Energy Infrastructure Investments

# Murraylink Transmission Annual Planning Report 2024

# Contents

# Executive Summary

Energy Infrastructure Investments (EII) owns and operates the Murraylink transmission asset. Murraylink Transmission Company Pty Ltd is wholly owned by EII and are registered Transmission Network Service Providers (TNSPs) in the National Electricity Market (NEM) as prescribed by the National Electricity Rules (NER). EII has prepared this Transmission Annual Planning Report (TAPR) in accordance with the requirements of section 5.12 of the NER.

The TAPR provides some key information on the Murraylink transmission asset, which is a high voltage direct current (HVDC) system serving the purpose of interconnection of the Victorian and South Australian regional electricity transmission systems. The asset consists of two converter stations located remotely from each other which are interconnected by an HVDC cable system.

This report also discusses the factors relating to the asset capability of providing a reliable service as an electrical interconnector between the relevant Australian states. A summary of projects is presented which aim to maintain the availability and reliability of the assets in line with the EII Asset Management Plan and NER requirements.

This report is written with consideration of the Australian Energy Market Operator's Integrated System Plan (ISP) published in June 2024. The ISP forecasts an increase in the connection of new renewable generation as the reliance on the fossil-fuelled power is scaled down which in turn requires the development of the transmission and distribution infrastructure as well as efficient utilisation of the existing assets.

With the commissioning of the Project Energy Connect AC transmission line in the near future which will operate in parallel with Murraylink, the utilisation of Murraylink is projected to decline but will still be utilised to the full capacity in both directions.

Furthermore, in a letter to APA, AEMO advised the future role of Murraylink in the evolving NEM will be to support resource firming, supporting peak demand, network controllability and outage management.

# 1. Introduction

## 1.1. Purpose of this Transmission Annual Planning Report

This Transmission Annual Planning Report (TAPR) is prepared as in accordance with the requirements of the National Electricity Rules (NER). Given the nature of the assets and the absence of any directly connected customers, this report covers those aspects of the prescribed TAPR content required by the NER[1] where specific comment is possible.

In its role as an interconnector between two transmission networks, the following content of the NER section 5.12 is not applicable to Murraylink:

- Clause 5.12.2 (c)(1) – information pertaining to the review and analysis of load forecasts; and
- Clause 5.12.2 (c)(2) – information pertaining to planning proposals for future customer or generator connection points.

The purpose of this report is to present key factors impacting the Murraylink HVDC transmission asset and define a level of asset capital investment considered by EII for the next 10-year period. In turn, this report looks to identify the need and opportunity for improvements in efficiency and reliability, general functionality of this asset in order to efficiently deliver the required services.

This TAPR also seeks to provide broader stakeholders with an overview of the planning processes and decision making on future capital investment applied to these assets. The aim is to provide information that helps stakeholders to understand this transmission asset's capability to transfer bulk electrical power and provide input into the future development of the transmission network.

### 1.2. Disclaimer

This TAPR is developed and made available entirely for information purposes. The information in this document reflects the forecasts, proposals and opinions adopted by EII and its subsidiaries as at the date of this report, except where otherwise specifically stated, and may change at any time. At any date, the reader should independently obtain the latest forecasts, proposals and opinions for their use.

Any information in this document that has been obtained from the Australian Energy Market Operator (AEMO), other Network Service Providers (NSPs) and other relevant sources has been adopted in good faith without further investigation or verification.

In all cases, anyone proposing to rely on or use the information in this document should:

- Seek to independently validate the accuracy, completeness, and suitability of the information pertained within;

[1] NER Clause 5.12 – Transmission Annual Planning Process

- Seek to independently validate the accuracy, completeness and suitability of the reports and source information used by EII for the development of this document; and
- Obtain independent and specific advice from appropriate experts or other sources.

