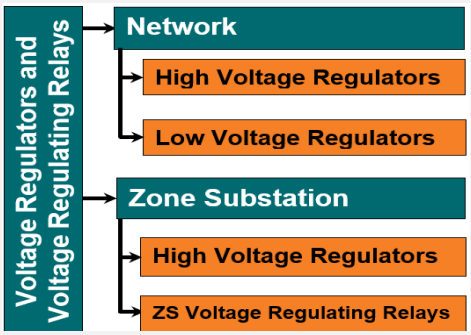
Voltage Regulators & Voltage Regulating Relays Investment Case

Voltage Regulators (both HV and LV) are located primarily on the network with a small number located in zone substations with fixed tap transformers. Voltage Regulating Relays are located in both Zone Substation and on the network to maintain voltage within prescribed limits. They are used to improve power quality performance and assist with the operation of Essential Energy's network.

Scope

This asset class investment case addresses Voltage Regulator and Voltage Regulating Relays both HV and LV and supports their installation, safety and maintainability.

The investment is required to meet the capital expenditure objectives (NER 6.5.7) for quality, reliability, safety and security of electricity supply and to meet regulatory and legislative obligations for Standard Control Services.



Forecast $FY24

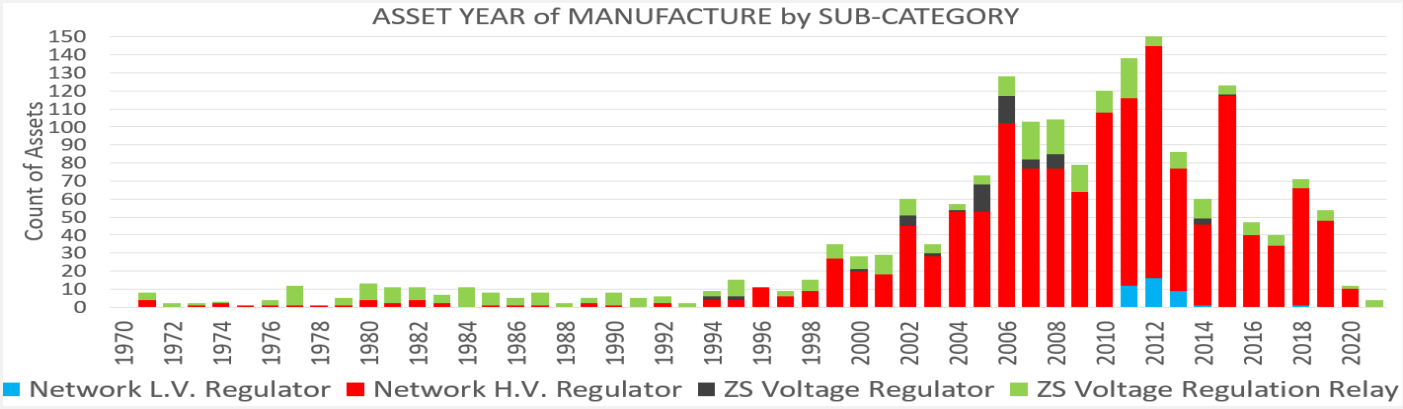
The Voltage Regulator and Relays forecast accounts for 0.26% of the total Repex portfolio for FY25 to FY29.

FY25	FY26	FY27	FY28	FY29
$0.58M	$0.6M	$0.53M	$0.61M	$0.59M

Asset Profile/Health

Asset Profile

Essential Energy currently has 1883 "in service" assets recorded. For the analysis groups of Network connected High Voltage Regulators / Low Voltage Regulators and Zone Substation Voltage Regulators and Voltage Regulating Relays were included. The network asset groups have an average age of 12 and 9 years respectively. The ZS asset groups have an average age of 16, and 13 years respectively.



The majority of voltage regulators and regulating relays are of good health. Using age as a proxy there are however, some assets that are approaching end of life.

Risk Analysis

This section provides an overview of the Voltage Regulators and Relays risk model. It is supported by documents and **6.03.02 Network Risk Management Manual, 6.03.03 Appraisal Value Framework and 6.03.04 System Capital Risk and Value Based Investment** methodology.

