Voltage Control in North West Victoria

Project Assessment Draft Report

Regulatory Investment Test - Transmission

April 2021

Important notice

Purpose

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

Disclaimer

This document may or may not contain all available information on the subject matter this document purports to address. The information contained in this document is subject to review and may be amended any time.

To the maximum extent permitted by law, AusNet Services makes no representation or warranty (express or implied) as to the accuracy, reliability, or completeness of the information contained in this document, or its suitability for any intended purpose. AusNet Services (which, for the purposes of this disclaimer, includes all of its related bodies corporate, its officers, employees, contractors, agents and consultants, and those of its related bodies corporate) shall have no liability for any loss or damage (be it direct or indirect, including liability by reason of negligence or negligent misstatement) for any statements, opinions, information or matter (expressed or implied) arising out of, contained in, or derived from, or for any omissions from, the information in this document.

Executive summary

AusNet Services is undertaking this Regulatory Investment Test for Transmission (RIT-T) to evaluate options to provide ongoing voltage control services in North West Victoria.

The Static Var Compensator (SVC) at Horsham Terminal Station (HOTS) is owned and operated by AusNet Services. It was commissioned in 1986 to provide dynamic voltage and reactive power control services in North West Victoria. The SVC is reaching the end of serviceable-life which is driving the timing of this investigation.

The Project Specification Consultation Report (PSCR), which represents the first step in the RIT-T process in accordance with relevant clauses in 5.16 of the *National Electricity Rules (NER) version151*[1] and section 4.2 of the *RIT-T Application Guidelines*[2] was published in June 2020. This report, the Project Assessment Draft Report (PADR), is the second stage of the RIT-T and provides information about the draft conclusions of the RIT-T.

Identified need

The SVC at HOTS has been providing dynamic voltage and reactive power control services for an extended period (35 years) and is reaching the end of its serviceable-life. A failure of the SVC would mean that AusNet Services is unable to meet its obligation to provide voltage and reactive control capability services as outlined in the Network Agreement between AEMO and AusNet Services. Further, it would reduce the ability to maintain voltages in North West Victoria within the limits specified under clauses S5.1a.4 and S5.1a.5 of the NER (see extract in section 2.4.1) and clauses 110.2.2(a) and 110.2.3(a)[3] of the Victorian Electricity System Code. Consequently, a failed SVC would require emergency asset replacement to be undertaken as there are significant impacts to the power system and the wholesale electricity market.

Therefore, the 'identified need' this RIT-T intends to address is to: continue to provide voltage and reactive power control capability services at HOTS such that voltages in the North West transmission network can be maintained within the limits specified in the NER and Victorian Electricity System Code; and mitigate risk of increased costs associated with emergency asset replacement.

AusNet Services classifies the identified need as '*reliability corrective action'*[4] to ensure continued compliance with appropriate clauses in the NER and Victorian Electricity System Code.

Credible options

AusNet Services identified a number of investments that may deliver more economical and reliable solutions to address the identified need, compared with the base case where the existing assets are kept in service and emergency asset replacements are implemented when the SVC fails. The credible network options considered in this RIT-T are:

[1] Australian Energy Market Commission, *"National Electricity Rule version151,"* available at https://www.aemc.gov.au/regulation/energy-rules/national-electricity-rules/current viewed on 27 October 2020.
[2] Australian Energy Regulator, *"Application guidelines Regulatory investment test for transmission,"* available at https://www.aer.gov.au/system/files/AER%20-%20Final%20RIT-T%20application%20guidelines%20-%2014%20December%202018_0.pdf, , viewed on 24 February 2021.
[3] "A transmitter must use best endeavours to maintain the normal voltage level at each point of supply with a nominal voltage at or above 100 kV within a range of plus or minus 10% of the voltage level nominated by VENCorp from time to time to the relevant transmitter and the relevant Participants which are supplied at that point of supply." Office of the Regulator-General, Victoria, '*Electricity System Code,*' available at https://www.esc.vic.gov.au/sites/default/files/documents/3d1fc9fd-18e0-4e10-a87a-e68ba2151a1a.pdf, viewed on 24 February 2021.
[4] 'NER 5.10.2 defines reliability corrective action as a network business' investment in its network to meet 'the service standards linked to the technical requirements of schedule 5.1 or in applicable regulatory instruments and which may consist of network options or non-network options'.' - Australian Energy Regulator, *"Application guidelines Regulatory investment test for transmission,"* available at https://www.aer.gov.au/system/files/AER%20-%20Final%20RIT-T%20application%20guidelines%20-%2014%20December%202018_0.pdf, viewed on 24 February 2021.

- Option 1 – Replacement of the existing SVC with a modern equivalent SVC; and
- Option 2 – Replacement of the existing SVC with a synchronous condenser.

Since the PSCR, there have been updates to the capital cost assumptions for these options. The cost for Option 1 has decreased to $23.98 million, while for Option 2, the current estimate is $24.79 million.

Responses to the Project Specification Consultation Report

AusNet Services received three proposals from proponents of non-network options in response to the PSCR for this RIT-T. However, due to the confidential nature of their submissions, AusNet Services is not publishing any part of their proposals.

Assessment approach

AusNet Services employed a two-step approach to evaluate the credible options: a power system analysis which was used to evaluate the options' impact on the ability to comply with regulatory obligations, on the operation of the power system, and on the limitations imposed on the system; and economic modelling which estimates the risk costs from the potential impacts on the wholesale electricity market, safety, environment, emergency replacement and other components.

The net economic benefits and the optimal timing of the options were assessed against a business-as-usual case where no proactive capital investment is made, and the existing maintenance regime continues to be implemented.

The analysis was implemented under three scenarios to explore the range of net economic benefits of the options. Sensitivity analysis that involves variations of assumptions on the failure rates, financial risk costs, capital costs, and discount rate was also implemented to confirm the robustness of the preferred option.

Options assessment and draft conclusion

AusNet Services has assessed that all options and non-network proposals are technically feasible in providing the voltage management services needed to comply with the limits specified under clauses S5.1a.4 and S5.1a.5 of the NER and clauses 110.2.2(a) and 110.2.3(a)[5] of the Victorian Electricity System Code with varying degree of effectiveness.

However, from the cost-benefit assessment, AusNet Services confirms that replacement with a synchronous condenser (Option 2) is the most economic option as it provides the highest present value (PV) of net economic benefits in most scenarios and across all sensitivities investigated, as illustrated in Table 1 and Figure 1.

[5] "A transmitter must use best endeavours to maintain the normal voltage level at each point of supply with a nominal voltage at or above 100 kV within a range of plus or minus 10% of the voltage level nominated by VENCorp from time to time to the relevant transmitter and the relevant Participants which are supplied at that point of supply." Office of the Regulator-General, Victoria, '*Electricity System Code*,' available at https://www.esc.vic.gov.au/sites/default/files/documents/3d1fc9fd-18e0-4e10-a87a-e68ba2151a1a.pdf, viewed on 24 February 2021.

Table 1 - Estimated PV of net economic benefits from each option in real 2020/21 $ million

Option	Low-benefit scenario (25%)	Central (50%)	High-benefit scenario (25%)	Weighted value	Rank
Cheapest non-network option	-18.82	19.43	146.46	41.63	3
Option 1 SVC	-3.16	34.69	163.79	57.50	2
Option 2 SCO	-3.28	37.16	169.57	60.15	1

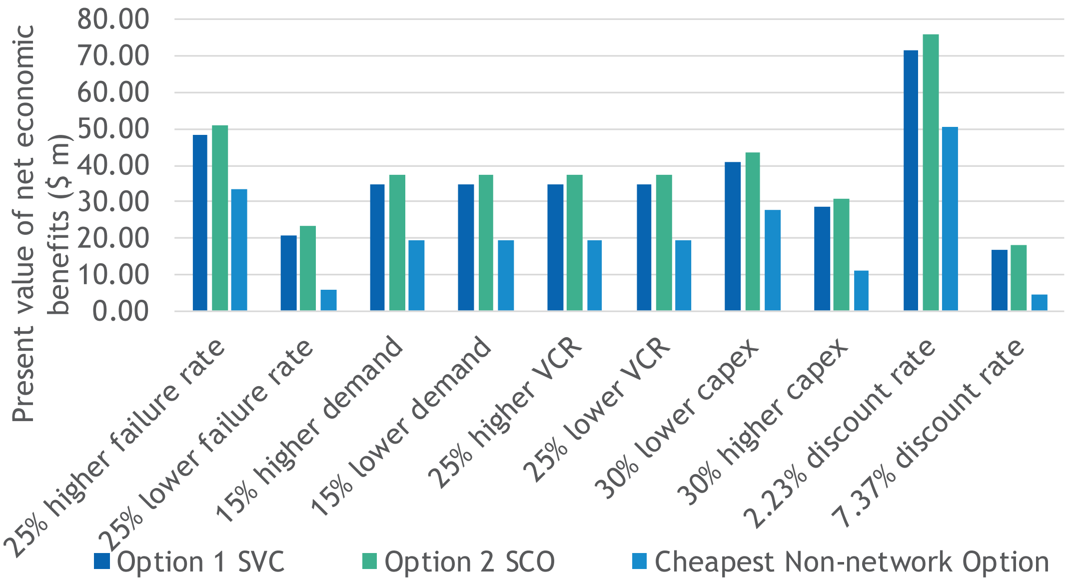

Figure 1 - Options sensitivity analysis

Additionally, based on the results of the sensitivity study shown in Figure 2 below, the optimal timing for Option 2 is 2021/22. However, allowing for regulatory and construction lead time, the earliest commissioning date is in 2023/24. Note that in figure below, size of bubble signifies larger number of sensitivities with similar net economic benefits.

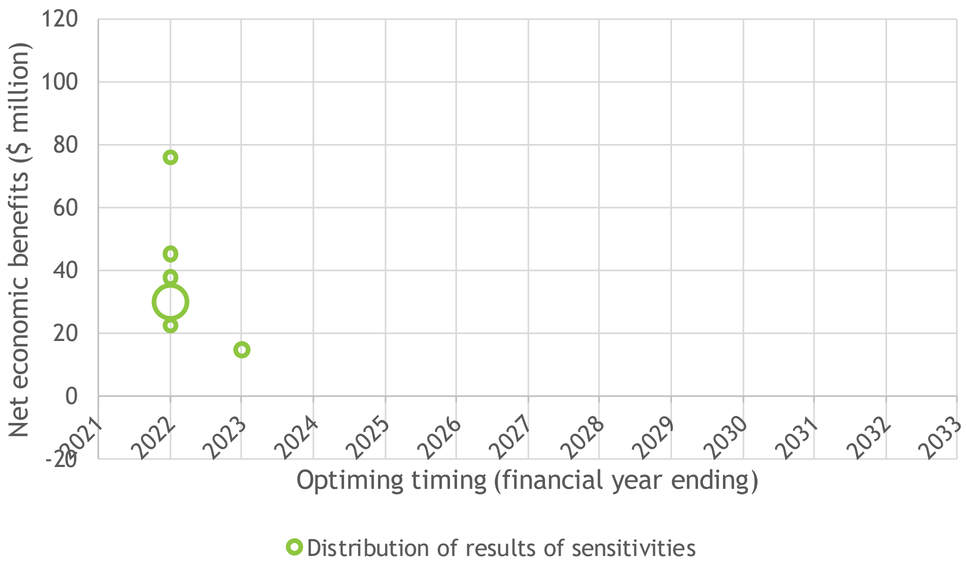

Figure 2 - Sensitivity of the optimal timing with respect to variation of key parameters

There is also significantly lower stranded risk cost for Option 2 SCO than any other options.

