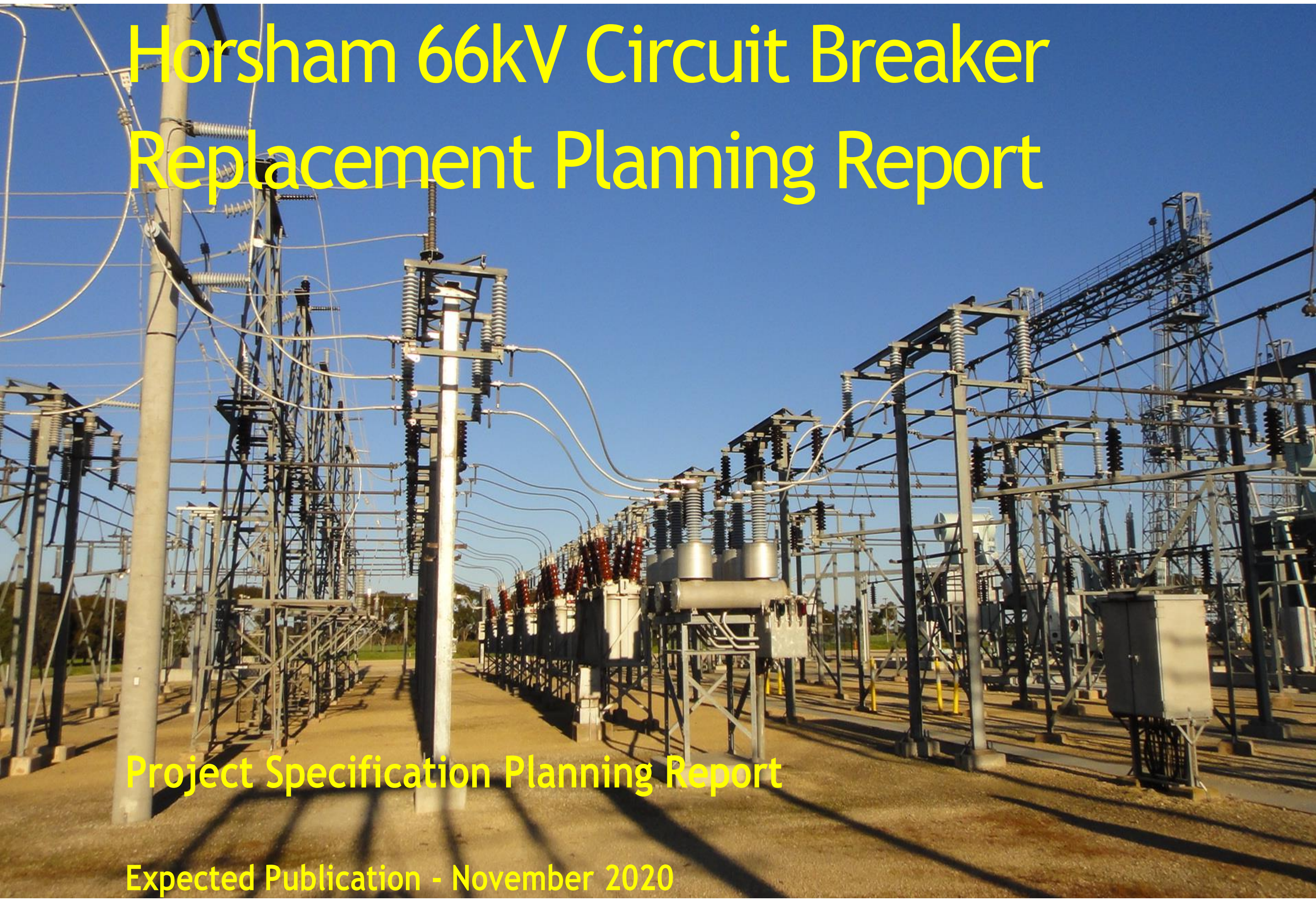
Horsham 66kV Circuit Breaker Replacement Planning Report



Project Specification Planning Report

Expected Publication - November 2020

Important notice

Purpose

AusNet Services has prepared this document to provide information about potential limitations in the Victorian transmission network and options that could address these limitations.