Probability of Failure (PoF)

Failure modes for Voltage Regulators and Voltage Regulating Relays have been identified through a Failure Mode Effects Analysis (FMEA) with subsequent analysis focusing only on those failure modes with asset life ending consequence.

5296 tasks (from 2006-2021) were analysed to inform the Weibull analysis. Task categories in this dataset did not provide a clear indicator of the failure modes for end-of-life / failed assets due to issues with current practices in classification of information. The limited availability and consistency of data also made it difficult to classify failures as repair or replace – therefore, only end of life replacement failures are consistent in the analysis. Following this method, 292 failure tasks and 2886 maintenance tasks were mapped to assets. 247 of the failures were from HV Regulators. Weibull parameters used in the risk model are shown below.

HV Regulators: Beta = 1.96; Alpha = 41.93	**Voltage Regulating Relays:** Beta = 1.43; Alpha = 89.98	**LV Regulators:** Beta = 1.57; Alpha = 37.44

Consequence of Failure (CoF)

The consequence of failure for these assets describes the impact of a functional failure. Consequence of failure models have been developed for catastrophic asset failure, evaluated using **6.03.03 *Appraisal Value Framework*** and ranked as shown in the adjacent table:

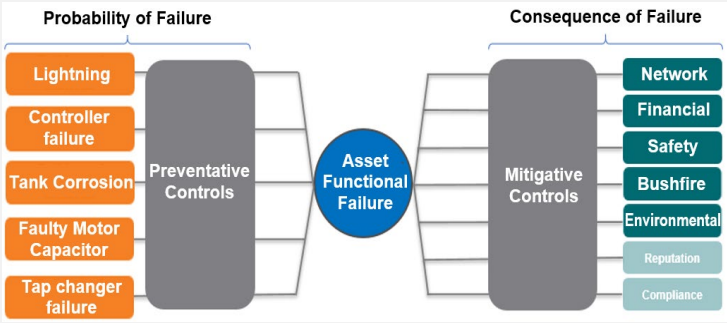
A safety fatality rate was calculated for each of the following asset types as per **6.03.02 Network Risk Management** with all assets within safety risk tolerability range.

Consequence costs are dominated by Network. There were smaller contributions from Financial, Safety, Bushfire and Environment. Compliance and Reputational risks have been considered but deemed insignificant based on the value framework.

Value Measure	Consequence		
	Total $M	Average ($ per asset	Median ($ per asset
Network	$282.59	$150,077	$9,400
Safety	$3.079	$1,635	$2,051
Bushfire	$0.044	$24	$1
Environment	$0.008	$4	$5
Financial	$58.381	$9,400	$29,374

Network Risk

Asset risk is a function of the probability of failure and the consequence of failure. The risk assessment has been developed using the **6.03.02 Network Risk Management** and represents the relationship between the primary drivers behind Voltage regulators and voltage regulating relays functional failures and the components used to determine the consequence of failure.



Forecasting Approach

The replacement Capex forecast (FY25-FY29) has been calculated using Essential Energy's optimisation software (Copperleaf) which uses a risk based methodology to maximise the value of the investment portfolio within constraints established by Essential Energy that are consistent with our Corporate Risk Framework, Asset Management System, applicable standards, rules, regulations and licence conditions. To assure efficiency our portfolio has been constrained to meet customer and stakeholder expectations.

In line with NER capital objectives, the objectives of our total replacement portfolio have been informed through extensive stakeholder engagement and consist of:

- Maintain reliability performance (network risk)
- Long term reduction of bushfire start risk by 20% over 20 years (2.5% FY25-29)
- Maintain safety performance