Therefore, AusNet Services determines that Option 2 is the preferred option.

Submissions

AusNet Services welcomes written submissions on the topics and draft conclusions presented in this PADR. Submissions should be emailed to rittconsultations@ausnetservices.com.au on or before 15 June 2021. In the subject field, please reference 'RIT-T PADR Horsham Terminal Station Static Var Compensator.'

Submissions will be published on AusNet Services' and AEMO's websites. If you do not wish for your submission to be made public, please clearly stipulate this at the time of lodgment.

Next steps

Assessments of the responses to this PADR will be presented in the Project Assessment Conclusions Report (PACR) which is intended to be published in July 2021.

Table of Contents

Figures

Tables

1. Introduction

AusNet Services initiated this Regulatory Investment Test for Transmission (RIT-T) to evaluate options for ongoing voltage control in North West Victoria. The Static Var Compensator (SVC) at Horsham Terminal Station (HOTS) is reaching the end of serviceable-life and that drives the timing of this investigation.

The Project Specification Consultation Report (PSCR) was published in June 2020 in accordance with clause 5.16 of the *National Electricity Rules (NER) version151*[6] and section 4.2 of the *RIT-T Application Guidelines*.[7] Publication of this Project Assessment Draft Report (PADR) represents the second step in the RIT-T process[8] and describes the following in accordance with the new versions of those regulatory documents:[9]

- identified need that AusNet Services is seeking to address, together with the assumptions used in identifying this need;
- reasons for classifying the identified need as *'reliability corrective action;'*
- updates on the credible network options that may address the identified need;
- discussions on the responses to the PSCR;
- assessment approach and scenarios AusNet Services used in this RIT-T assessment; and
- draft preferred option and conclusion.

The need for investment to address risks from deteriorating SVC is included in AusNet Services' revenue proposal for the current regulatory control period (2017 to 2022)[10]. This specific investment need is also identified in AusNet Services Asset Renewal Plan that was published as part of AEMO's 2020 Victorian Transmission Annual Planning Report (VAPR).[11]

---

[6] Australian Energy Market Commission, *"National Electricity Rule version151,"* available at https://www.aemc.gov.au/regulation/energy-rules/national-electricity-rules/current viewed on 27 October 2020.
[7] Australian Energy Regulator, *"Application guidelines Regulatory investment test for transmission,"* available at https://www.aer.gov.au/system/files/AER%20-%20Final%20RIT-T%20application%20guidelines%20-%2014%20December%202018_0.pdf, viewed on 24 February 2021.
[8] A RIT-T process will assess the economic efficiency and technical feasibility of proposed network and non-network options.
[9] Australian Energy Market Commission, *"National Electricity Rule version 157,"* available at https://www.aemc.gov.au/regulation/energy-rules/national-electricity-rules/current, viewed on 24 February 2021.
[10] Australian Energy Regulator, *"AusNet Services - Determination 2017-2022,"* p. 42, available at https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/ausnet-services-determination-2017%E2%80%932022/revised-proposal, viewed on 24 February 2021.
[11] Australian Energy Market Operator, *"Victorian Annual Planning Report,"* available at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/victorian-planning/victorian-annual-planning-report, viewed on 24 February 2021

2. Identified need

The SVC at HOTS plays an important role in the ongoing voltage control in the North West Victoria 220 kV transmission network. The condition of key assets and the quantification of the risk costs associated with their deterioration are discussed in this section.

2.1. Network configuration

North West Victoria transmission network

Horsham is in the Wimmera region of Victoria, situated approximately 300 km from Melbourne near the Grampians National Park. HOTS is located four kilometres east of Horsham.

HOTS is connected to a 220 kV single-circuit transmission loop which supplies terminal stations at Ballarat (BATS), Bendigo (BETS), Kerang (KGTS), Wemen (WETS) and Red Cliffs (RCTS) as shown in the figure below. The North West Victoria 220 kV transmission loop also provides connections to several generators including Waubra, Ararat, Crowlands, Murra Warra and Bulgana Wind Farms and Kiamal Solar Farm.

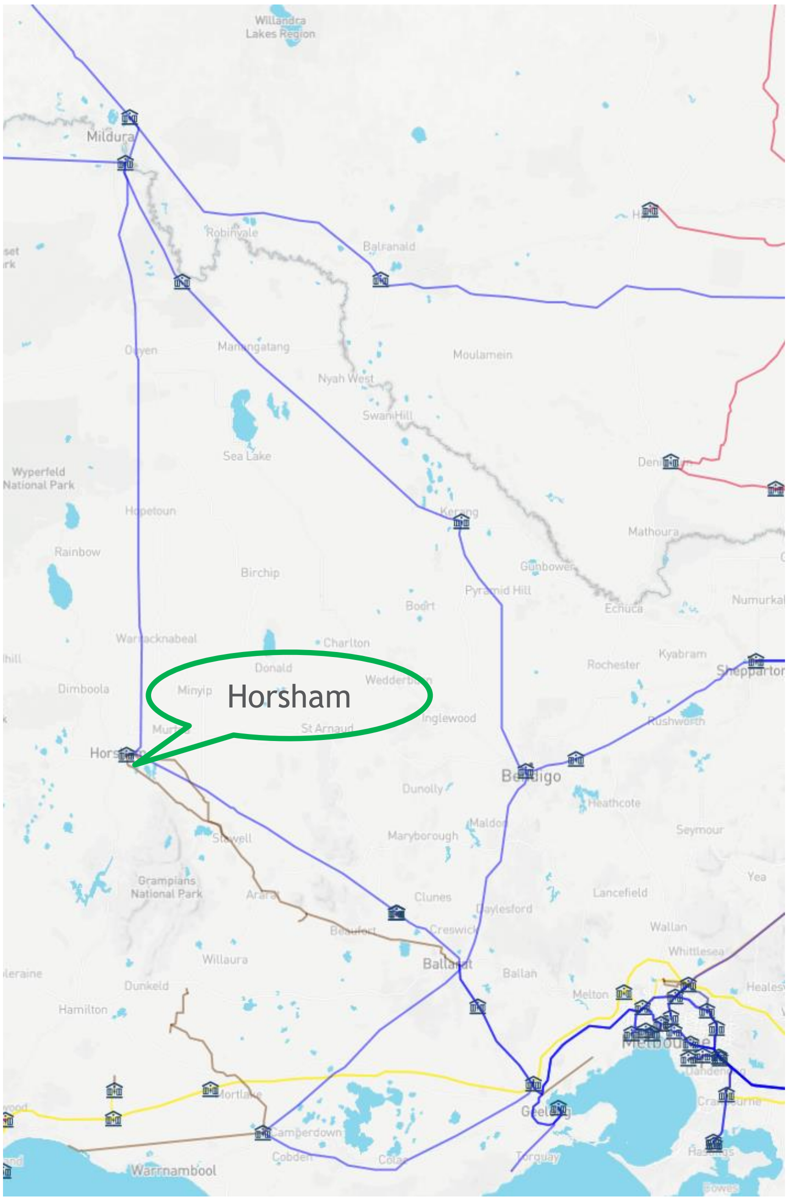

Figure 3 – North West Victoria transmission network

Horsham Terminal Station

HOTS supplies Powercor's 66 kV network via two 220/66 kV transformers. To manage the voltages, the reactive power control assets listed below and shown in figure below, are installed at HOTS:

- +50 MVar to -25 MVar 220 kV Static Var Compensator (SVC);
- Two 15 MVA 66 kV shunt reactors; and
- Three 15 MVA 66 kV shunt capacitors.

The shunt capacitors and reactors provide coarse and steady-state reactive support and the SVC provides dynamic voltage control at the 220 kV side of the terminal station. The switching of the shunt reactors and capacitors is managed so that there is always sufficient dynamic reactive reserve available to respond to network disturbances and contingency events, especially when the output of the SVC is near its limitations.

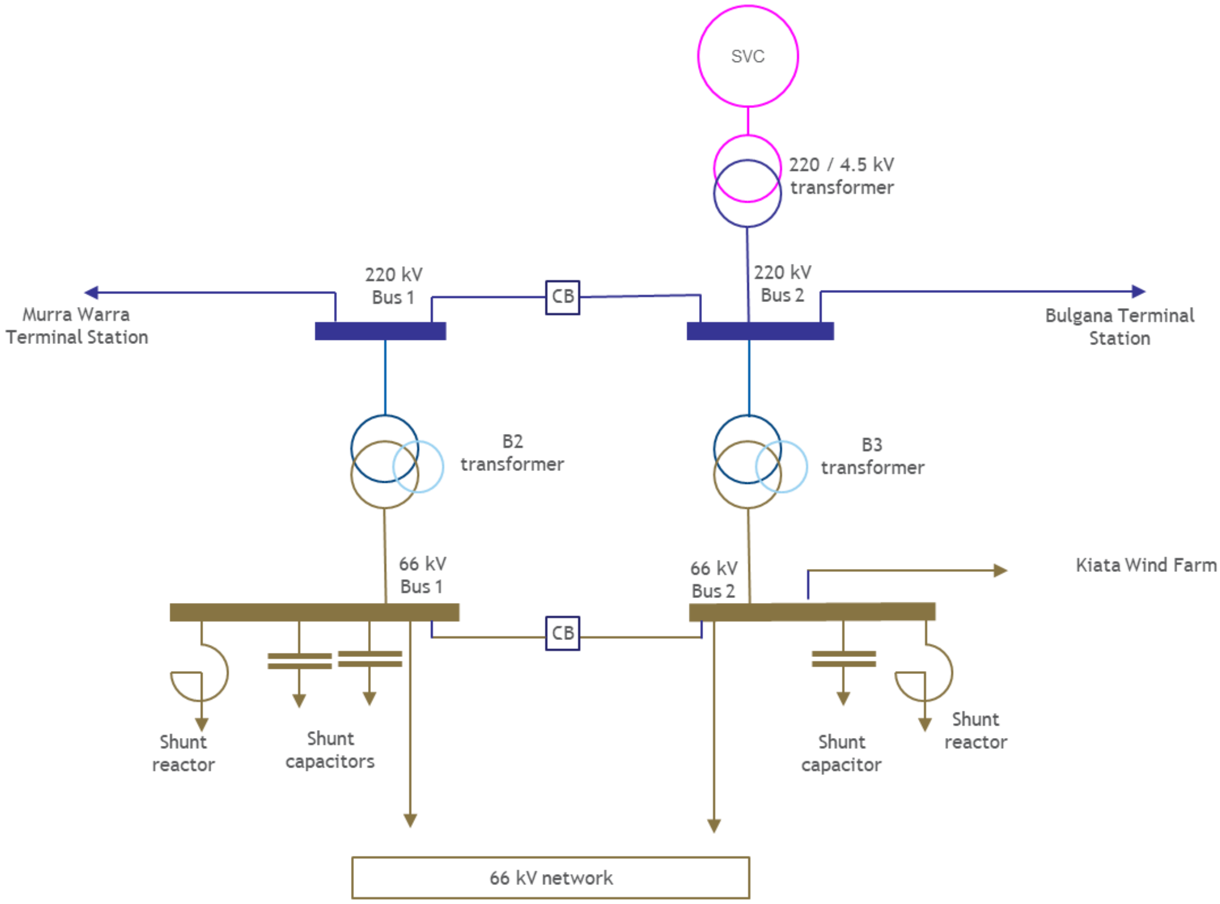

Figure 4 – HOTS single line diagram

2.2. HOTS SVC historical performance

The SVC and other reactive plants at HOTS have been instrumental in controlling voltages to support demand in North West Victoria.