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Executive summary

Responsibility

AusNet Transmission Group (AusNet Services) as a Transmission Network Service Provider (TNSP) in the state of Victoria has the ownership, operation, and maintenance responsibility for Horsham Terminal Station (HOTS). TNSP obligations include maintaining a safe working environment for staff and contractors, maintaining the quality, reliability, and security of customer supplies, and preventing operating and maintenance costs from escalating to inefficient levels.

Emerging Constraints

Some of the 66kV circuit breakers at HOTS are in a poor condition with an increasing risk of failure. Condition assessments indicate that these assets are approaching the end of their technical lives. The emerging service constraints are:

- Health and safety risks presented by a possible explosive failure of instrument transformers or circuit breakers;
- Security of supply risks presented by a failure of the five 66kV circuit breakers;
- Collateral plant damage risks presented by an explosive failure of an instrument transformer or circuit breaker bushing;
- Environmental risks associated with explosive asset failures.

Economic Option

This planning study considers credible options to address the service constraints and to meet the long-term planning requirements for HOTS outlined in the Victorian Annual Planning Report[1] (VAPR) and Transmission Connection Planning Report[2] (TCPR). The options that have been assessed are:

- Business as usual to define the baseline risk;
- Run to failure and replace assets upon failure;
- Staged replacement of assets

The most economic option to address the emerging constraints at HOTS is a selective (staged) replacement of critical circuit breakers. This option involves some network reconfiguration and addresses all emerging risks. This option has the lowest present value cost ($1.8 M) and is consistent with the future development plans for GNTS. The economic timing for project completion is before Summer 2024/25 with an estimated total capital cost of $1.6 M.

[1] Victorian Annual Planning Report, 2019
[2] Transmission connection planning report, 2017

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1. Purpose

This planning report outlines asset condition, asset failure risks and network development plans relevant to HOTS for the planning period from 2022/23 to 2026/27. It provides an analysis of viable options to address the identified risks and maintain the efficient delivery of electrical energy from HOTS consistent with the National Electricity Rules (NER) and stakeholder's requirements. It also summarizes the scope, delivery schedule and expenditures associated with the most economical solution to emerging constraints.

2. Regulatory Obligations and Customer Requirements

This planning report acknowledges AusNet Services' obligations as a TNSP under the National Electricity Rules with particular emphasis on:
Clause 6A.6.7 of the National Electricity Rules[3] requires AusNet Services to propose capital expenditures necessary to:

"(1) meet or manage the expected demand for prescribed transmission services over that period;

(2) comply with all applicable regulatory obligations or requirements associated with the provision of prescribed transmission services;

(3) to the extent that there is no applicable regulatory obligation or requirement in relation to:

(i) the quality, reliability, or security of supply of prescribed transmission services; or

(ii) the reliability or security of the transmission system through the supply of prescribed transmission services,

to the relevant extent:

(iii) maintain the quality, reliability, and security of supply of prescribed transmission services; and

(iv) maintain the reliability and security of the transmission system through the supply of prescribed transmission services; and

(4) maintain the safety of the transmission system through the supply of prescribed transmission services."

The Electricity Safety Act (section 98(a)) requires AusNet Services to "design, construct, operate, maintain and decommission its supply network to minimise the hazards and risks, so far as is practicable, to the safety of any person arising from the supply network; having regard to the:

a) severity of the hazard or risk in question; and

b) state of knowledge about the hazard or risk and any ways of removing or mitigating the hazard or risk; and

c) availability and suitability of ways to remove or mitigate the hazard or risk; and

d) cost of removing or mitigating the hazard or risk".

[3] National Electricity Rules, Sep 2020

3. Background

Horsham Terminal Station (HOTS) is located in central western Victoria and supplies approximately 35,000 customers in the area including Grampians area. The location of HOTS in the Victorian grid is shown in Figure 1.