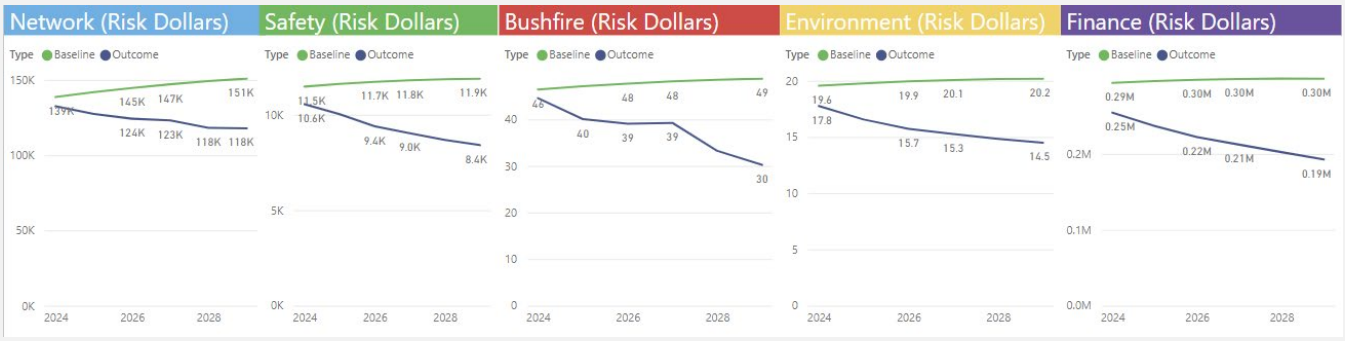
The replacement quantities of **Voltage Regulators** are the optimised **risk-based replacements to maintain overall network risk values within defined objectives.**

The above asset interventions utilise a probabilistic approach that has been developed through detailed analysis of historical asset performance to establish Weibull parameters.

Refer to **6.03.04 System Capital Risk and Value Based Investment** methodology for details on the portfolio wide optimisation planning approach and risk outcomes, and **10.01.04 Capital Unit Rates** for unit rates.

Optimised Portfolio Outcomes

Risk Trend (2024-29 Optimised portfolio)
Over the 5 year regulatory window, total **baseline** monetised risk due to **functional** Voltage Regulator and Relay failures is estimated to increase to $0.46M by 2030. The figure below depicts the **baseline** scenario and investment **outcomes** ($0.32M) of the optimised program for Voltage Regulators and Relays.



Grouping

The Voltage Regulators and Relay assets have been grouped into one group for investment optimisation purposes:

1. **Risk-based** replacement - e.g. the risk attributed to an asset through its combination of probability of failure and consequence of failure is high and replacement is the prudent action to reduce this risk. Assets within this risk-based replacement group have been included in the optimisation process where they will have reached Equivalent Annualised Cost (EAC) positive by FY34.

- 953 asset groups were loaded into 90 investments in Copperleaf to provide flexibility in portfolio optimisation. Of the 90 investment groups, 23 were optimised into the portfolio.

