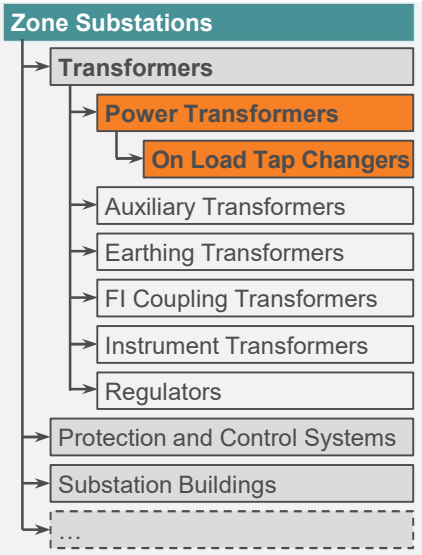
# Zone Substation Transformers Investment Case

Zone Substation Transformers provide the necessary voltage conversion that enables the efficient transport of electrical energy at voltages which reduce losses and facilitate the efficient sizing of cables, conductors, and support structures.

## Scope

This investment case address power transformers that are located within zone substations, including their key subassemblies of windings, tank, bushings and on load tap changers (OLTCs).

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




## Forecast $FY24

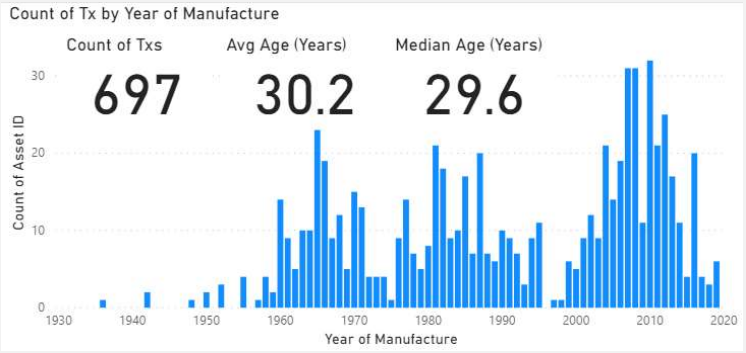
The Zone Substation Transformer forecast accounts for 2.55% of the total Repex portfolio for FY25 to FY29.

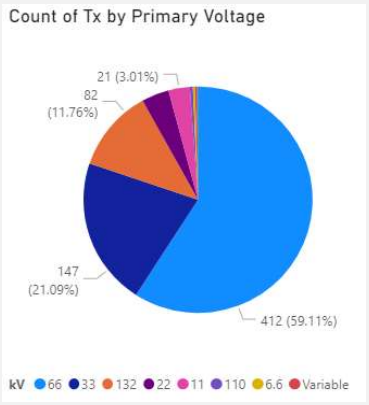
| FY25 | FY26 | FY27 | FY28 | FY29 |
|---|---|---|---|---|
| $6.4M | $5.5M | $5.6M | $5.4M | $5.7M |