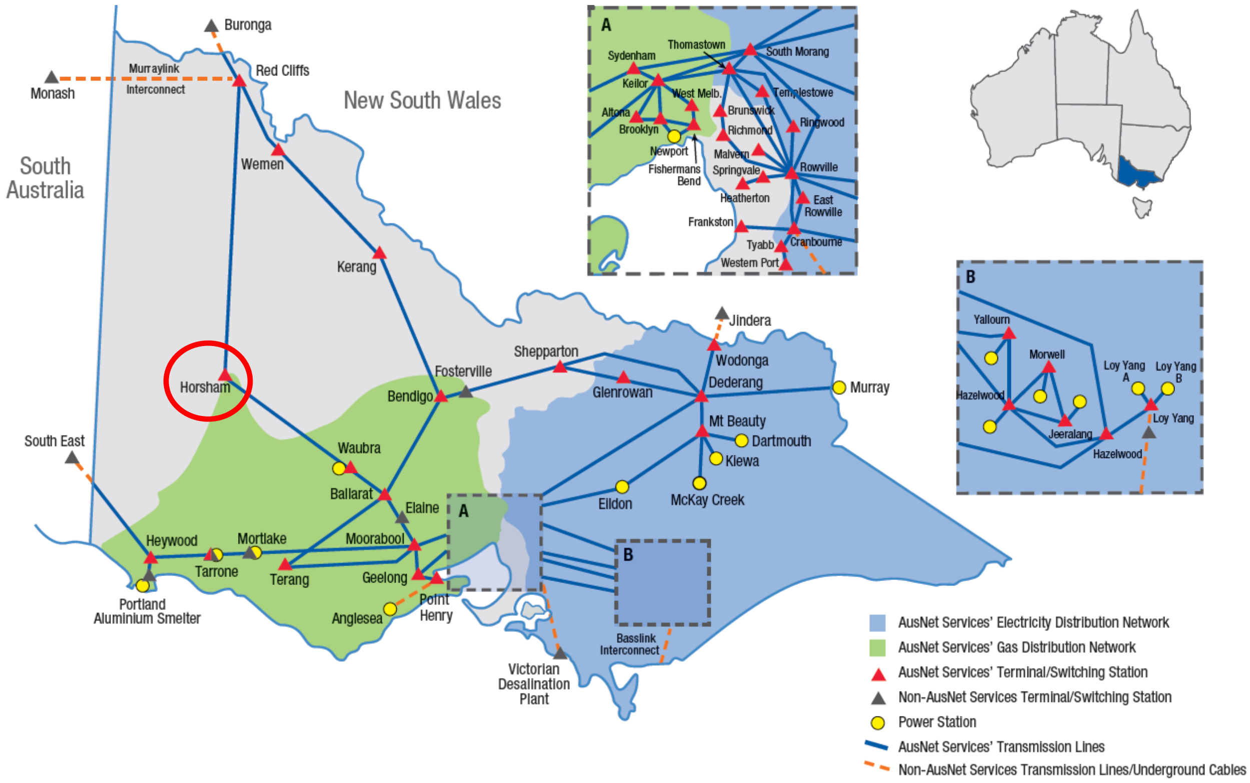

Figure 1 - Victorian Transmission Network

The terminal station forms an integral part of the Victorian transmission network and has 220kV connections to Red Cliffs (RCTS) and Ballarat (BATS) terminal stations. The station consists of a 220kV switchyard, 66kV switchyard and two 220/66/22kV transformers.

The terminal station was build in 1958, significant work has been completed on the station during the last two decades, particularly the 220kV transformers and associated 220kV switchgear and protection were replaced in 2007, and remainder of 220kV assets in 2012.

4. Planning Considerations

4.1. Planning Responsibilities

The augmentation responsibility for HOTS lies with the Australian Energy Market Operator (AEMO) for the shared transmission network and with the distributors, Powercor, and AusNet Services for the transmission connection assets and replacement planning.

4.2. Demand Forecast

The rate of growth in summer and winter peak demand at HOTS 66kV has been low in recent years, and demand is forecast to continue increasing slowly, averaging around 0.7% per annum for the 10-year planning horizon.