Figure below shows the actual reactive power generation and consumption of the SVC during calendar year 2020. The reactive power generation and absorption ranges from +23.4 MVar to -23.8 MVar during this period.

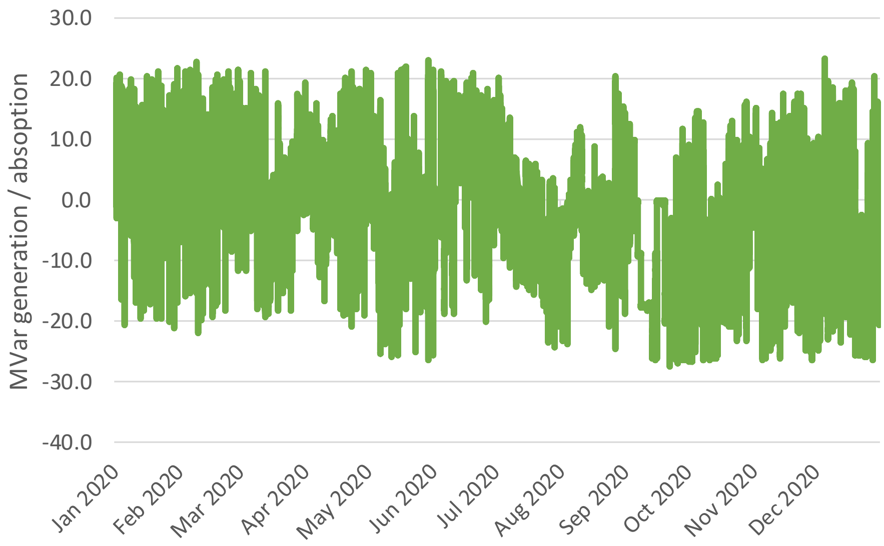

Figure 5 - Typical annual reactive power performance of SVC at HOTS

The 2020 Victorian Annual Planning Report (VAPR)[12], prepared by AEMO, assesses the network need for assets across the Victorian transmission system. AEMO reviews the network need for replacement of assets included in AusNet Services' Asset Renewal Plan and publishes the plan as an attachment to the VAPR. In relation to the SVC, AEMO notes that if this asset were to be retired without replacement or network augmentation, voltage could not be maintained within limits, and there would be reduced Murraylink export during outage of Western Victoria 220 kV lines.[13]

2.3. Asset condition

In 2019, there have been two unplanned outages of the SVC with durations of 55 and 21 hours respectively. The number of forced outages is expected to rise as the SVC components continue to deteriorate with age and continued service.

AusNet Services classifies asset condition using scores that range from C1 (initial service condition) to C5 (extreme deterioration) – as set out in Appendix C of the PSCR.[14]

In September 2019, AusNet Services conducted a full asset condition assessment of the SVC where all major components were evaluated across a range of criteria including: physical condition; spares availability; estimated rate of deterioration; and manufacturer support.

The assessment found that the SVC has deteriorated and most of the core components are in poor condition (C4) or in a state of extreme deterioration (C5) as expected of assets that have been in service for an extended period. Furthermore, with manufacturer support no longer available and the scarcity of spare parts, the SVC is reaching the end of its serviceable life. With an overall weighted condition score of 4.28 out of 5, the SVC is not expected to remain in service longer than five years under the existing maintenance regime. No alternative maintenance strategies have been identified that would significantly reduce the failure rates or address the lack of manufacturer support.

[12] Australian Energy Market Operator, *"Victorian Annual Planning Report,"* available at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/victorian-planning/victorian-annual-planning-report, viewed on 24 February 2021

[13] Australian Energy Market Operator, *"Victorian Annual Planning Report,"* p82, available at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/victorian-planning/victorian-annual-planning-report, viewed on 24 February 2021

[14] AusNet Services, *"Voltage Control in North West Victoria Project Specification Consultation Report Regulatory Investment Test - Transmission,"* available at https://ausnetservices.com.au/About/Projects-and-Innovation/Regulatory-Investment-Test, viewed on 24 February 2021

For the affected components, the probabilities of failure are high, and likely to increase further if no remedial action is taken. Appendix D of the PSCR[15] provides a summary of the condition of key components.

The overall condition score for the SVC and associated plant is presented in Table 1 of the PSCR[16] and is a weighted average of the condition scores for the various components. The weighting factor for each component is derived based on the following four characteristics:

- Availability - the effect on the operation of the SVC for any component failure
- Reliability - based on the number of unplanned work orders associated with those components
- Maintainability - based on the duration of an outage to reinstate the SVC when that component fails
- Relative cost - based on the cost of the smallest element in that component.

2.4. Description of the identified need

The dynamic voltage and reactive control service is an ongoing need as operational demand for electricity at North West Victoria is forecast to continue at or above the current level, and renewable generation continues to grow.

The deteriorating condition of the components of the SVC has increased the likelihood of asset failure and prolonged SVC outages resulting in:

- lack of dynamic reactive support services to respond to network disturbances and contingency events;
- voltages at HOTS and surrounding area being non-compliant with requirements outlined in the NER and Victorian Electricity System Code; and
- risk of increased costs resulting from emergency asset replacements and repairs.

Additionally, since the publication of the PSCR, larger potential impact on the power system and the wholesale market have been analysed and could be expected if the SVC were to fail. This is discussed in detail in Chapter 6.

Therefore, the 'identified need' this RIT-T intends to address is to maintain capability to control voltages and mitigate risk of increased costs resulting from an emergency asset replacement.

AusNet Services classifies the identified need as '*reliability corrective action*'[17] to allow continued compliance with clauses S5.1a.4 and S5.1a.5 of the NER and clauses 110.2.2(a) and 110.2.3(a)[18] of the Victorian Electricity System Code.

---

[15] AusNet Services, *"Voltage Control in North West Victoria Project Specification Consultation Report Regulatory Investment Test - Transmission,"* available at https://ausnetservices.com.au/About/Projects-and-Innovation/Regulatory-Investment-Test, viewed on 24 February 2021

[16] AusNet Services, *"Voltage Control in North West Victoria Project Specification Consultation Report Regulatory Investment Test - Transmission,"* available at https://ausnetservices.com.au/About/Projects-and-Innovation/Regulatory-Investment-Test, viewed on 24 February 2021

[17] 'NER 5.10.2 defines reliability corrective action as a network business' investment in its network to meet 'the service standards linked to the technical requirements of schedule 5.1 or in applicable regulatory instruments and which may consist of network options or non-network options'.' - Australian Energy Regulator, *"Application guidelines Regulatory investment test for transmission,"* available at https://www.aer.gov.au/system/files/AER%20-%20Final%20RIT-T%20application%20guidelines%20-%2014%20December%202018_0.pdf, viewed on 24 February 2021.

[18] "A transmitter must use best endeavours to maintain the normal voltage level at each point of supply with a nominal voltage at or above 100 kV within a range of plus or minus 10% of the voltage level nominated by VENCorp from time to time to the relevant transmitter and the relevant Participants which are supplied at that point of supply." Office of the Regulator-General, Victoria, '*Electricity System Code*,' available at https://www.esc.vic.gov.au/sites/default/files/documents/3d1fc9fd-18e0-4e10-a87a-e68ba2151a1a.pdf, viewed on 24 February 2021.

2.4.1. Assumptions

AusNet Services has adopted several assumptions to quantify the risks associated with asset failure. These assumptions are detailed in the following subsections.

Voltage level requirements

Schedule 5.1a of the *National Electricity Rules version 157*[19] (NER) establishes system standards for the safe and reliable operation of the network including limits on changes in voltage levels at connection points during different network conditions. S5.1a.4 is reproduced below. This requirement is also reflected in Clause 110.2.2(a)[20] of the Victorian Electricity System Code, which requires the same standard for voltage for levels at or above 100 kV.

S5.1a.4 Power frequency voltage

Except as a consequence of a contingency event, the voltage of supply at a connection point should not vary by more than 10 percent above or below its normal voltage, provided that the reactive power flow and the power factor at the connection point is within the corresponding limits set out in the connection agreement. As a consequence of a credible contingency event, the voltage of supply at a connection point should not rise above its normal voltage by more than a given percentage of normal voltage for longer than the corresponding period shown in Figure S5.1a.1 for that percentage. As a consequence of a contingency event, the voltage of supply at a connection point could fall to zero for any period.

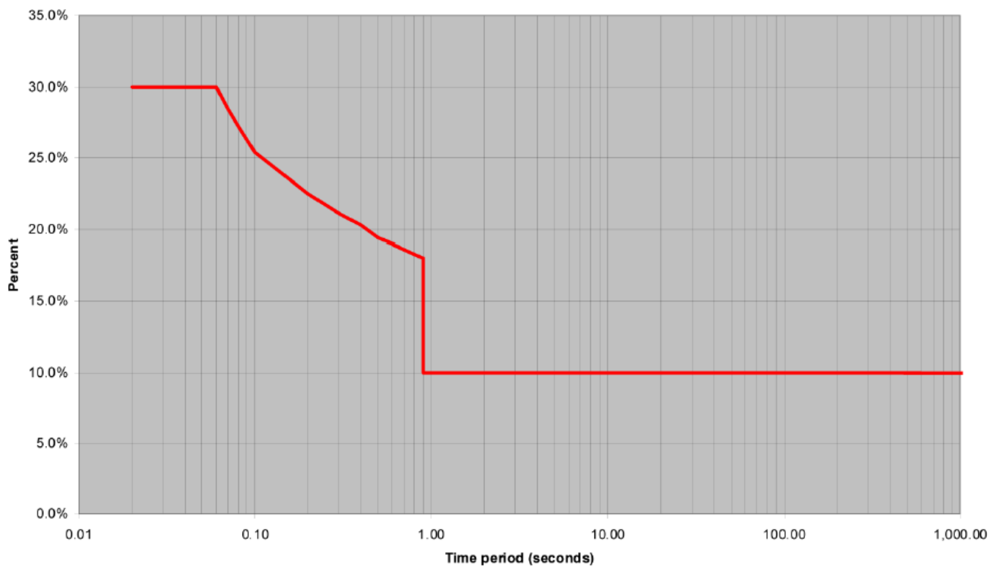

Figure 6 - Figure S5.1a.1 of NER

Failure rate and repair time

Condition assessment suggests that as the asset ages and deteriorates, the probability of failure and the time required to repair the asset and return to service will increase.

The SVC is a system that consists of several components including capacitors, reactors, thyristors, and secondary systems, that are operated together to dynamically generate or absorb reactive power. In

[19] Australian Energy Market Commission, *"National Electricity Rule version 157,"* available at https://www.aemc.gov.au/regulation/energy-rules/national-electricity-rules/current, viewed on 24 February 2021.

[20] "A transmitter must use best endeavours to maintain the normal voltage level at each point of supply with a nominal voltage at or above 100 kV within a range of plus or minus 10% of the voltage level nominated by VENCorp from time to time to the relevant transmitter and the relevant Participants which are supplied at that point of supply." Office of the Regulator-General, Victoria, '*Electricity System Code*,' available at https://www.esc.vic.gov.au/sites/default/files/documents/3d1fc9fd-18e0-4e10-a87a-e68ba2151a1a.pdf, viewed on 24 February 2021.

an integrated system of this type, failure of one or more individual components will reduce or remove the capability of the system to provide the required service.