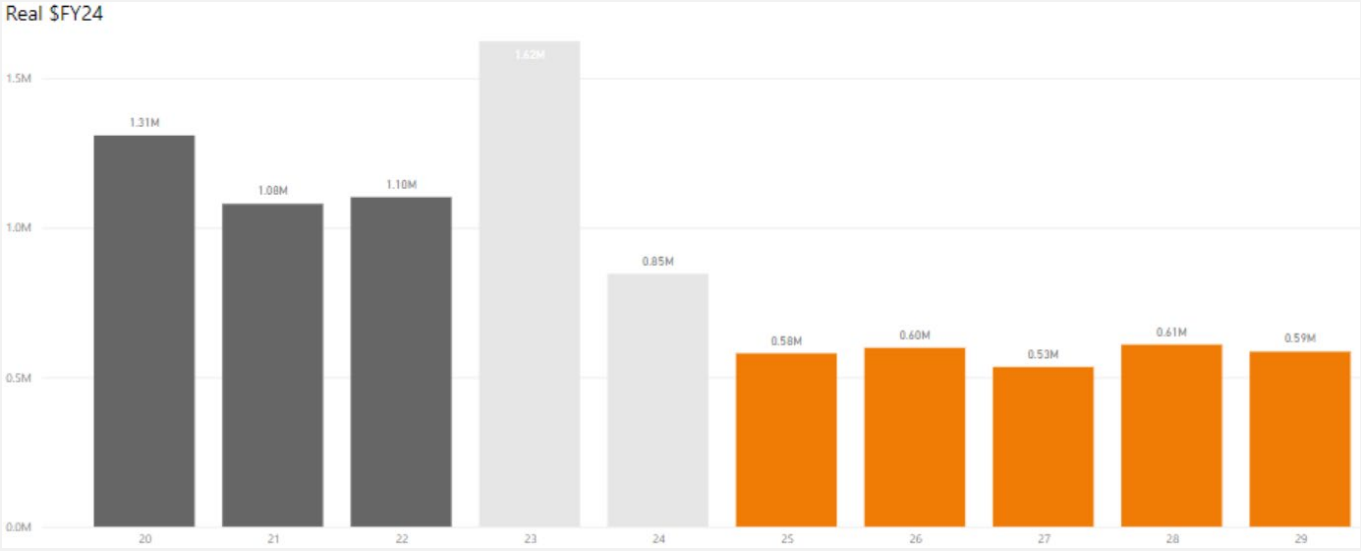
Investment Options

1. Voltage Regulators and Relays replacement expenditure has been modelled on a replace with current standard or like-for-like.
2. Risk based asset groupings are treated as additional optional investments for consideration in the total optimised portfolio to meet overall portfolio objectives.

- Non-network solutions are not considered when planning the replacement of this asset class.

10 Year Replacement Capex Forecast

Forecast replacement expenditure for Voltage Regulators across the 2024-29 period is $2.91M, averaging $0.58M per annum. Actual and projected expenditure for the remainder of the 19-24 period $6M.



Data source: Actuals: Internal delivery reports, Forecasts: Copperleaf
Note: All values are in FY2023-24 real dollar terms

Justification

We are confident that our approach delivers an efficient and prudent level of investment because:

- **Clear, prudent drivers from Asset Management Objectives (detailed in Attachment 10.01 SAMP) for Reliability, Quality, Safety and Compliance:** Our forecast has been developed in line with the asset management objectives for this asset class which include: maintaining present reliability levels for our customers; maintaining safety incidents at or below present levels; and reducing unassisted fire starts.
- **NER Capex Objectives:** form the basis of our proposal
- **Review and moderation:** Our forecasts have been tested and reviewed by our customers, our executive management and the Board, and the forecasts have been moderated based on feedback and discussion.

The major benefits expected from these investments are:

- **Maintain network and safety risk and reduce bushfire risk**: through continuation of the Bulk Replacement program, we will proactively address locations of greatest risk across our overhead network, and in a manner that minimises costs; and
- **Maintain levels of service for our customers:** Maintaining the health of the fleet, and through addressing locations of highest risk, will result in fewer unplanned failures through asset degradation and therefore will enable us to maintain service reliability for customers.

Forecast replacement expenditure for Voltage Regulators and Relays across the 2024-29 period is $2.91M. The reduction from 2019-24 actual/forecast expenditure of $6M is due to Copperleaf optimisation selecting only those investments required in order to achieve the portfolio objectives.

Assumptions

- **Attribution of tasks to specific assets** was difficult in general. To approximate an age at task date for replacements, modelling assumed an installation date for the replaced asset equivalent.
- **Categorisation of task maintenance activity** was performed in a task code mapping spreadsheet. Tasks were categorised (Replace, Repair, Inspect, Install, Modify) based off their task group, task description, and cause description. The ‘Replace’ category was reserved for replacement of an entire assembly, with minor component replacements being categorised as ‘Repair’.
- **Age profile** was determined using the asset installation date where available, some assumptions were made for sites without this information using site age.
- **Development of Weibull Parameters** occurred through fitting within Power BI, relying on user-selected filtering and censoring of the categorised data (tasks and in-service asset ages). Adjustment of these selected controls was informed by the calibration process described below. The final Weibull parameters were based on analysis of all Replace tasks with no censoring applied.
- **Calibration of Weibull Parameters** was achieved by comparing failures predicted in 2020 by a given set of Weibull parameters to historical failures recorded in the assessed Failure Data between 2006-2021.
- **Consequence models** were developed in accordance with **6.03.03 Appraisal Value Framework**.