The 2019 Joint DB Transmission Connection Planning Report noted that there is no energy at risk under 50th percentile or 10th percentile loading conditions for the summer period for the next ten years. There is therefore not expected to be any need for augmentation over the ten-year planning period.

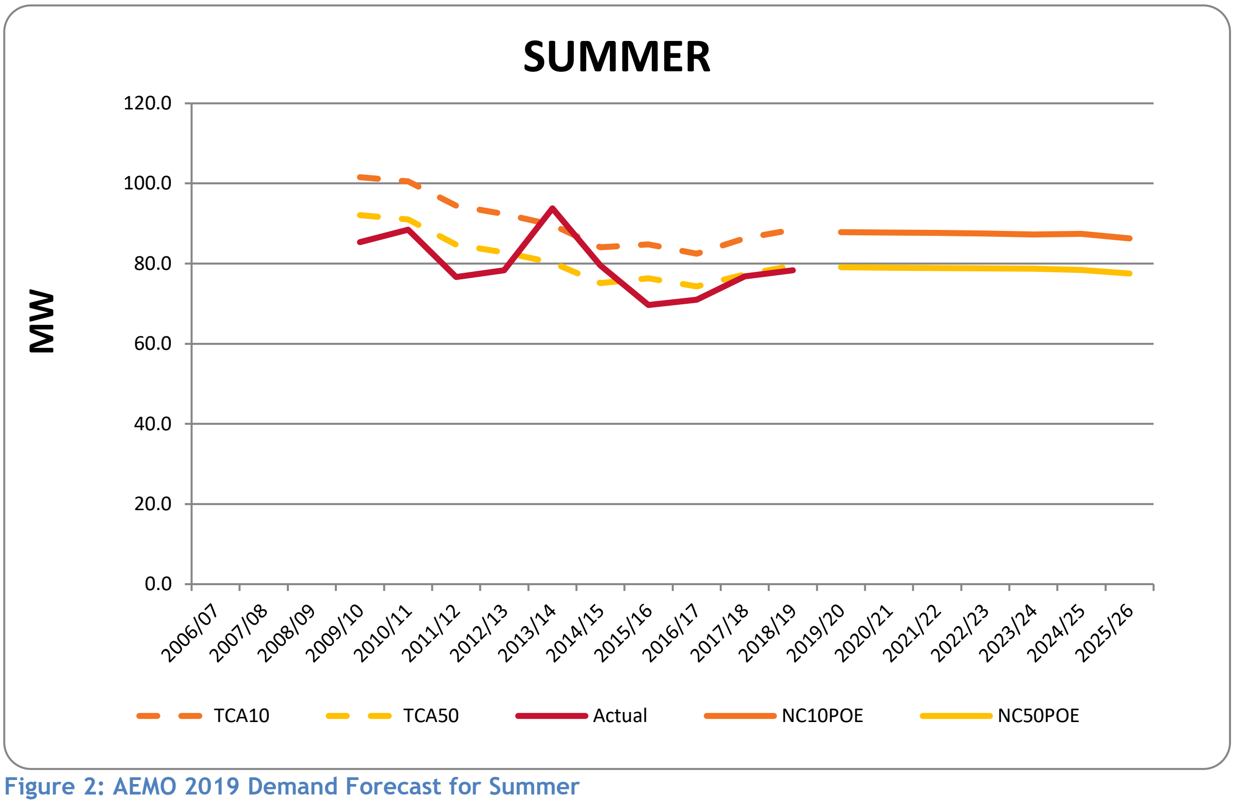

Figure 2: AEMO 2019 Demand Forecast for Summer

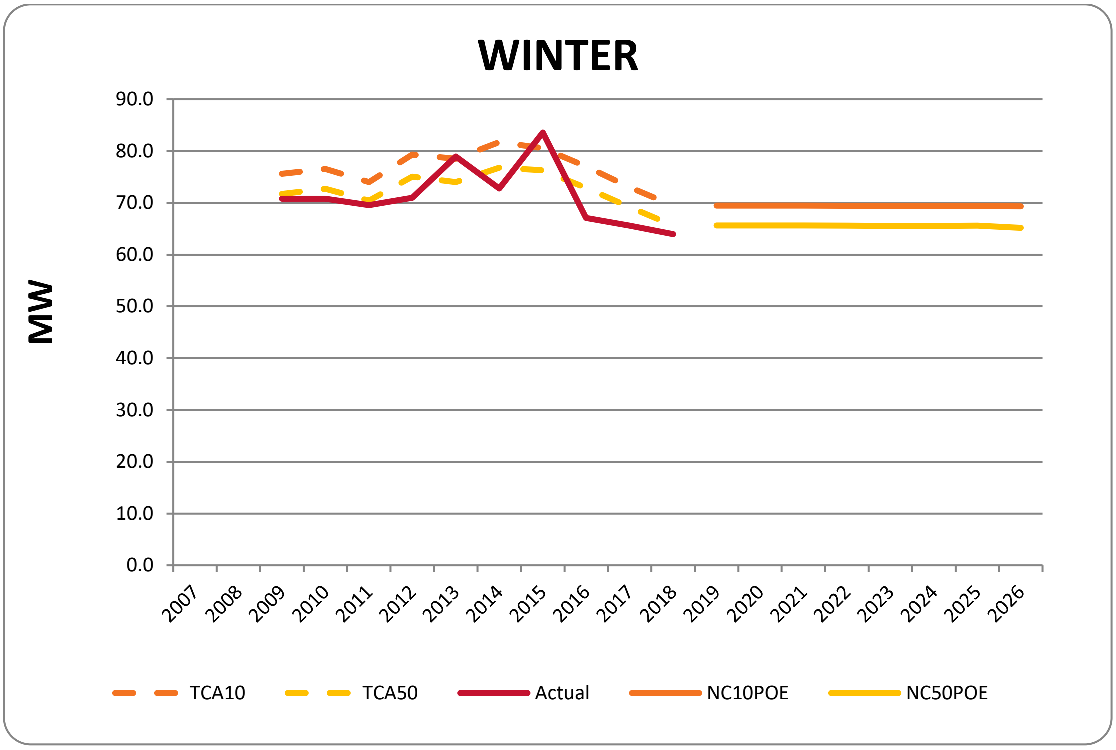

Figure 3: AEMO 2019 Demand forecast for Winter

There is no growing demand on HOTS as shown in Figure 2and Figure 3, it is generally a flat-line showing that the demand in the area is only slightly increasing but steadily remaining flat.

4.3. Future Planning Requirements

Any significant asset replacements at HOTS must consider the longer-term shared network and connection network development plans of other parties to ensure individual decisions will not compromise security of supply or impede economic future capacity augmentation.

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As noted in the section above there is no energy at risk forecast for the next ten years and there are therefore no future plans to augment the capacity of the station.

5. Asset Condition

AMS 10-19 Plant and Equipment Maintenance describes AusNet Services' strategy and approach to monitoring the condition of assets as summarised in this section. Asset condition is measured with reference to an asset health index, on a scale of C1 to C5. The C1 to C5 condition range is consistent across asset types and relates to the remaining service potential. The table below provides a simple explanation of the asset condition scores.

Condition Score	Likert Scale	Condition Description	Recommended Action	Remaining Service Potential%
C1	Very Good	Initial Service Condition	No additional specific actions required, continue routine maintenance and condition monitoring	95
C2	Good	Better than normal for age or refurbished		70
C3	Average	Normal condition for age		45
C4	Poor	Advanced Deterioration	Remedial action/replacement within 2-10 years	25
C5	Very Poor	Extreme deterioration approaching end of life	Remedial action/replacement within 1-5 years	15

Table 1 - Condition Score and Remaining Service Potential

Asset condition is the main driver for this project. The condition, installation year and age of the selected 66kV circuit breakers at HOTS are shown in Table 2 below.