The Victorian transmission network contains only a few SVCs, hence, establishing an SVC-specific failure rate forecast that is statistically robust is not possible. Using the failure rates from the transformer asset class with C3 condition as a proxy for this RIT-T is a conservative estimate as the rest of the SVC components are in C4 and C5 conditions. Appendix D of the PSCR[21] provides a summary of the condition of key components.

AusNet Services will finalise this assumption on the next stage of this is RIT-T, which is the publication of the Project Assessment Conclusions Report.

Financial risk costs

As there is an ongoing need for the services provided by the SVC, an emergency asset replacement would be required to continue the service should the asset fail. It would require immediate diagnosis, sourcing of spares, if available, from other sites, and mobilisation of staff on short notice, hence would involve higher costs than a planned replacement.

The failure rate-weighted emergency asset replacement cost (or undertaking reactive maintenance) has been estimated and is included in the assessment.[22]

Safety risk costs

The Electricity Safety Act 1998[23] requires AusNet Services to design, construct, operate, maintain, and decommission its network to minimize hazards and risks to the safety of any person as far as reasonably practicable or until the costs become disproportionate to the benefits from managing those risks.

The transformer and transformer bushings associated with the SVC contains oil that is subject to explosive failure risk. AusNet Services uses the following factors to assess safety risks from explosive failure:

- a value of statistical life[24] to estimate the benefits of reducing the risk of death;
- a value of lost time injury[25]; and
- a disproportionality factor[26].

AusNet Services notes that this approach, including the use of a disproportionality factor, is consistent with the RIT-T Practice Notes[27] provided by the AER.

[21] AusNet Services, *"Voltage Control in North West Victoria Project Specification Consultation Report Regulatory Investment Test - Transmission,"* available at https://ausnetservices.com.au/About/Projects-and-Innovation/Regulatory-Investment-Test, viewed on 24 February 2021

[22] The assets are assumed to have survived and their condition-based age increases throughout the analysis period.

[23] Victorian State Government, Victorian Legislation and Parliamentary Documents, "Energy Safe Act 1998," available at http://www.legislation.vic.gov.au/domino/Web_Notes/LDMS/LTObject_Store/ltobjst9.nsf/DDE300B846EED9C7CA257616000A3571/1D9C11F63DEBA5E2CA257E70001687F4/%24FILE/98-25aa071%20authorised.pdf, viewed on 24 February 2021.

[24] Department of the Prime Minister and Cabinet, Australian Government, *"Best Practice Regulation Guidance Note: Value of statistical life,"* available at https://www.pmc.gov.au/resource-centre/regulation/best-practice-regulation-guidance-note-value-statistical-life, viewed on 24 February 2021.

[25] Safe Work Australia, "The Cost of Work-related Injury and Illness for Australian Employers, Workers and the Community: 2012-13," available at https://www.safeworkaustralia.gov.au/system/files/documents/1702/cost-of-work-related-injury-and-disease-2012-13.docx.pdf, viewed on 24 February 2021.

[26] Health and Safety Executive's submission to the1987 Sizewell B Inquiry suggesting that a factor of up to 3 (i.e. costs three times larger than benefits) would apply for risks to workers; for low risks to members of the public a factor of 2, for high risks a factor of 10. The Sizewell B Inquiry was public inquiry conducted between January 1983 and March 1985 into a proposal to construct a nuclear power station in the UK.

[27] Australian Energy Regulator, *"Industry practice application note for asset replacement planning,"* available at https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/industry-practice-application-note-for-asset-replacement-planning, viewed on 24 February 2021.

Environmental risk costs

Environmental risks related to the potential release of transformer oil in the event of asset failure, is valued at $30,000 per event.

3. Credible network options

AusNet Services considers both network and non-network options to address the identified need resulting from the SVC at HOTS reaching end of serviceable life.

The network options that AusNet Services has identified are presented below.

3.1. Option 1 – Replacement of the existing SVC with a modern equivalent SVC

Option 1 involves full replacement of all components of the SVC in a single integrated project. A modern equivalent SVC is assumed in this option, with the same size at output voltage as the existing assets – i.e. (+50 MVar/-25 MVar). The SVC will come with a new transformer in a new building to allow the current SVC to operate while the new asset is being constructed and minimise the network and market impact during construction. The required outage will be limited to the cut-over period.

The works involve installing a new SVC including:

- One new 220/4.5 kV transformer,
- One new SVC Prefab building,
- New primary equipment,
- New thyristor valves,
- New protection & control system, and
- New cooling system

Implementing this option will improve the reliability of the service and significantly reduce the risk of asset failure.

The estimated real capital cost of this option has been revised down since the PSCR to $23.98 million. The cost reduction from what was quoted in the PSCR came from implementing detailed estimation of the cost components of the option. However, the operating cost of this option is not significantly different to the operating and maintenance cost of the current SVC, or approximately $10,000 per year.

AusNet Services' preliminary analysis shows that the optimal timing to deliver this option is as soon as possible. However, when construction and delivery lead times are taken into account, this option could realistically be delivered by 2023/24.

3.2. Option 2 – Replacement of the SVC with a synchronous condenser

Option 2 involves replacing the SVC with a synchronous condenser of similar size (50 MVar to -25 MVar) to the current SVC in a new building, which is to be constructed next to the current SVC. Similar to Option 1, this option will result in shorter outages and lower impact on the wholesale electricity market as the SVC can continue to operate while the new asset is being constructed. The required outage will be limited to the cut-over period.

The works will involve installing:

- Synchronous condenser,
- One (1) 220/13.8 kV transformer,

- Synchronous condenser protection & control,
- Transformer protection & control,
- New Building,
- 13.8 kV switchgear,
- One (1) 13.8/0.4 kV auxiliary transformer,
- One (1) 400 V switchboard,
- One (1) UPS system,
- New protection & control system and
- Synchronous condenser spare parts and tool set.

This option is expected to replace the current functionality of the SVC and provides additional inertia and system strength benefits.

Implementing this option will improve the reliability of the service and significantly reduce the risk of asset failure.

The estimated real capital cost of a new synchronous condenser of similar size to the current SVC is $24.79 million, while the operating and maintenance cost is estimated to be $35,000 per year.

AusNet Services' preliminary analysis shows that the optimal timing to deliver this option is as soon as possible. However, when construction and delivery lead time are taken into account, this option could realistically be delivered by 2023/24.

3.3. Options considered but not progressed

The following options are not likely to become the preferred option:

- Retirement of the SVC - asset retirement would avoid emergency asset replacement cost and safety risk costs, however retiring the SVC would reduce the capability to manage ongoing requirements for voltage control as required by clauses S5.1a.4 and S5.1a.5 of the NER and clauses 110.2.2(a) and 110.2.3(a) of the Victorian Electricity System Code. Additionally, market modelling simulations using several constraints imposed on the network if the HOTS SVC is out of service[28] shows significant market impact risks in the order of more than $30 million per year if the SVC were to be retired. Therefore, the option of retiring the SVC is not progressed.
- Options to remediate or refurbish the SVC do not materially reduce the failure rates as technology obsolescence continues to be a limiting factor, hence refurbishment option is not progressed further.
- Options utilising static capacitors and reactors are not considered credible as they do not provide the necessary dynamic support to respond to network disturbances and contingency events. Therefore, this option is not technically feasible.
- A new synchronous condenser of the same size at Red Cliffs Terminal Station (RCTS) – although this option would maximise the potential benefit to the system strength gap declared by AEMO at Red Cliffs, the distance between RCTS and HOTS does not make this option effective at managing voltage in North West Victoria, especially at HOTS, and at maintaining compliance with the regulatory obligation; most especially, when there is outage of RCTS-HOTS line.

[28] Australian Energy Market Operator, *"Victorian Transfer Limit Advice - Outages,"* available at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/victorian-transfer-limit-advice-outages.pdf?la=en, viewed on 26 March 2021.

Therefore, this option is not considered technically feasible and not progressed.

- A new synchronous condenser of the same size at Wemen Terminal Station (WETS) – similar to the option proposed at Red Cliffs Terminal Station, a synchronous condenser at Wemen Terminal Station is not effective at managing voltage in North West Victoria and maintaining compliance with the regulatory obligation. Additionally, a new synchronous condenser at WETS would duplicate the voltage management solution in that part of North West Victoria loop as there is already a SVC at Kerang Terminal Station (KGTS) - not far from WETS. Therefore, this option is not considered technically feasible and not progressed.

3.4. Material inter-regional network impact

AusNet Services assessed that none of the credible network options being considered are likely to have a material inter-regional network impact. A ‘material inter-regional network impact’ is defined in the NER as:

> *“A material impact on another Transmission Network Service Provider’s network, which may include (without limitation): (a) the imposition of power transfer constraints within another Transmission Network Service Provider’s network; or (b) an adverse impact on the quality of supply in another Transmission Network Service Provider’s network.”*

AEMO’s screening test for material inter-network impact of a transmission investment is described as follows:[29]

- a decrease in power transfer capability between transmission networks or in another TNSP’s network of more than the minimum of 3% of the maximum transfer capability and 50 MW
- an increase in power transfer capability between transmission networks or in another TNSP’s network of more than the minimum of 3% of the maximum transfer capability and 50 MW
- an increase in fault level by more than 10 MVA at any substation in another TNSP’s network
- the investment involves either a series capacitor or modification in the vicinity of an existing series capacitor.

[29] Inter-Regional Planning Committee, *“Final Determination: Criteria for Assessing Material Inter-Network Impact of Transmission Augmentations,”* available at https://www.aemo.com.au/-/media/Files/PDF/170-0035-pdf.pdf, viewed on 24 February 2021.

4. Non-network options

AusNet Services received three proposals for a non-network solution. As all proponents wish their submissions be treated confidential, AusNet Service is not publishing any part of their submissions.

These proposals were evaluated from economic, technical, and project delivery perspectives. While all proposals are technically feasible to varying degree of effectiveness, none are economically superior compared against the credible network options in deferring or avoiding the capital cost of the credible network options considered in this RIT-T.

5. Assessment approach

AusNet Services employed a two-step approach to evaluate the credible options. A power system analysis was used to evaluate the options' impact on the ability to comply with regulatory obligations, on the operation of the power system, and on the limitations imposed on the system.

The insights taken from this engineering analysis were then fed into the market model to further estimate the economic impact of those options. The following sections discuss these methodologies in detail.

5.1. Technical assessment

AusNet Services has undertaken a technical assessment and comparison of the two identified credible options:

- Option 1 - Replacement of the existing SVC with a modern equivalent SVC at HOTS;
- Option 2 - Replacement of the existing SVC with a synchronous condenser at HOTS;

It is noted that this technical assessment was completed by performing steady state studies using PSSE (i.e. load flow and fault level) OPDMS[30] snapshots.

5.1.1. Voltage management

Operation of the 220 kV transmission network in North West Victoria has evolved significantly since the HOTS SVC was installed around 35 years ago. In particular, the Murraylink interconnector was commissioned in 2002 and there has been significant new renewable generation investment in recent years.