## Asset Profile/Health

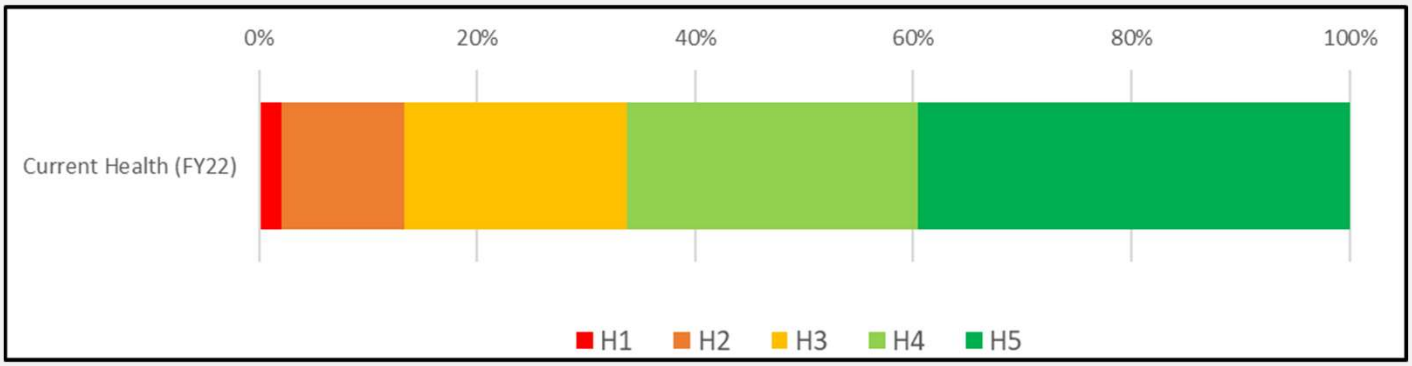
### Asset Profile

Essential Energy currently has 697 subtransmission transformers in-service, with the oldest 84 years of age. 59.1% of the transformer fleet have a primary voltage of 66kV.




The current health of the zone substation transformer is shown in the following figure.




Asset health considers measured results from regular:

- oil analysis;
- paper samples;
- electrical testing;
- visual inspection; and
- maintenance results.

| AHI | Replacement Timeframe | Description |
|---|---|---|
| H1 | 0 to 3 years | Asset at or approaching end of life |
| H2 | >3 to 7 years | High risk of failure, replace in short term |
| H3 | >7 to 15 years | Elevated risk of failure, replace in medium term |
| H4 | >15 to 25 years | Acceptable deterioration and condition |
| H5 | >25 years | Low failure risk, asset in good condition |

Risk Analysis

This risk section provides an overview of the ZS Transformer 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 of all preventative and corrective maintenance tasks have been resolved into failure modes. They have then been attributed to one of three subsystems within the asset, as shown at right.

Weibull distributions were developed based on historical Essential Energy catastrophic failure data, which inherently incorporates the preventative controls currently employed for the treatment of failure risk.

The subsequent risk modelling utilised the dominant winding failure mode Weibull distribution due to the complexities of computing 3 failure modes in the analysis.

Weibull parameters used in the risk model are:
- Alpha = 86.9
- Beta = 3.3

| Subsystem | Component | Failure Mode |
|---|---|---|
| **Transformer** | • Coil mechanical support<br>• Conductor<br>• Core<br>• Insulation<br>• Peripherals<br>• Tank | • {blocked}<br>• {broken}<br>• {damaged}<br>• {leaking}<br>• {loss of dielectric strength} |
| **Tapchanger** | • Barrier Board<br>• Drive linkage<br>• Fixed contacts<br>• Indication<br>• Insulation<br>• Motorbox<br>• Moving contact system<br>• Tank | • {broken}<br>• {contaminated}<br>• {damaged}<br>• {leaking}<br>• {loose}<br>• {loss of dielectric strength}<br>• {misaligned}<br>• {seized}<br>• {tracking} |
| **Bushing** | • Conductor<br>• Housing<br>• Insulation<br>• Test tap | • {broken}<br>• {damaged}<br>• {leaking}<br>• {loose}<br>• {short circuit}<br>• {tracking} |

### Consequence of Failure (CoF)

Consequence of failure models have been developed for catastrophic transformer failure, due to each of Winding, Tapchanger and Bushings, evaluated using the **6.03.03 Appraisal Value Framework** and ranked as shown below:
Consequence costs are dominated by Network and Financial costs.

Totals for each subassembly show the consequence cost should the entire transformer fleet fail catastrophically.

It is important to note that due to zone substations frequently having n-1 transformer backup designs, the consequence of failure of a single transformer can be relatively low, including in critical locations such as Terranora.

| Component | Consequence | | |
|---|---|---|---|
| | Total ($ million) | Average ($ per Tx) | Median ($ per Tx) |
| Network | $1,030.34 | $1,482,508 | $117,603 |
| Financial | $607.25 | $873,741 | $594,794 |
| Safety | $9.97 | $14,345 | $22,632 |
| Bushfire | $0.02 | $30 | $1 |
| Environment | $4.09 | $5,886 | $5,400 |
| **Total** | **$1,651.67** | **$2,376,509** | **$740,430** |

### Risk Model Calibration

Asset risk is a function of the probability of failure and the consequence of failure.