Equipment ID	Model	Condition Score	Installation Year	Age	Technology
30138695	LG4C/66G (1200A)	5	1970	50	Bulk oil
30419314	LG4C/66G (1200A)	5	1969	51	Bulk oil
30002098	LG4C/66G (1200A)	5	1970	50	Bulk oil
30013261	LG4C/66G (800A)	5	1980	40	Bulk oil
30207712	LG4C/66G (800A)	5	1966	54	Bulk oil

Table 2 - Asset Information

6. Emerging constraints

The key service constraints and monetised risk identified for the aging and deteriorated assets at HOTS are described in this section.

6.1. Safety and Environmental Hazards

6.1.1. Circuit Breakers

As described in AMS 10-54 - Circuit Breakers, there is asbestos containing material found in older bulk oil circuit breakers such as 66kV AEI LG4C circuit breakers in arc chutes, covers and panels used in control cubicles. Asbestos material has the potential to cause harm to the safety and health of people and the environment. Certain control measures have to be adopted when it is required to modify or removing asbestos as per HSP-05-05-1 guideline. The are several circuit breakers in HOTS that have asbestos materials contained within them.

6.2. Safety, Plant Collateral Damage and Environmental Risk Cost

The Electricity Safety Act requires AusNet Services to design, construct, operate, maintain, and decommission its supply network to minimize hazards and risks, so far as is practicable, to the safety of any person arising from the supply network.
In practice this means safety risk should be proactively managed until the cost becomes disproportionate to the benefits. With respect to the management of safety risks that may cause a single fatality amongst a crew of workers; application of the principle of "as low as reasonably practicable" indicates costs in excess of $20 Million may be disproportionate. The following assumptions were used to calculate the monetised safety, plant collateral damage and environmental hazards presented by the plant described in Section 7.1; consistent with the methodology described in AMS 10-24 Victorian Electricity Transmission Network – Asset Renewal Planning Guideline:

- An explosive failure or oil fire could injure or kill workers on site with an economic consequence cost of $20 Million;
- Plant that contains large volumes of oil poses an environmental risk with an average consequence cost of $30k per event;
- Transformer with oil that contains poly-chlorinated biphenyls (PCB) poses an environmental risk with an average consequence cost of $100k per event;
- Plant collateral damage, including consequent supply outages, is on average $1.0 Million per event.

The likelihood of the above hazards occurring at HOTS have been calculated from the major failure rates in the circuit breaker reliability centred maintenance (RCM) models and the CIGRE research into the probability of explosion and fire associated with major plant failures[4].

[4] Cigre Final Report of the 2004 – 2007 International Enquiry on Reliability of High Voltage Equipment.

7. Options to Address Risks

The following options have been assessed to address the increasing community risk at HOTS:

- Business as usual. This option is included in the option analysis to define the baseline risk and to quantify the potential benefits of options that address the baseline risk
- Run to failure and replace assets upon failure
- Staged replacement of assets

Refurbishment option was not considered as there is asbestos containing material in the circuit breakers and they would need to be replaced safely, to get rid of asbestos material.

8. Evaluation of Options

An economic cost-benefit assessment is used to assess and rank the economic efficiency of the network options listed in Section 8. The option analysis considers key aspects like operating cost versus capital cost trade-offs, security of supply risk during the construction phase of the project, economic merits of a staged replacement and the future augmentation plans for HOTS.

A "Business as usual" option (Option 1) has been included in the option analysis to presents the baseline risk. It illustrates whether deferment of asset replacement presents an economical option or whether the risk has reached a level that needs to be addressed during the 2022 to 2027 regulatory period. Option 2 is a reactive asset replacement option. Options 3 involve proactive replacement of deteriorated and failure prone equipment based on the assessed risk of an asset failure.

The economic analysis allows comparison of the economic cost and benefits of each option to rank the options and to determine the economic timing of the preferred option. It quantifies the capital, operation and maintenance, and risk cost for each option. The risk cost includes safety, security of supply, environmental and collateral damage risks at HOTS. The robustness of the economic evaluation is tested for three discount rates, a sensitivity analysis of the forecast plant failure rates, different demand growth scenarios and different VCR rates.