Murraylink and the generator connections all provide some level of voltage and reactive power control. AEMO's VAPR notes that there is ongoing collaboration between AEMO and generators to ensure that any available reactive support can be made available to when needed. AusNet Services has undertaken a high-level screening study, using Operations and Planning Data Management System (OPDMS) snapshots from the past 12 months, to assess the ongoing need for the voltage and reactive power control service provided by the HOTS SVC. Given that the SVC and the synchronous condenser are both rated for +50/-25 MVAR, it is assumed they will provide equivalent reactive support, albeit with different dynamic response. As such the results of this study, presented in Section 6.1.1, apply equally to both Option 1 and Option 2.

5.1.2. System strength

It is known the system strength in North West Victoria is low, impacting the stability and dynamics of control systems used in inverter-based resources[31]. Indeed, AEMO declared a fault level shortfall at Red Cliffs in 2019[32] and has engaged non-market service providers to fill the identified gap in the short term.

Unlike SVCs, synchronous condensers are a source of system strength. AusNet Services has undertaken fault level studies to quantify the system strength benefit of installing a synchronous condenser at HOTS (i.e. Option 2). Results for this study are presented in Section 6.1.2.

---

[30] OPDMS – Operations and Planning Data Management System

[31] Australian Energy Market Operator "System Strength in the NEM Explained" March 2020 available at https://aemo.com.au/-/media/files/electricity/nem/system-strength-explained.pdf?la=en

[32] Australian Energy Marker Operator, *'Notice of Victorian Fault Level shortfall at Red Cliffs,'* available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2019/Notice_of_Victorian_Fault_Level_Shortfall_at_Red_Cliffs.pdf, viewed on 24 February 2021.

5.1.3. Market impact

A review of AEMO's limit advice reports[33] identified the limit equations that would be impacted by the options to address the identified need of this RIT-T. These equations (summarised in the table below) formed the basis of the market modelling activities presented in this report. A qualitative review of the market value derived from these constraints is presented in Section 6.1.3.

Table 2 – Victorian limit equations impacted by the replacement of HOTS SVC

Equation ID	Description
Voltage oscillation (system normal and prior outage)	This represents a set of network limit equations associated with voltage oscillation during system normal and a range of prior outage conditions.
Vic to SA transfer limit - voltage stability (system normal) (V^SML_X5_X3, V^SML_BEKG)	To avoid voltage collapse at Red Cliffs for: • loss of Darlington Point to Balranald (X5) or Balranald to Buronga (X3) 220 kV lines when the New South Wales Murraylink runback scheme is unavailable OR • loss of Bendigo to Kerang 220 kV line.
Vic to SA transfer limit – voltage stability (prior outage) (V^S[MRLK] BATS-BETS_X5 and V^S[MRLK] BETS-SHTS_X5)	Prior outage limit equations to manage the voltage stability export limit from Victoria to SA for fault and trip of Buronga to Balranald to Darlington point 220 kV line.
Transient Stability Limits (NILV)	Vic transient export limit to New South Wales (NSW) for fault and trip of a Hazelwood – South Morang (HWTS-SMTS) 500 kV line. Based on study conditions under which Vic accelerates ahead of the other states.

5.2. Economic assessment

Consistent with the RIT-T guidelines[34] and on the RIT-T Economic Handbook[35] on risk-cost assessment methodology, AusNet Services undertook a cost-benefit analysis to evaluate and rank the net economic benefits of various credible options. The assessment covered the 45-year[36] life of the proposed assets for the network options described.

All options considered were assessed against a business-as-usual case where no proactive capital investment is made, and the existing maintenance regime continues.

The year when the annual benefits from implementing the option become greater than the annualised investment costs was taken as the optimal timing of the investment.

AusNet Services also applied the following methodologies in this RIT-T.

---

[33] Australian Energy Market Operator, "*Victorian Transfer Limit Advice - System Normal v20*" and "*Victorian Transfer Limit Advice - Outages v33*" available at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource/limits-advice, viewed on 24 March 2021.

[34] Australian Energy Regulator, *"Guidelines to make the integrated system plan actionable,"* available at https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/guidelines-to-make-the-integrated-system-plan-actionable/final-decision, viewed on 24 February 2021.

[35] Energy Networks Australia, *"RIT-T Economic Assessment Handbook for non-ISP RIT-Ts,"* available at https://www.energynetworks.com.au/resources/fact-sheets/ena-rit-t-handbook-2020/, viewed on 24 February 2021.

[36] Australian Energy Regulator, *"ElectraNet - Main grid system strength contingent project Supporting Information - GHD Advisory - MGSS Contingent Project - Economic Life Advice - 28 June 2019,"* available at https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/contingent-projects/electranet-main-grid-system-strength-contingent-project/initiation, viewed on 24 February 2021.

Market modelling

To estimate the market impact of all the credible options, an industry-accepted market modelling approach was employed. The counterfactual development paths for the Central, Slow Change, and Fast Change scenarios[37] were used for the base cases. While outage cases emulating a retirement or absence of an asset were constructed using the same base cases, but with additional or tighter power system constraints imposed on the dispatch simulation.

Treatment of non-network options

In August 2020, AER released updates on a suite of documents governing the application of the RIT-Ts[38]. In those documents, the AER made clear that estimates of the capital costs and operating cost must be used, instead of the annual payment requirements, in the economic assessments of non-network options that have yet to be built. However, for those non-network proposals that are already built, the annual payment requirements are the appropriate figures to be used.

AusNet Services also implemented Energy Networks Australia's suggestions in the RIT-T Economic Handbook[39] that RIT-T assessments in progress at the time of AER publication should continue to evaluate non-network options using the submitted annual payment requirements.

Estimating '*Option value*'

For any investment decision, there is always a risk of choosing the wrong option. Therefore, there exists a risk of stranding part of, or the whole of, that investment cost. The '*option value*' of a credible option is the difference between the maximum potential stranded cost among all credible options and *the* credible option's potential stranded costs.

'Option Value' are not explicitly included in the cost-benefit analysis but are estimated to provide additional and separate method of weighing options.

Scenario weighting assumptions

The weighting parameter represents the probability of occurrence of the scenario and is given in the next sub section.

5.2.1. Proposed input assumptions and sensitivity analysis

AusNet Services extended the economic assessment to include two more scenarios where the extremes of net economic benefits are explored. The details of all scenarios explored in this PADR are presented in the table below.

[37] Australian Energy Market Operator, *"2020 Integrated System Plan (ISP),"* available at https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2020-integrated-system-plan-isp, viewed on 24 February 2021.
[38] Australian Energy Regulator, *"Guidelines to make the integrated system plan actionable,"* available at https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/guidelines-to-make-the-integrated-system-plan-actionable/final-decision, viewed on 24 February 2021.
[39] Energy Network Australia, *"ENA RIT-T Economic Assessment Handbook,"* available at https://www.energynetworks.com.au/resources/fact-sheets/ena-rit-t-handbook-2020/, viewed on 11 March 2021.

Table 3 - Input assumptions used for the sensitivity studies

Parameter	Low-benefit scenario	Central	High-benefit scenario
Description	explore the lower bound of potential benefits	most likely scenario	gives high estimates for the benefits
Weighting	25%	50%	25%
Asset failure rate	AusNet Services assessment – 25%	AusNet Services assessment	AusNet Services assessment + 25%
Capital cost	AusNet Services assessment + 30%	AusNet Services assessment	AusNet Services assessment – 30%
Discount rate	7.37% - a symmetrical adjustment upwards	4.8% - the latest commercial discount rate[40]	2.23% - the WACC rate of a network business
Market Modelling Input Assumptions	AEMO's 2020 ISP Slow Change scenario	AEMO's 2020 ISP Central scenario	AEMO's 2020 ISP Fast Change scenario

Sensitivity analysis

The robustness of the net economic benefits and the optimal timing of the options considered were tested using sensitivity analysis. This analysis involved variations of assumptions on the failure rates, financial risk costs, capital costs, and discount rate.

5.2.2. Materiality of classes of market benefits

The options currently identified in this RIT-T were not expected to have a material impact on the wholesale electricity market and therefore the following classes of market benefits set out in NER version 157 clause 5.15.A.2(b)(4) were not included in this analysis.[41] Details of the high-level assessment for excluding these classes of market benefits are provided in the following points:

- Changes in involuntary load shedding – the operational demand at HOTS was not sufficiently large that any of the options considered would pose material risk of load shedding due to prolonged under-voltages.
- Changes in voluntary load curtailment – there was no material impact on the wholesale electricity market prices that may trigger voluntary load curtailment.
- Change in network losses – changes in network losses were estimated to be small and unlikely to be a material class of market benefits for any of the credible options.
- Competition benefits – quantifying the impact of the credible options on the bidding behaviour would involve a disproportionate level of effort compared to the additional insight it would provide. Additionally, the identification of the preferred option was not expected to significantly change if competition benefits were to be included in this assessment. Therefore, this class of market benefit was excluded from this RIT-T.

[40] Australian Energy Market Operator, *"Draft 2021 Inputs, Assumptions and Scenarios Report,"* available at https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/inputs-assumptions-methodologies/2021/draft-2021-inputs-assumptions-and-scenarios-report.pdf?la=en, viewed on 28 February 2021.
[41] Australian Energy Regulator, *"Application guidelines Regulatory investment test for transmission,"* p32, available at https://www.aer.gov.au/system/files/AER%20-%20Final%20RIT-T%20application%20guidelines%20-%2014%20December%202018_0.pdf, viewed on 24 February 2021.

However, the class of market benefit associated with *changes in fuel consumption arising through different patterns of generation dispatch* could arise:

- from avoiding imposition of dispatch constraints that limit generation from cheap renewable energy in the North West Victoria during planned and forced outages of current SVC or other transmission lines in the North West Victoria.
- from relaxed transient stability constraints that impact Victorian ability to export power to New South Wales and South Australia. This benefit was only included for options that include a synchronous condenser.

AusNet Services also estimated that there are significant benefits in maintaining flexibility to allow further investments or avoid stranded assets. Therefore, the class of market benefit associated with '*option value'* was considered material in this RIT-T.

'Option Value' are not explicitly included in the cost-benefit analysis but are estimated to provide additional and separate method of weighing options.

Interaction with other planning processes

In December 2019, AEMO declared a fault level shortfall[42] of 312 MVA at the Red Cliffs fault level node in Victoria. This figure was subsequently reduced to 66 MVA[43]. Since then, AEMO had successfully procured contracts for immediate solution using existing providers to cover system strength gaps and is in the process of assessing a range of potential longer-term options to meet the system strength gap.[44]

While that process for filling the system strength gap at Red Cliffs was progressing, AusNet Services and AEMO worked closely to understand and take advantage of the potential synergies between the solutions to this RIT-T and to that system strength gap. Though expected to be minimal, those synergies, or the avoided cost to filling up the gap for options that may additionally provide system strength services, is captured in this RIT-T as *'changes in costs for parties, other than the RIT-T proponent.'*

Other classes of benefits

AusNet Services expected that a material reduction in the risk costs from the need for emergency asset replacements and repairs could come from the credible options identified in this RIT-T.

The treatment of this risk cost saving in the RIT-T analysis is aligned with the RIT-T Practice Notes[45] published by the Australian Energy Regulator (AER).