The asset risk has been calibrated against top-down performance figures. The table to the right demonstrates the difference between the unscaled risk model output and the monetised top-down performance. Scaling factors are applied to the Model Outputs to equate the two methods.
The modelling takes a bottom up probabilistic approach that has a number of estimates and assumptions to calculate across the population. This has been compared with a top down split of the actual recent events as valued by our Value Framework (6.03.03).

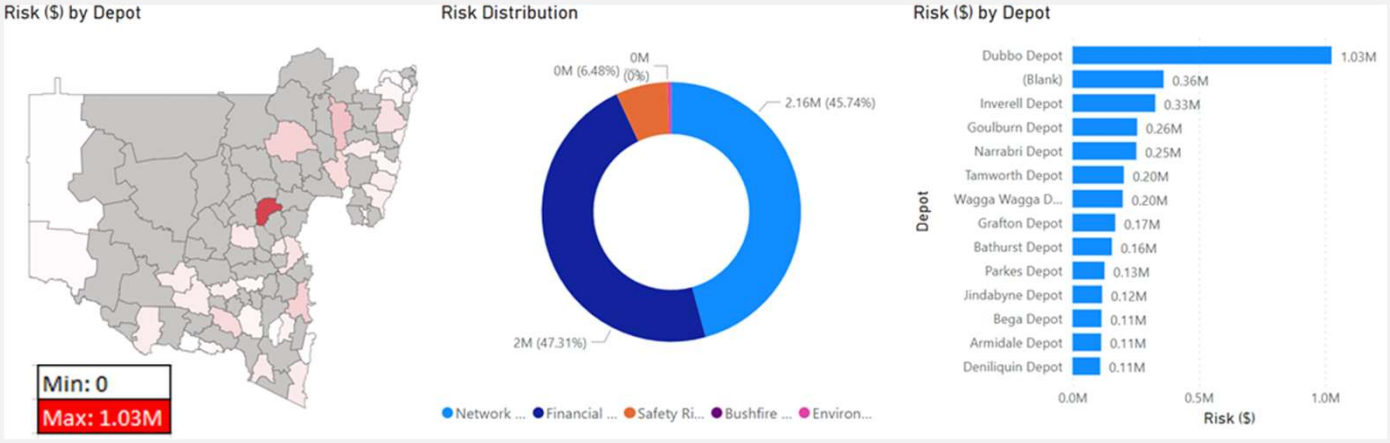
| Value Measure | Safety | Network | Bushfire | Financial | Total |
|---|---|---|---|---|---|
| Unscaled Model Outputs ($M) | 0.07 | 4.08 | 0 | 2.88 | 7.05 |
| Top-Down Performance ($M) | 0.31 | 2.16 | 0 | 2.24 | 4.73 |

Risk Analysis, cont

## Risk heatmap (Scaled)

The map below displays the summed risk of failure for zone substation transformers by nearest depot. The primary differentiator of risk for transformers is the Network risk, followed by Financial risk.

The number of assets within a depot area, in conjunction with individual asset CoFs, influence where the depot sits in the ranked list by depot.




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 ZS Transformers consist of:

1. Optimised risk-based replacements to maintain overall network risk values within defined objectives.

The above asset intervention utilises a probabilistic approach that has been developed through detailed analysis of historical asset performance to establish Weibull parameters (refer 6.03.03.27).

The probabilistic method has been tested and validated against historical volumes to ensure that it is accurate at the population level.