Each of the identified options for HOTS is evaluated based on the incremental benefits it delivers in the following areas:

- Reduction in health and safety risk due to plant explosive failures;
- Reduction in supply risk due to unplanned outages;
- Reduction in environmental risk due to insulating oil spillage;
- Reduction in collateral plant damage risk due to explosive plant failures;
- Reduction in operation and maintenance cost, including network losses.

8.1. Option 1: Business as Usual

The baseline risk at HOTS, defines the economic cost for the "Business as Usual" option for the period until 2026/27. The Present Value of the risk cost, assuming a flat risk profile after 2026/27, is more than $4.5 M[5]. This suggests that a business as usual approach would not be an economical option or a prudent management strategy for the assets at HOTS.

The progressive reduction in reliability of supply and increase in safety risk are inconsistent with AusNet Services' obligations under the National Electricity Rules. Recurring asset failures are furthermore inconsistent with the requirements of the Electricity Safety Act and AusNet Services' accepted Electricity Safety Management Scheme.

This option is used in the economic evaluation as a reference to measure the economic benefits of options that mitigate the identified risks at HOTS and to ascertain the economical time[6] for a particular option to proceed.

5 This is a conservative assumption as the risk cost is more likely to increase as a result of deteriorating plant condition and consequent failure rates, and demand growth.
6 "Do Nothing" is the default option until the year when the annual benefits (reduction in risk cost and operating cost) of the most economical option exceed the annual cost.

8.2. Option 2: Run to fail

This option involves replacing assets upon failure, which poses a significant risk to the community. The community costs that would result from applying an asset management strategy to only replace an asset after the asset has failed is as follows:

- $8.9 M for a circuit breaker failure.

Some of the plant (CB porcelain bushings) at HOTS also presents a safety risk should they fail explosively. This risk cannot be managed with a "run to failure" strategy as it would involve workers replacing failed equipment in a switchyard containing other equipment known to be in a deteriorated condition with a potentially hazardous mode of failure. This type of safety risk is valued at $20 M as a person/s could be injured or killed following an explosive failure. This is assumed based on information gathered from legal.

Unplanned replacement of assets after a failure occurred is furthermore an inefficient asset replacement strategy for terminal stations due to the significant higher cost (project mobilisation and demobilisation) of emergency replacements. Recurring unplanned outages associated with a series of asset failures is inconsistent with the requirements of the Electricity Safety Act, AusNet Services' accepted Electricity Safety Management Scheme[7] and the National Electricity Rules[8]. This option is hence only used for modelling purposes.

8.3. Option 3: Stage replacement of assets

This option includes replacing the five 66kV circuit breakers. Whilst being careful to remove the circuit breakers due to the potential of asbestos containing materials within the circuit breakers. This will allow the new 66KV circuit breakers to replace the very poor condition old circuit breakers.

8.4. Present Value Analysis

The present value cost (taking into account the total project capital cost, supply risk cost, operation and maintenance cost, safety risk cost, environment cost and plant collateral damage risk costs) is calculated for all credible options and is summarised in Table 3. This allows for the options to be ranked based on their economic merits. A real discount rate of 2% is used for the base case.

Options Title	Assessment of Options	Capital Cost[9]	PV Cost (2% DCR)[10]
1. Business as usual	The baseline risk rises quickly, suggesting that a "Business as usual" approach is not sustainable.		$3.7 M
2. Run to failure	This option is inconsistent with AusNet Services' accepted ESMS, the Electricity Safety Act and AusNet Services' obligations under the NER.		

[7] Electricity Safety Management Scheme, 2019
[8] National Electricity Rules, 2019
9 Total project cost expressed in real 2020 dollars and includes project overheads and finance charges.
10 Present value cost expressed in real 2020 dollars at a 4.68% discount rate.

Options Title	Assessment of Options	Capital Cost[9]	PV Cost (2% DCR)[10]
3. Replacement of circuit breakers	Address most of the identified risks at the lowest cost. Enables replacement of circuit breakers	$1.6 M	$1.8 M

Table 3 - Economic Assessment of Options - Base case assumptions

8.5. Economic Option and Economic Timing

The replacement option (Option 3) is the most economic option to address the plant failure risks at HOTS as it has the lowest PV cost for all the scenarios shown in Table 4.