[42] Australian Energy Marker Operator, *'Notice of Victorian Fault Level shortfall at Red Cliffs,'* available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2019/Notice_of_Victorian_Fault_Level_Shortfall_at_Red_Cliffs.pdf, viewed on 24 February 2021.
[43] Australian Energy Market Operator, *"Notice of Change to System Strength requirement and Shortfall at Red cliffs,"* available at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-security-market-frameworks-review/2020/notice-of-change-to-red-cliffs-220kv-minimum-fault-level-requirement-and-shortfall.pdf?la=en&hash=5C3EDDABDF81891B3989F6FF0466C486, viewed on 24 February 2021.
[44] Australian Energy Market Operator, *"AEMO Invitation to Tender for System Strength Services - Victoria,"* available at https://aemo.com.au/consultations/tenders/victorian-transmission/aemo-invitation-to-tender-for-system-strength-services-victoria, viewed on 24 February 2021.
[45] Australian Energy Regulator, *"Industry practice application note for asset replacement planning,"* available at https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/industry-practice-application-note-for-asset-replacement-planning, viewed on 24 February 2021.

6. Options assessment

6.1. Technical evaluation

6.1.1. Voltage management

To assess the ongoing need for voltage management at HOTS, load flow studies were conducted using OPDMS snapshots from the past 12 months spread across a range of load and generator dispatch conditions. These studies were carried out with and without the HOTS SVC connected for critical 220 kV line contingencies.

Pre and post contingent bus voltages were monitored against the following assessment criteria:

- Bus voltages maintained within +/-10% of normal voltage for all operating conditions[46]; and
- Post-contingent voltage variation less than 3% of pre-contingent voltage[47].

Figure 7 shows the distribution on HOTS 220 kV bus voltage measurements under system normal. The voltage is maintained within +/- 10% of normal voltage even when the SVC is out of service. This suggests that even without the HOTS SVC there is sufficient reactive power support to manage voltages in North West Victoria when the 220 kV network is intact.

Figure 8 shows the impact of the HOTS SVC on the step voltage change seen at the HOTS 220 kV bus following trip of the HOTS-Murra Warra Terminal Station (MWTS)-Kiamal Terminal Station (KMTS). If the HOTS SVC is in service, the voltage variation always remains within the allowable 3%. When the HOTS SVC is out of service, approximately 5% of cases results in a voltage variation greater than the allowable 3%.

It is noted in the VAPR[48] that high voltages have been observed in North West Victoria during low demand periods when the 220 kV transmission lines are lightly loaded. Although these high voltages were not seen in the OPDMS snapshots used for the screening study, AusNet Services has reproduced high voltages at HOTS 220 kV bus, following outage of the HOTS-MWTS-KMTS 220 kV line using a minimum load case, and reducing the penetration of wind generation in North West Victoria. These results confirm the ongoing need for the voltage regulation service at HOTS to maintain operational flexibility under planned and unplanned outages in North West Victoria.

---

[46] Australian Energy Market Commission, clause S5.1a.4 *"National Electricity Rule version 157,"* available at https://www.aemc.gov.au/regulation/energy-rules/national-electricity-rules/current, viewed on 24 February 2021.

[47] TR IEC 61000.3.7:2012 Table 6

[48] Australian Energy Market Operator, *"Victorian Annual Planning Report,"* available at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/victorian-planning/victorian-annual-planning-report, viewed on 24 February 2021

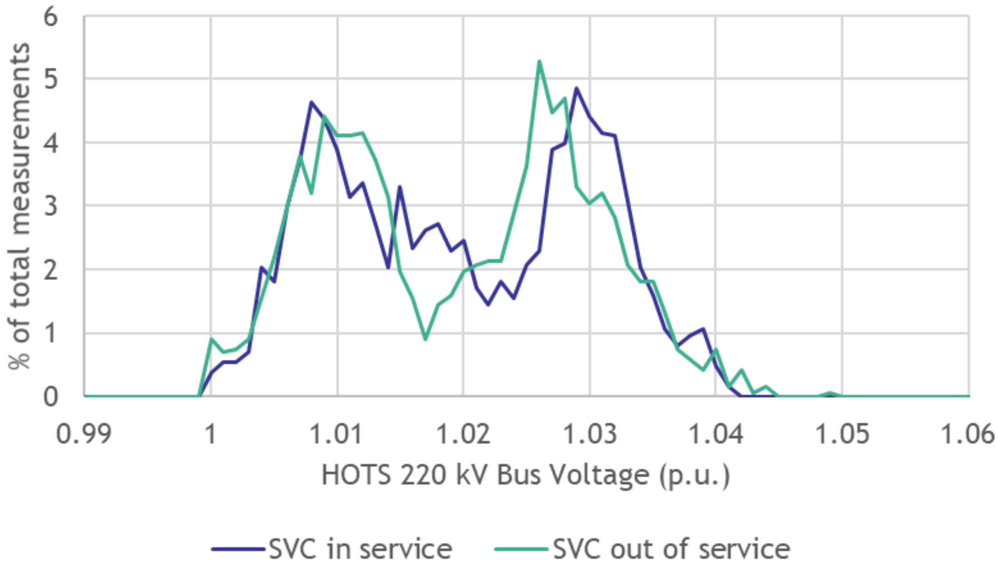

Figure 7 - Distribution of HOTS 220 kV bus voltage for system normal

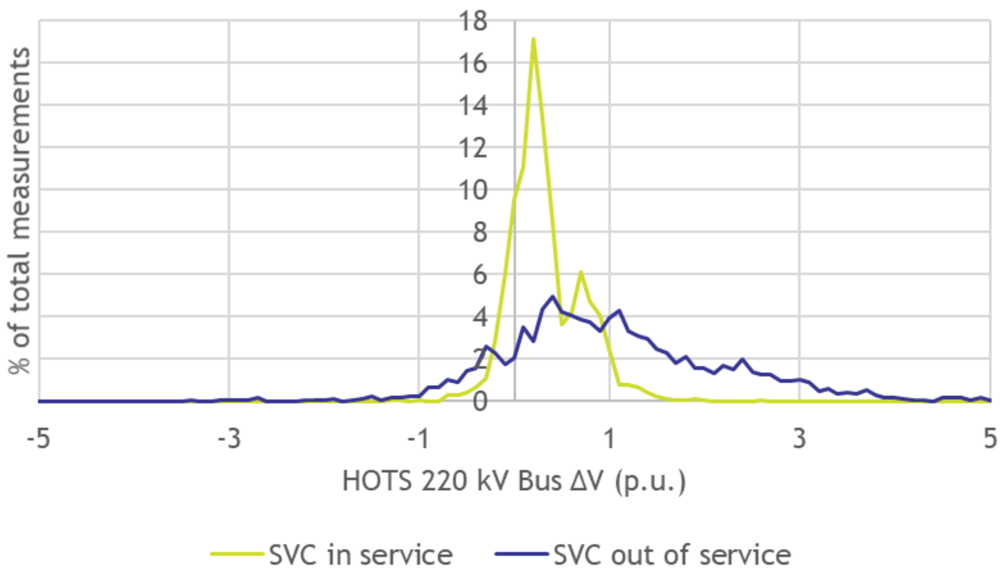

Figure 8 - Distribution of HOTS 220 kV bus voltage variation for HOTS-MWTS-KMTS contingency

6.1.2. System strength

Table 4 summarises the fault level impact of a 50 MVar synchronous condenser at the HOTS and RCTS 220 kV buses. These values have been derived using a minimum fault level OPDMS snapshot and assuming typical sub-transient reactance values for the synchronous condenser. A synchronous condenser at HOTS has only marginal impact on the declared system strength gap at RCTS, particularly when the HOTS-MWTS-KMTS 220 kV line is out of service. However, it does contribute significantly to fault level at HOTS, particularly when the BATS-Waubra Terminal Station (WBTS)-Ararat Terminal Station (ARTS)-HOTS 220 kV line is out of service. This additional system strength in this area may enable the existing Murra Warra Wind Farm to stay connected for this line outage, reducing the total amount of generation lost for this contingency. The additional system strength will also help to enable future generator connections in the area including the proposed Horsham Solar Farm.

Table 4 – System strength impact of synchronous condenser at HOTS

220 kV Network configuration	HOTS 220 kV fault level (MVA)			RCTS 220 kV fault level (MVA)		
	Without sync con	With sync con	Increase	Without sync con	With sync con	Increase
System normal	923	1167	244	925	977	52
HOTS-MWTS-KMTS OOS	684	921	237	668	669	1
BATS-WBTS-ARTS-HOTS OOS	399	633	234	667	780	113

6.1.3. Market impact

Voltage oscillation

As outlined in Section 23 of AEMO's *Victorian Transfer Limit Advice – Outages*[49], if the HOTS SVC is out of service generators in North West Victoria are constrained to prevent oscillations for trip of an Ararat to Waubra to Ballarat 220 kV line or Bendigo to Kerang 220 kV line. The market value associated with these constraints is significant and forms a large portion of the economic benefits described below.

There are number of voltage oscillation limits associated with prior outage of 220 kV lines in North West Victoria which are enabled to prevent voltage oscillations for trip of another 220 kV line. Under these prior outage conditions, the HOTS SVC is either switched off or set to manual mode, suggesting that it contributes to the oscillatory behaviour through control system interactions with the asynchronous generation in the area. While the market value associated with these prior outage voltage oscillation limits is likely to be relatively low as it is weighted against the probability of an unplanned line outage, they can make it difficult to get planned outages in this area due to impact on generator constraints.

It is well known that there is a risk of adverse interactions between asynchronous generation and power electronic FACTS devices (including SVCs) in networks with low system strength[50]. It is expected that replacement of the HOTS SVC with a synchronous condenser will reduce the probability of the oscillatory behaviour which currently constrains the generation in North West Victoria. The degree to which it might relieve these constraints would need to be confirmed through detailed PSCAD studies which are outside the scope of this PADR and therefore has not been considered in the market modelling.

Voltage stability – Vic to SA transfer on Murraylink

The reactive power supplied from the HOTS SVC helps to increase the reactive margin at RCTS thus helping to prevent voltage collapse in Red Cliffs following critical 220 kV line contingencies, as captured in Victoria to SA (Murraylink) transfer limit equations.

In the case of the system normal voltage stability limits (i.e. V^SML_BEKG AND V^SML_X5_X3), the co-efficient corresponding to the SVC contribution (i.e. HOTS+KGTS_SVC_MVAR) is small compared to the intercept value. In the prior-outage voltage stability limit equations (i.e. V^S[MRLK] BATS-BETS_X5

[49] Australian Energy Market Operator, "*Victorian Transfer Limit Advice – System Normal v20*" and "*Victorian Transfer Limit Advice - Outages v33*" available at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource/limits-advice, viewed on 24 March 2021.
[50] Australian Energy Market Operator "*System Strength Impact Assessment Guidelines*" available at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/system-security-market-frameworks-review/interim-system-strength-impact-assessment-guidelines-2018, viewed on 24 March 2021.

and V^S[MRLK] BETS-SHTS_X5), the coefficients are larger, but this is offset by the probability of a line outage at any given time.

Based on these observations, it is concluded that the market benefit derived from the HOTS SVC terms in these equations would be negligible. As such these equations have been excluded from the market modelling for this PADR.

Transient stability

The installation of a synchronous condenser at HOTS will provide additional inertia in Victoria which should see an uplift in the Victorian transient export limit to New South Wales (NSW) for fault and trip of a Hazelwood to South Morang 500 kV line. For the purposes of the market modelling, it is assumed that the synchronous generator inertia will have a co-efficient of 5.0, and an inertia value of 1.92.