Strategic Direction

Lifecycle Stages

Acquisition

Selection Criteria

- HV voltage regulators: Maintain current selection criteria.
- LV voltage regulators: Maintain current selection criteria.
- Voltage Regulating Relays: Maintain current selection criteria.

Maintain awareness of alternate supplier designs and trial where commercially and technically viable.

Investigate viability of replacing failures only where value can be demonstrated.

Procurement

- Continue the current period contract approach with vendors for HV Regulators, LV Regulators and Voltage Regulating Relays. Maintain awareness of obsolescence issues and availability of critical components.

Supply Chain

- Continue to work with suppliers for new product opportunities.
- Maintain catalogue options for HV Regulators, LV Regulators and voltage regulating relays from multiple suppliers, to maintain supply diversity.

Ops & Maintenance

Preventative Maintenance (Inspections):

- Continue to do non-intrusive examination and inspection of high voltage ZS Voltage Regulators and Voltage Regulating Relays with visual inspections to detect signs of surface or corrosion defects on assets as per CEOP8011 for ZS Assets
- Continue to inspect assets as per *CEOP8011 Substation Inspection:*
- ZS HV REGULATORS: 3year intervals (Oil sample), 6yrs full maintenance.
- ZS VOLTAGE REGULATING RELAYS: Electro -Mechanical: 1year interval. Electronic & PLC VRR: 3yrs.
- Network HV and LV regulators: continue inspections and maintenance as per CEOP8009.
- HV REGULATORS GROUND: 3 mthly inspection & AVR op test, 3year interval: Oil, 6year interval: Full.
- HV REGULATORS POLE: 12 mthly inspection & AVR op test, 4year interval: Full.
- LV REGULATORS POLE: No formalised inspection listed in AI manual CEOM7005 or CEOP8009. Add a formal confirmation of operational status during the AI inspection in CEOM7005.

Corrective Maintenance (Repairs):

- Continue with existing repair (ref Asset Forecast Lifecycle – p6). Continue on-condition corrective maintenance where financially viable and spares readily available.

Breakdown Maintenance:

Continue to carry out breakdown maintenance on ZS HV regulators / Voltage Regulating Relays and network HV regulators / LV Regulator assets for repair or replacement.

Larger investments will undergo and require demonstration of a positive value calculation.

Interventions

Replacement Programs

- HV Regulators, ZS voltage regulating relays and LV Regulators: Replace on functional failure and develop a cost effective replacement program based on asset end of life.
- Continue to improve the Value assessments for High Voltage Regulators and voltage regulating relays to determine the future use and where replacement of this plant is required.

Prioritisation

- Continue to prioritise replacement projects with the value calculation and investment optimisation process.
- Update *CEOP8032 Transmission and Zone Substation Design Guidelines* to include design recommendations for Voltage regulators and voltage regulating relays.

Disposals

Individual Assets

- Continue to investigate opportunities to re-use and recycle assets in accordance with *CECP8074.*
- Continue to dispose of assets as per *CECP8074.01 Company Policy Asset Disposal.*

Entire Asset Variant

- Continue to dispose of assets as per *CECP8074.01 Company Policy Asset Disposal.*

Hazardous Materials

Continue to manage hazardous materials in accordance with *CECM1000.10.*

Asset Support

Process & Information	• Improve use of EAM as the central repository of asset information, preventative and corrective actions and test results. • Create records in EAM for Voltage regulators and voltage regulating relays and their failures to capture asset profile. • Enhance asset risk-value assessments leveraging capabilities of new and existing software. • Continue to follow *CEOM7074 Operational Manual: Entry into electrical stations* for safety directions for employees working in Zone Substations.
People & Training	• Continue with other current training practices, including awareness of associated conditional failure when inspecting or maintaining Voltage regulators and voltage regulating relay assets. • Continue to manage knowledge and skills regarding significant repairs.
Supply Chain	• Continue to manage spares for Voltage regulators and voltage regulating relay assets.