The PV for Option 3 is also calculated for a series of different years to determine the economical timing for it to proceed, consistent with the RIT-T guidelines. This assessment concludes that the project is already economic by Summer 2024/25 where after the PV cost rise significantly.

8.6. Sensitivity Studies

A sensitivity study[11] for higher (x 1.25) and lower (x 0.75) failure rates shows the economic timing of the circuit breaker replacement project at HOTS may be as early as 2022/23 or as late as 2024/25. Due consideration of this sensitivity is important to avoid assets failure during the construction phase of the planned replacement project given the significant worker safety and community consequence.

The robustness of the economic assessment is tested for different discount rates[12], DCR rates (low case at -2.0% off base case and high case at +2.0% off base case), asset failure rates (low case at 1.25 x base case failure rate and high case at 0.75 x base case failure rate) and replacement costs (low case 1.25 x base case and high case at 0.75 x base case) as shown in Table 4 below. This discount rate of 2% is assumed to be real therefore the range is low case at 2.68% and high case at 6.68%.

11 The intersection of the annualized project cost plot and the incremental project benefits plot shows the project timing that delivers the optimum economic outcome.

12 AER Regulatory Investment Test for Transmission. The present value calculations must use a commercial discount rate appropriate for the analysis of a private enterprise investment in the electricity sector. The discount rate used must be consistent with the cash flows being discounted. The lower boundary should be the regulated cost of capital, which is estimated at 6% (real and pre-tax).

Options	CAPEX	Risk Cost	Present Value	PV Cost Ratio
Option 1: Business as Usual	-	$7.3 M	$3.7 M	-
Option 3: Replacement	$1.6 M	$108.5 k	$1.8 M	2.09

Options	DCR		Failure Rate		Replacement cost	
	-2% off base rate	+2% off base rate	1.25 x base rate	0.75 x base rate	1.25 x base rate	0.75 x base rate
Option 1: Business as Usual	$4.9 M	$2.9 M	$4.6	$2.8 M	$3.7 M	$3.7 M
Option 3: Replacement	$1.8 M	$1.8 M	$1.8 M	$1.75 M	$2.2 M	$1.4 M

Table 4 - Economic Assessment of Options - Sensitivity Study

9. Scope of Work

The high-level scope of work for the preferred solution (Option 3) includes:

- Replace the five 66kV circuit breakers
- Secondary replacement

Appendix A - Asset condition framework

AusNet Services uses an asset health index, on a scale of C1 to C5, to describe asset condition. The condition range is consistent across asset types and relates to the remaining service potential. The table below provides an explanation of the asset condition scores used.

Table 5 - Condition scores framework

Condition score	Likert scale	Condition description	Recommended action	Remaining service potential (%)
C1	Very Good	Initial service condition	No additional specific actions required, continue routine maintenance and condition monitoring	95
C2	Good	Better than normal for age		70
C3	Average	Normal condition for age		45
C4	Poor	Advanced deterioration	Remedial action or replacement within 2-10 years	25
C5	Very Poor	Extreme deterioration and approaching end of life	Remedial action or replacement within 1-5 years	15

Asset failure rates

AusNet Services uses the hazard function of a Weibull two-parameter distribution to estimate the probability of failure of an asset in a given year. The asset condition scores are used to establish a condition-based age which is used to calculate the asset failure rates using a two-parameter Weibull Hazard function (h(t)), as presented below.

$$h(t) = \beta.\frac{t^{\beta-1}}{\eta^{\beta}}$$

Equation 1: Weibull Hazard Function

where:

t = Condition-based age (in years)

η = Characteristic life (Eta)

β = Shape Parameter (Beta)

Hazard functions are defined for the major asset classes including power transformers, circuit breakers, and instrument transformers. All assets in the substation risk-cost model use a Beta (β) value of 3.5 to calculate the failure rates. The characteristic life represents that average asset age at which 63% of the asset class population is expected to have failed.

The condition-based age (t) depends on the specific asset's condition and characteristic life (η).