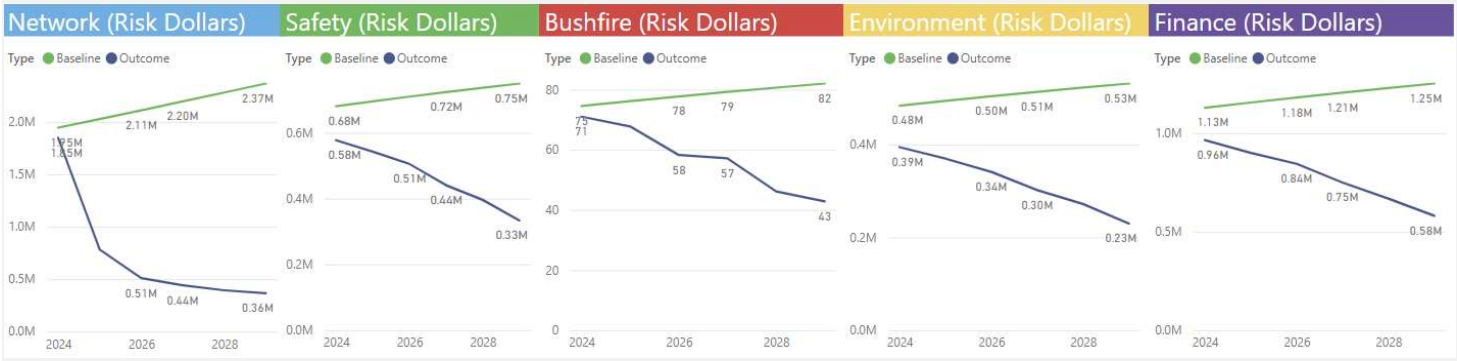
Forecast investment expenditure has been determined by multiplying the forecast replacement quantities of ZS Transformers assets by SME defined unit rates.

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.

Optimised Portfolio Outcome

## Risk Trend (2024-29 Optimised portfolio)

Over the 5 year regulatory window, total **baseline** monetised risk due to **functional** ZS Transformers failure is estimated to increase to $7.7M by 2030. The figure below depicts the **baseline** scenario and investment **outcomes** ($4.3M) of the optimised program for ZS Transformers.



## Asset Grouping

The ZS Transformers assets have been grouped into three broad categories for investment optimisation purposes according to the different modes of replacement:

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;
2. **Functional** failure replacement - where the ZS Transformers is no longer able to perform its function due to damage and requires immediate replacement.

- 38,707 asset groups were loaded into 720 investments in Copperleaf to provide flexibility in portfolio optimisation.