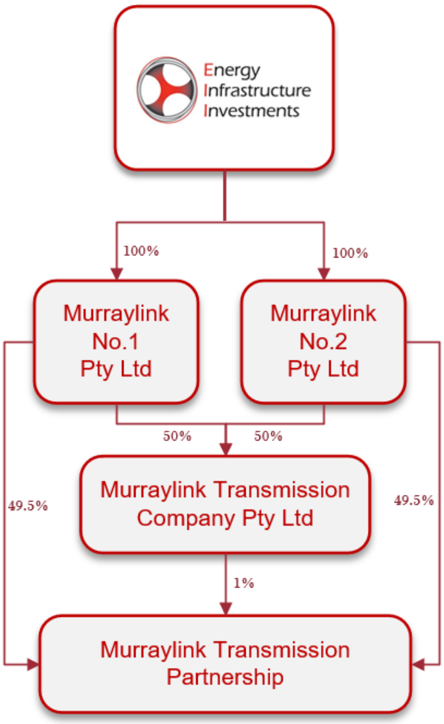
While care is taken in the preparation of the information presented in this report, EII accepts no responsibility or liability for any loss or damage that may be incurred by persons acting in reliance on this information or assumptions drawn from it.

## 1.3. APA Group and Related Entities

EII is an energy infrastructure investment company that owns and operates the Murraylink transmission asset. The asset is maintained and operated by APA Group under a Management, Operations, Maintenance and Commercial Services Agreement (MOMSCA). The Murraylink transmission asset provides transmission services to the NEM as prescribed by the NER.

The overview of ownership and management structure of the Murraylink interconnector is shown in Figure 1.

**Figure 1: Murraylink Ownership and Management Structure**



### 1.4. Registration Status and NER Obligations

The Murraylink proprietary limited company shown in Figure 1 is wholly owned by EII and is a registered Transmission Network Service Provider (TNSP).

The NER sets out the required processes for developing networks as well as minimum performance requirements of the network, which subjects the interconnector to the application of the Australian Energy Regulator's (AER's) Regulatory Investment Test for Transmission (RIT-T) where required.

## 2. EII's Transmission Assets

The Murraylink transmission asset is a high voltage direct current (HVDC) facility owned by EII, which serves the purpose of connecting two regional electricity transmission systems. The asset consists of two HVDC converter stations (which convert electrical power between AC and DC) located remotely from each other and are connected by a HVDC cable system. The Murraylink approximate converter station locations and cable routes are shown in Figure 2.

**Figure 2: Murraylink Cable Routes and Converter Station Locations [4]**

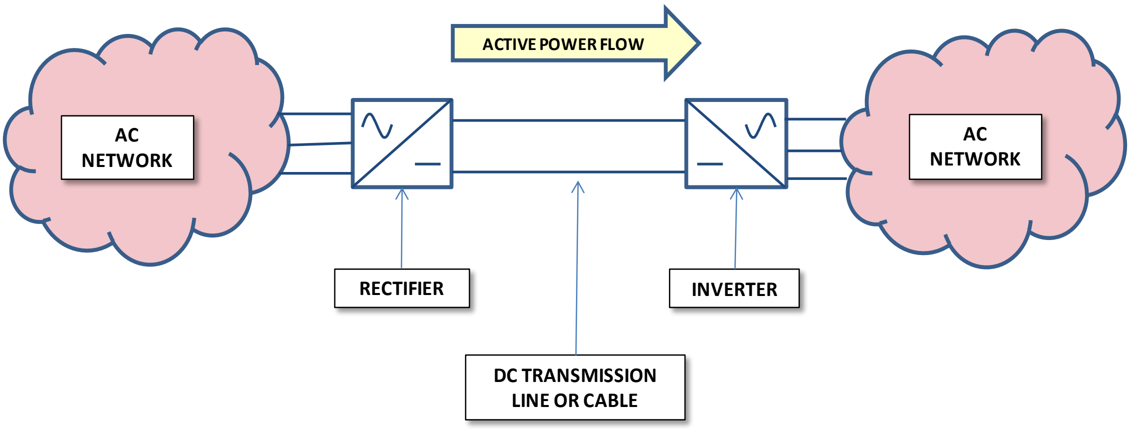

Murraylink was commissioned shortly after (2002) and connects the regional electricity markets of the South Australia and Victoria. Murraylink utilises voltage source converter (VSC) HVDC technology.