6.2. Economic evaluation

The most efficient option is determined through economic evaluation and details are presented in the following sections.

6.2.1. Estimated costs

Table below shows the present value of all costs associated with implementing the options considered. These include the capital costs, the operation and maintenance costs, and the annual payment requirements for non-network options that are already existing.

The table shows that apart from the base case, Option 1 has the lowest present value of the capital and operating cost. Note that these incorporates the discounting due to the cost of the options being spent in the future, hence are not numerically similar to the cost quoted in Chapter 3.

Due to confidentiality arrangements, AusNet Service only presents the cost of the non-network option that has the lowest weighted value. AusNet Services is not publishing any further information on non-network options.

Table 5 - Estimated PV of capital and operating costs for each option, in real $2020/21 million

Option	Low-benefit scenario (25%)	Central (50%)	High-benefit scenario (25%)	Weighted value
Cheapest non-network option	41.82	39.63	39.94	40.26
Option 1 SVC	25.20	20.85	15.74	20.66
Option 2 SCO	26.05	21.56	16.27	21.36

6.2.2. Estimated benefits

The largest component of market benefits estimated for this RIT-T is the avoided fuel cost from replacement of the deteriorating asset. These components of benefits are presented below.

'Changes in fuel consumption arising through different patterns of generation dispatch'

Based on the estimates from market modelling, the fuel cost savings from the reduced risk of forced outage, as a result of replacement, are given in the table below. These figures are calculated based on the avoided market impact of dispatch constraints during an outage of the SVC; and are included in the total gross benefits for all options.

Table 6 – Fuel cost savings from avoided market impact of power system constraints, in real $2020/21 million

Low-benefit scenario (25%)	Central (50%)	High-benefit scenario (25%)	Weighted value
6.24	23.42	112.0	41.27

For options that include inertia, e.g. synchronous condenser, the fuel cost savings from relaxed transient stability constraints that impact Victorian ability to export power to New South Wales and South Australia are presented below. These figures come from allowing higher renewable generation and cheaper Victorian energy sources to replace more expensive New South Wales and South Australian generation.

Table 7 – Fuel cost savings from relaxed transient stability constraints, in real $2020/21 million

Low-benefit scenario (25%)	Central (50%)	High-benefit scenario (25%)	Weighted value
0.73	3.18	6.33	3.36

'Option value'

By investing in assets that provide system strength and inertia in addition to the minimum requirement for voltage management, the benefit of maintaining flexibility to minimise further investments or to minimise the risk of stranded assets could be realised. This '*option value'* of a credible option is the reduction in potential stranded cost if a wrong investment decision was made.

For example, the potential stranded cost for Option 1 SVC is its full cost of $23.98 million if it turns out that Option 2 SCO is the more effective investment, e.g. a new SCO would be built and the recently built SVC will be useless.

Meanwhile, the potential stranded cost for Option 2 SCO is just the difference between the costs of the two options, $0.81 million. Reason is that it is only the incremental cost of Option 2 SCO that will be un-utilised as the newly built SCO will continue to be used and no additional investment for an SVC will be required.

The final potential stranded risk costs for the options considered are given in the following table.

Table 8 - Maximum stranded cost estimates, in real $2020/21 million

Option	Low-benefit scenario (25%)	Central (50%)	High-benefit scenario (25%)	Weighted value
Cheapest non-network option	41.82	39.63	39.94	40.26
Option 1 SVC	16.78	23.98	31.17	23.98
Option 2 SCO	0.57	0.81	1.057	0.81

From the table above, there is significantly larger stranded risk cost for Option 1 SVC than Option 2 SCO. This means that the consequence of making wrong decision is significantly lower in Option 2 SCO. For non-network options, as all submissions are long-term offers, the value of the potential contracts were taken as the potential stranded cost.

The *option value* is then taken as the reduction in potential stranded risk cost compared to the option that has the highest potential stranded risk cost, i.e. Option 2 SCO's *option value* for the Central scenario is the difference between 39.63 and 0.81.

The following table presents provides the detailed results. While these figures are in dollar value, they are not added in the cost benefit analysis but are presented to provide additional and separate method of weighing options.

Table 9 - *Option value* estimates, in real $2020/21 million

Option	Low-benefit scenario (25%)	Central (50%)	High-benefit scenario (25%)	Weighted value
Cheapest non-network option	0	0	0	0
Option 1 SVC	25.04	15.65	8.77	16.28
Option 2 SCO	41.25	38.82	38.883	39.45

'Changes in costs for parties, other than the RIT-T proponent'

Based on the engineering analysis employed by AusNet Services, while a synchronous condenser near the Victorian – New South Wales border may be able to assist with closing the system strength gap at Red Cliffs, any dynamic reactive asset in any of those locations are not effective at managing voltage fluctuations at HOTS; and therefore, those proposals are not technically feasible. And vice versa, a synchronous condenser at HOTS is not effective at providing system strength services to the gap declared at Red Cliffs.

Therefore, for Option 2, there is no market benefit associated with '*changes in costs for parties, other than the RIT-T proponent.*'

Other classes of benefits

Table below shows the net present value of all the benefits of reduction in safety risks, environment risks, and risks of replacement should the asset fail. In accordance with the RIT-T Practice notes[51] These risk reductions form part of the total gross benefits for each option.

[51] Australian Energy Market Operator, "Industry practice application note for asset replacement planning," available at https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/industry-practice-application-note-for-asset-replacement-planning, viewed on 24 February 2021.

Table 10 - Other risk reduction benefits from replacement of the asset, in real $2020/21 million

Risk	Low-benefit scenario (25%)	Central (50%)	High-benefit scenario (25%)	Weighted value
Safety	0.03	0.05	0.12	0.062
Environment	0.01	0.00	0.02	0.007
Losses	0.13	0.20	0.32	0.213
Financial	15.56	31.72	66.84	36.46
Collateral	0.03	0.06	0.13	0.07

Total gross benefits

Based on the components of benefits presented above, the total gross benefits for each of the option are summarized in the following table.

Table 11 - Estimated PV of gross economic benefits from each option, in real $2020/21 million

Option	Low-benefit scenario (25%)	Central (50%)	High-benefit scenario (25%)	Weighted value	Rank
Cheapest non-network option	22.94	58.99	186.28	81.80	1
Option 1 SVC	21.99	55.47	179.40	78.08	3
Option 2 SCO	22.71	58.64	185.72	81.43	2

6.2.3. Net economic benefits

The following table shows the net economic benefit when all the costs and risk reduction benefits are summated together. It shows that replacement with a synchronous condenser (Option 2) provides the highest present value of net economic benefits across most scenarios.

Note that Table 12 does not present the arithmetic subtraction of the figures in all proceeding tables as it incorporates the baseline operating and maintenance costs, and not all options have all the benefits mentioned above.

Table 12 - Estimated PV of net economic benefits from each option, in real 2019/20 $ million

Option	Low-benefit scenario (25%)	Central (50%)	High-benefit scenario (25%)	Weighted value	Rank
Cheapest non-network option	-18.82	19.43	146.46	41.63	3
Option 1 SVC	-3.16	34.69	163.79	57.50	2
Option 2 SCO	-3.28	37.16	169.57	60.15	1

Other benefits

Synchronous condensers also provide ability to implement planned outage for maintenance that otherwise would not be possible due to system strength limitations. In recent years, several planned outages of the 220 kV network making up the North West Victoria transmission network were postponed and cancelled due to potential lack of system strength.

Option 2 SCO will allow planned outage to proceed, enabling more efficient asset maintenance programs.

6.2.4. Sensitivity analysis

This section describes the sensitivity of the net economic benefits, ranking of options, and optimal timing of the preferred option to different assumptions on key variables.

Sensitivity of net economic benefits

Using the Central scenario as the reference, the net economic benefits from implementing an option changes with different assumptions on key variables. By using sensitivity analysis, the robustness of the conclusion is tested.

In all the sensitivities tested, Option 2 is most economical amongst all the options considered, as shown in the following figure.

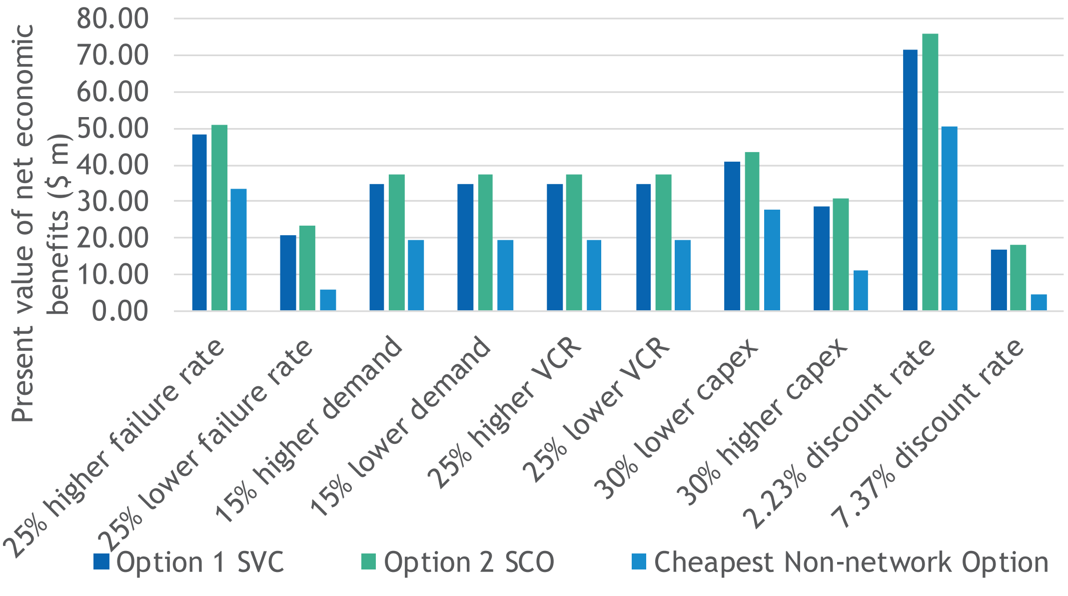

Figure 9 - Sensitivity of the net economic benefits with respect to variation of key parameters

Sensitivity of optimal timing

Figure below shows that under majority of the sensitivities investigated, the optimal timing of the preferred option is as soon as possible. However, to allow for construction lead time, this option is expected to be commissioned in 2023/24. Note that in figure below, size of bubble signifies larger number of sensitivities with similar net economic benefits.