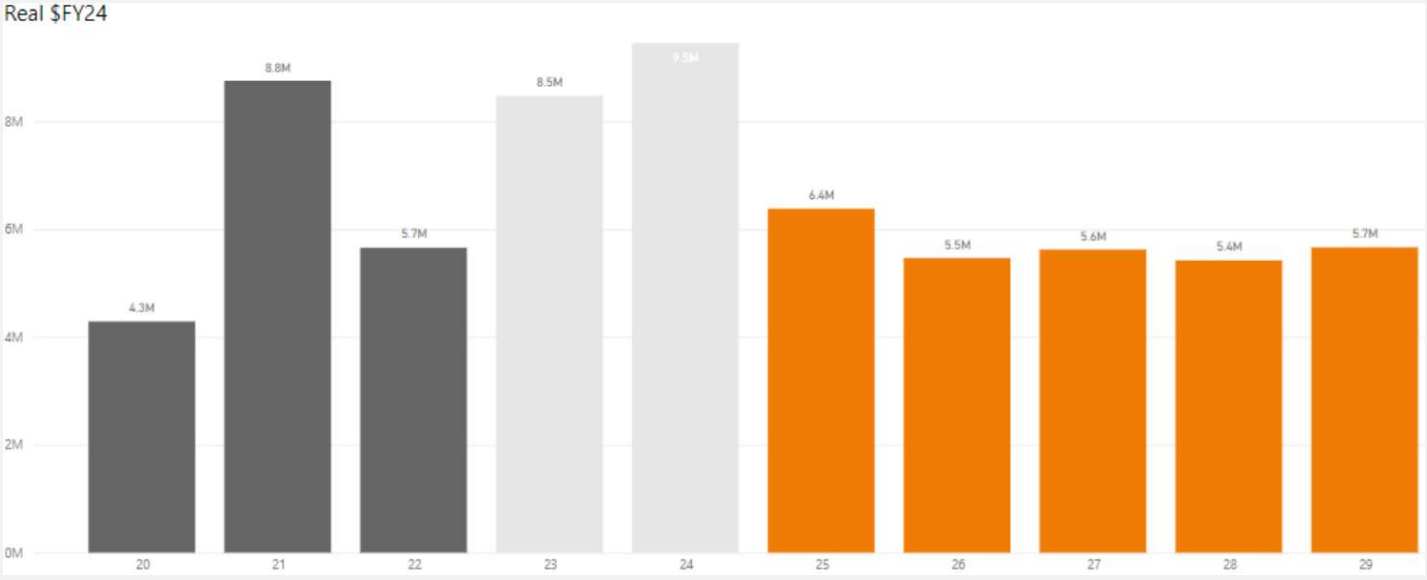
## Options

1. ZS Transformers replacement expenditure has been modelled on a replace with like-for-like within supplied capacities,
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 considered when planning the replacement of a specific asset.
- Value calculators determine the most prudent and efficient investment choice available at the time for a specific project. For example, options include: like-for-like replacement; replacement of ZS Transformers elements with different types or materials; or replacement of a feeder segment by a non-network solution.

## 10 Year Replacement Capex Forecast

Forecast replacement expenditure for ZS Transformers across the 2024-29 period is $28.6M, averaging $5.7M per annum. Actual and projected expenditure for the remainder of the 19-24 period is $36.6M.




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 as:

- **Clear drivers from Asset Management Objectives** for Reliability, Quality, Safety and Compliance (as detailed in 10.01 Strategic Asset Management Plan).
- **NER Capex Objectives:** form the basis of our proposal
- **Review and moderation:** Our forecasts have been tested and reviewed by our executive management and the Board, subject to top-down challenges (as detailed in **6.03.04 System Capital Risk and Value Based Investment**) and the forecasts moderated based on feedback and discussion.
- **Critical Environmental Factors:** There is increased risk associated with ZS Transformers due to factors such as geography and climate.
- **Customer needs:** Through customer engagement, refer Chapter 4 of our Regulatory Proposal, customers indicated a desire to maintain current levels of safety and reliability, and increase expenditure for resilience based projects. This asset class does not explicitly have expenditure related to resilience and therefore has a flat forecast for replacements. The investment will contribute to maintaining safety and reliability, within the wider Repex portfolio (as per copperleaf forecast).

The major benefits from the proposed ZS Transformers investments (against the **change nothing** scenario) are:

- **Improved network risk and maintainability**: Investment in this asset class will reduce network risk through replacement of ZS Transformers of degraded condition and/or in high risk locations with more resilient materials of acceptable condition; and
- **Maintained service level outcomes:** management of asset health will result in better control of unplanned failures thus will maintain network reliability.

Forecast ZS Transformers Repex expenditure for the 2024-29 period is $28.6M. The reduction from 2019-24 actual/forecast of $36.6M is due to:

- Reduced volume of replacements to achieve portfolio risk outcomes.
- Assets currently in reasonable health.

## Key Assumptions

- Where calculation of age of scrapped assets has not been possible – such as through no year of manufacture – these assets have not been included in the development of the probability of failure models.
- The development of consequence of failure event trees aligned to the value framework have relied on SME estimates of probability of events, and accepted EE and industry parameters.
- Asset data has been relied upon for the development of consequence of failure ($) for each zone substation transformer, although it is known that the bushing data against each transformer is incomplete, therefore the true consequence of failure for some transformers may be higher than stated.
- Consequence models use the costs for replacements of transformers, which include decommissioning of assets being replaced.
- Consideration of distribution backup has been disregarded at this point due to a lack of data.
- Consequence costs for Safety, Network, Environment and Bushfire have been taken from the 6.03.03 Appraisal Value Framework.
- Unit rates for this asset class are experiencing high volatility due to material supply costs. Volatility has been absorbed up to overall CPI rates, however pricing has well exceeded this value in the short term. Unit rates may require review prior to final submission as inflation and long term contracts are reviewed and finalised.