## 2.1. VSC HVDC Technology

### 2.1.1. Summary of VSC HVDC Technology and Capabilities

At the most basic level, HVDC power transmission is the point to point transmission of power by first converting it from AC to DC at the rectifier converter station, transmitting in DC to the inverter converter station and then converting back to AC at the inverter converter station. This is represented in Figure 3. The HVDC converter stations can operate in either rectifier or inverter mode depending on the direction of power dispatch.

**Figure 3 - HVDC Power Transmission - Basic Representation**




VSC HVDC technology uses the switching of insulated gate bipolar transistors (IGBTs) to develop an AC voltage waveform of sufficient amplitude and phase angle difference to cause both active power and reactive power to flow in either direction. The same IGBTs are used to create a DC voltage to allow active power to flow to or from the other converter. Consequently, VSC systems are capable of bi-directional, independent real and reactive power transfer. At each converter station, active and reactive power can be controlled independently within defined power limits. Reactive power at each end can be controlled independent of the converter at the other end.

VSC technology can connect to relatively weak[2] networks. VSC converters have no requirement to absorb reactive power and the filtering requirements are minimal, considerably reducing footprint area compared to other HVDC technologies. VSC technology can also provide other benefits at the connection point, including AC voltage control or frequency control where specified.

### 2.1.2. HVDC vs. AC Transmission Interconnection

There are pros and cons with the use of either AC or VSC HVDC technology for high power transmission interconnection. Table 1 provides a high-level comparison of AC and HVDC technologies for the purpose of transmission interconnection.

[2] System strength is an inherent characteristic of a power system, which is a measure of stability of a system under all reasonably possible operating conditions.

**Table 1 – Comparison of AC and VSC HVDC Technology for Power Transmission Interconnection**

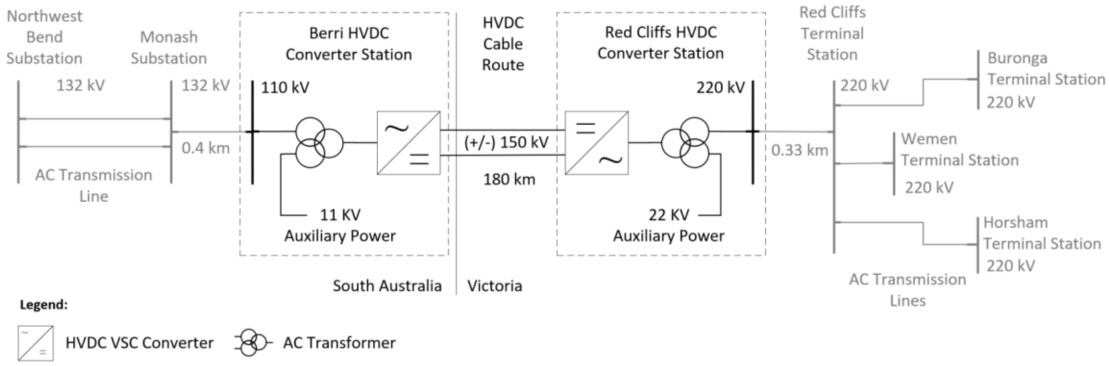
| Parameter | AC | VSC HVDC |
|---|---|---|
| **Controllability** | N/A | High |
| **Losses – substation/converters** | Lower | Higher |
| **Losses – lines/cables** | Higher | Lower |
| **Voltage support capability** | N/A | Available where specified |
| **Frequency control capability** | Yes, through synchronisation. Can only connect networks of same frequency. | Available where specified. Can connect networks with different frequency. |
| **Damping control capability** | N/A | Available where specified |
| **Overhead line** | Larger conductors, more conductors, larger towers | Smaller conductors, fewer conductors, smaller towers |
| **Underground cable capability** | More and larger cables, distance limited by cable capacitance. | No practical limit on distance, fewer and smaller cables. |
| **Transfer of issues of one region to next** | Managed via dispatch and external special protection schemes. | Controllable and inherently flexible. |
| **Tap off points along route** | No technical limit, low cost | Limited to a few and preferably known in advance, high cost |
| **Substation/converter station footprint** | Smaller | Larger |
| **Easement width for overhead lines** | Larger | Smaller |
| **Visual amenity of overhead lines** | Greater | Lesser |
| **Contribution to short circuit current** | High | Low |