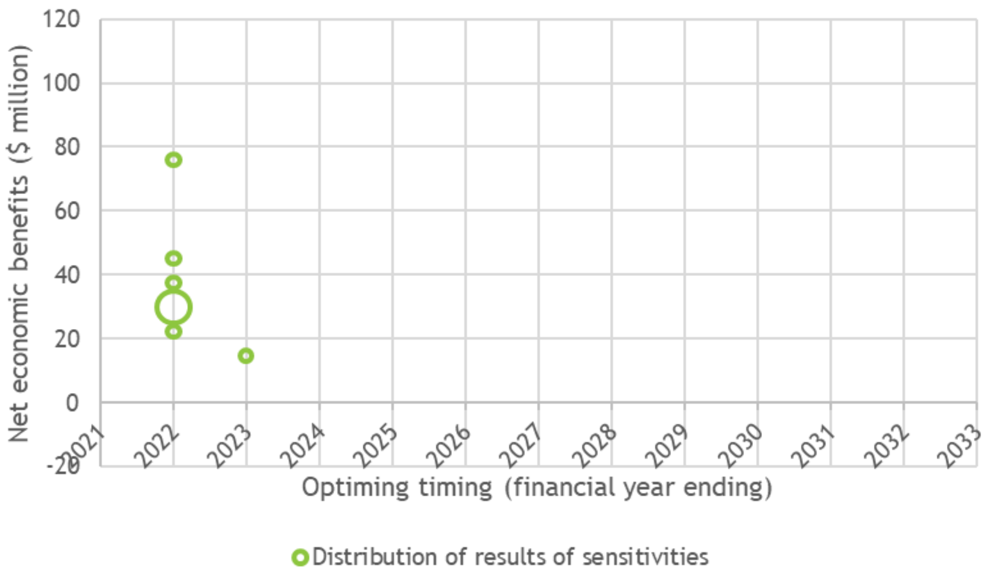

Figure 10 - Sensitivity of the optimal timing with respect to variation of key parameters

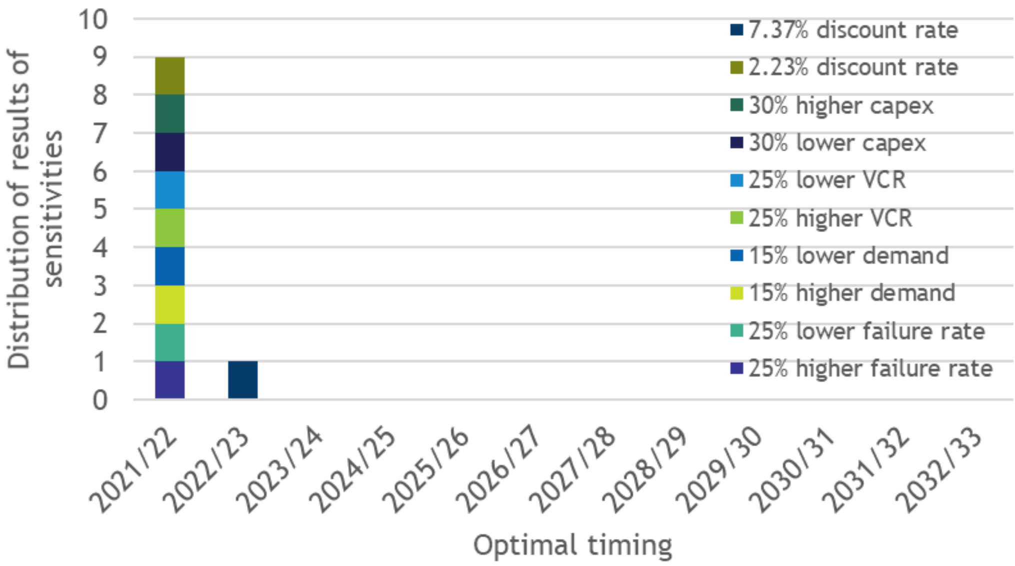

Figure 11 - Sensitivity of the optimal timing with respect to variation of key parameters

6.2.5. Capital deferment benefits from non-network option

While AusNet Services received three proposals from non-network options, none are cost-effective in deferring nor replacing any of the network options considered. The annual cost of any of the non-network options is higher than the deferral benefits from delaying the capital expenditure associated with the preferred network option.

For reasons of confidentiality requested by the proponents of non-network option, AusNet Services is a not able to present further information of the detailed analysis that supports this conclusion.

7. Draft conclusion and next steps

AusNet Services has assessed that while all network options and non-network proposals provide voltage management services in North West Victoria, as required by clauses S5.1a.4 and S5.1a.5 of the NER and clauses 110.2.2(a) and 110.2.3(a)[52] of the Victorian Electricity System Code, not all are effective at HOTS.

Additionally, none of the non-network proposals are economically superior in replacing or deferring the credible network options being considered in this RIT-T.

On the cost-benefit assessment standpoint, AusNet Services confirms that replacement with a synchronous condenser (Option 2) is the most economic option as it provides the highest present value of net economic benefits in most scenarios and across all sensitivities investigated, as illustrated in Table 12, Figure 9, Figure 10, and Figure 11.

There are also other benefits from investing in Option 2 SCO that are not captured by the quantitative cost-benefit analysis such as option value and ability to implement transmission outages for maintenance.

This preferred option involves the following scope of work:

- Synchronous condenser,
- One (1) 220/13.8 kV transformer,
- Synchronous condenser protection & control,
- Transformer protection & control,
- New Building,
- 13.8 kV switchgear,
- One (1) 13.8/0.4 kV auxiliary transformer,
- One (1) 400 V switchboard,
- One (1) UPS system,
- New protection & control system and
- Synchronous condenser spare parts and tool set.

This option is expected to replace the current functionality of the SVC and provides additional inertia and system strength benefits.

Implementing this option will improve the reliability of the service and significantly reduce the risk of asset failure.

The estimated real capital cost of a new synchronous condenser of similar size to the current SVC is $24.79 million, while the operating and maintenance cost is estimated to be $35,000 per year.

AusNet Services' preliminary analysis shows that the optimal timing to deliver this option is as soon as possible. However, when construction and delivery lead time are taken into account, this option could realistically be delivered by 2023/24.

AusNet Services is the project proponent for the preferred option.

[52] "A transmitter must use best endeavours to maintain the normal voltage level at each point of supply with a nominal voltage at or above 100 kV within a range of plus or minus 10% of the voltage level nominated by VENCorp from time to time to the relevant transmitter and the relevant Participants which are supplied at that point of supply." Office of the Regulator-General, Victoria, '*Electricity System Code*,' available at https://www.esc.vic.gov.au/sites/default/files/documents/3d1fc9fd-18e0-4e10-a87a-e68ba2151a1a.pdf, viewed on 24 February 2021.

Appendix A - RIT-T assessment and consultation process

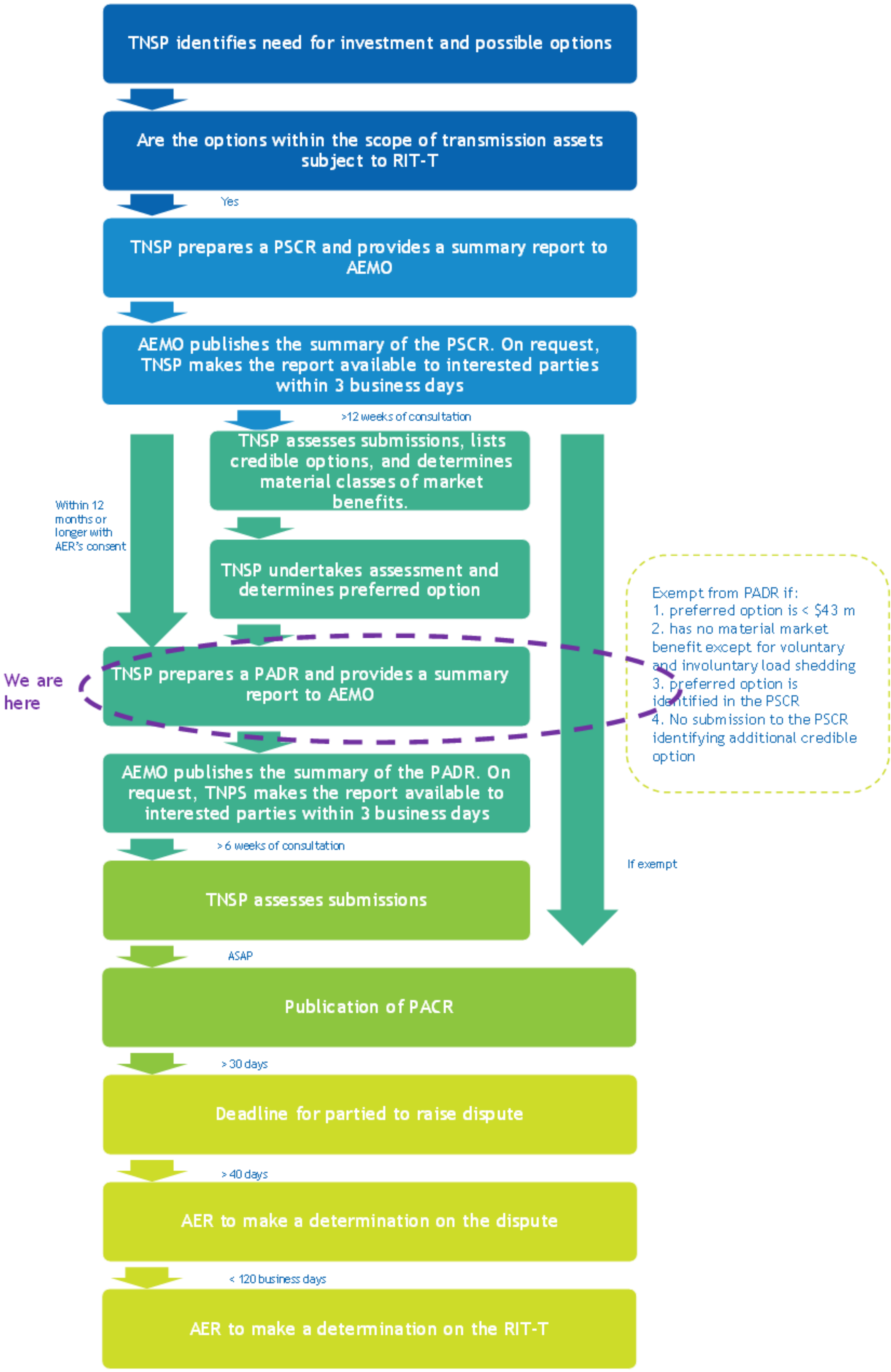

Figure 12 - RIT-T process

Appendix B - Checklist of compliance clauses

The table below demonstrates the compliance of this PADR with the requirements of clause 5.16.4(k) of the *National Electricity Rules version 157*[53], which states that a RIT-T proponent must prepare a PSCR which must include:

Table 13 - Summary of requirements

Requirement	Relevant section
(1) a description of each credible option assessed;	3
(2) a summary of, and commentary on, the submissions to the project specification consultation report;	4
(3) a quantification of the costs, including a breakdown of operating and capital expenditure, and classes of material market benefit for each credible option;	3 and 6
(4) a detailed description of the methodologies used in quantifying each class of material market benefit and cost;	5
(5) reasons why the RIT-T proponent has determined that a class or classes of market benefit are not material;	5
(6) the identification of any class of market benefit estimated to arise outside the region of the Transmission Network Service Provider affected by the RIT-T project, and quantification of the value of such market benefits (in aggregate across all regions);	3
(7) the results of a net present value analysis of each credible option and accompanying explanatory statements regarding the results;	6
(8) the identification of the proposed preferred option;	6 and 7
(9) for the proposed preferred option identified under subparagraph (8), the RIT-T proponent must provide: (i) details of the technical characteristics; (ii) the estimated construction timetable and commissioning date; (iii) if the proposed preferred option is likely to have a material inter-network impact and if the Transmission Network Service Provider affected by the RIT-T project has received an augmentation technical report, that report; and (iv) a statement and the accompanying detailed analysis that the preferred option satisfies the regulatory investment test for transmission.	3 and 7

[53] Australian Energy Market Commission, *"National Electricity Rule version 157,"* available at https://www.aemc.gov.au/regulation/energy-rules/national-electricity-rules/current, viewed on 24 February 2021.