected life and should be considered for replacement with other works as a site.

Exceeded EOL	FY 2025/26	FY 2026/27	FY 2027/28	FY 2028/29	FY 2029/30	Total AER Period 2025-30
Total	1,500	1,500	1,500	1,500	1,500	7,500

Table 3: Age Based Forecasted Replacement Volume

5.3 Optimal Timing and NPV Analysis

The optimal timing of replacement of an asset, NPV analysis, risk evaluation and bundling of works with other poor condition network assets at a specific time is carried out when we develop individual projects.

After conducting the risk evaluation, optimal timing and NPV analysis for individual projects to optimise the cost/benefits for the community the proposed Replacement Program (volume and expenditures) has been provided in Table 4.

Year	2025/26	2026/27	2027/28	2028/29	2029/30	Total
$m, direct 2022-23	8.6	13.8	12.9	12.3	9.3	**56.9**
Quantity	28	86	186	65	406	**771**

Table 4: Proposed Replacement Program – RIN Forecast

Of the 771 relay replacements being undertaken in the regulatory control period, just under half are accounted for in five projects:

- Stafford Zone Substation Transformer and Circuit Breaker Replacement
- Victoria Park Bulk Supply Substation Switchgear Replacement

  Makerston St Switchgear Replacement
- Loganholme Zone Substation Transformer and Circuit Breaker Replacement
- Nudgee Substation Switchgear Replacement

6 RECOMMENDATION

The proposed volume provides the best balance of benefits and risks for the organisation. As such, the decision has been made to continue with counterfactual replacement strategy, with a focus on optimising existing processes and enhancing efficiencies where possible.