Strategic Direction

## Lifecycle Stages

### Acquisition

**Selection Criteria**

We shall continue to select transformers based on key attributes including:

- Mineral oil or FR3, based on environment and cost factors
- Bushing types (Solid or RIP Condenser) based on voltage levels
- Bolt on tapchanger requirements

We shall continue to procure through period contract orders or by detailed specifications submitted with supply tender.

**Procurement**

Period contracts are in place with two venders. Units are supplied with the ability to change the vector group and in some cases with dual ratio capability. These options allow for network flexibility and spares management.

Assets are ordered as required. Lead times vary by transformer type and factory demand, however, lead times are typically in the range of 30 weeks.

### Operations & Maintenance

**Inspections:**

We shall continue to inspect as per *CEOP8011*.

**Frequency:**

- Full site visual inspection: 1/2/3 monthly based on site criticality and available SCADA monitoring.
- Full site annual thermographic survey and partial discharge testing.
- PTX scheduled at 1/6 yearly inspections.
- OLTC scheduled based on number of operations and/or at 3/6 years based on OLTC model as per *CEOP8011* and detailed in maintenance regimes.

**Activities:**

- PTX annual oil sample, DGA and moisture.
- PTX 6 yearly, as per annual plus oil quality, with possible additional oil tests upon request.
- OLTC 3 yearly oil sample (for bolt on tapchangers)
- OLTC 6 yearly detailed inspection activities to coincide with preventative maintenance.

**Preventative Maintenance:**

We shall continue preventative maintenance through:

- PTX scheduled maintenance at 6 years.
- OLTC scheduled on number of operations and/or 6 years based on operations performed and OLTC model as per *CEOP8011* detailed maintenance regimes.

**Corrective Maintenance (Repairs):**

We shall continue corrective maintenance by replacing or repairing defective components. This can also include the consideration of a major refurbishment project on the PTX/OLTC.

**Breakdown Maintenance:**

We shall continue to rectify failures with an economic viability assessment of repair or replacement, with larger investments undergoing a value calculation.

### Interventions

**Replacement programs**

We shall continue to identify assets for replacement or major refurbishment through our Zone Substation Engineering or Transmission Services teams.

**Prioritisation**

We shall continue to prioritise replacement and major refurbishment projects through the value calculation and Capex optimisation processes.

### Disposals

**Individual Assets**

We shall continue to dispose of PTX and OLTC as per *CECP8074.01 Company Policy Asset Disposal* and via *Disposal Panel: Panel 105 - Distribution Apparatus and Power Transformer Disposal*

**Hazardous Materials**

We shall continue to consider any additional disposal management required to protect the community:

- Transformers containing PCBs managed as per *CECM1000.10*

### Asset Support

| | Current Approach | Actions |
|---|---|---|
| **Process & Information** | • Some asset data is contained within the existing EAM, however, digitalisation of asset data capture uplift to be completed. | • Improve data capture and management so as to facilitate mass data analysis and ease of strategic direction improvement. |
| **People & Training** | • Highly trained workforce with limited elasticity to match demand due to extensive training requirements.<br>• Small asset populations requiring extremely specialised skillsets which are currently held by an ageing workforce. | • Improve knowledge of field staff of the linkages between what they are doing and how their work impacts other parts of the business – i.e. the reliance of the business on good data that originates from the field (i.e. how/what they do in the field)<br>• Improve long term replacement forecasting to assist with both staffing levels as well as forward view of requirements for highly specialist skills required for small subset populations to allow for decisions to be made to let those skills go or for them to be transferred to other staff. |
| **Supply Chain** | • Current TX supply is provided by two Australian suppliers<br>• OLTC parts are currently obtained from 3 suppliers with legacy parts salvaged from other units or custom made by 3rd parties. | • Ensure appropriate level spares holdings to match the expected failure rate of transformers (i.e if value calculations push transformer replacements closer to a run to failure model a more extensive spares store may be required).<br>• Investigate the advantages and disadvantages of a truck based spare. |