VSC HVDC transmission has a number of technical advantages over AC transmission, including controllability of active and reactive power, lower losses on the transmission lines, voltage support and damping control capability. Conversely, AC transmission will have lower losses in the terminals (substations). For the same power transfer level, VSC HVDC transmission will be superior in terms of environmental impact and aesthetics – where underground cables are more viable, overhead towers are smaller, easement requirements are lesser and fewer conductors per bundle in the DC transmission lines may be achievable.

## 2.2. Murraylink

The Murraylink transmission asset is a HVDC facility, with an approx. 180 km HVDC transmission line between Red Cliffs in Victoria and Berri in South Australia, originally commissioned in 2002. The asset can transmit up to 220 MW of power bi-directionally between the two states. The DC transmission line consists of a pair of ±150 kV HVDC cables buried underground between the converter stations at Berri and Red Cliffs. The simplified single line diagram of Murraylink is shown in Figure 4.

**Figure 4: Murraylink Simplified Single Line Diagram**




Connection to the South Australian AC transmission system is established through the 132 kV Monash substation. This substation contains two line bays to accommodate the existing 132 kV transmission lines and a bay for connection of a 400 m underground AC cable tie to the Berri Converter Station. In Victoria, the Red Cliffs Converter Station is connected to a 220 kV bay at the Red Cliffs Terminal Station, by a 330 m underground AC cable tie. Three 220 kV transmission lines emanate from Red Cliffs terminal station connecting into the transmission networks in New South Wales and Victoria.

The dispatch of active power across the interconnector is determined by AEMO on a five-minute basis, within the physical constraints imposed by the AusNet and ElectraNet transmission networks.

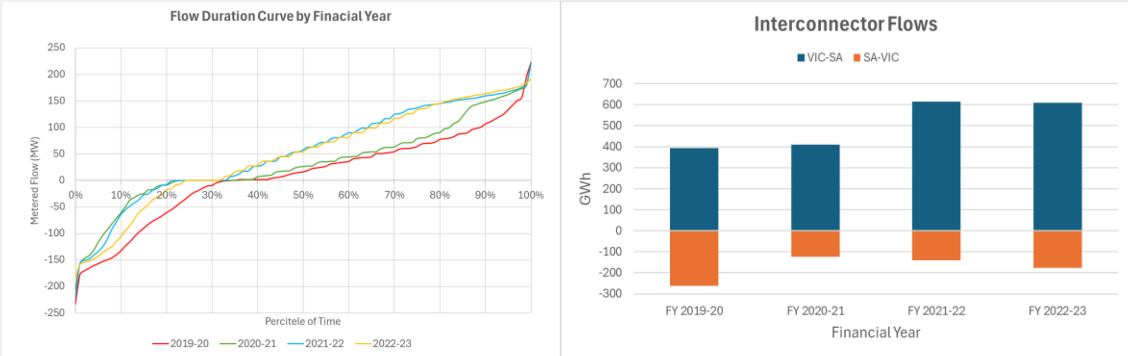
Being a point-to-point transmission network, there are no connections for generation or load on Murraylink and there are no individual connection point demand requirements associated with the asset. Murraylink is a transmission licensee in South Australia and exempt in Victoria.

# 3. Utilisation of Murraylink

The demand for Murraylink's services arises from the need for energy to be dispatched between Victoria and South Australia. Murraylink can control power transfers to the limit of its capacity, in either direction, between the two transmission networks.

The historic flows across the Murraylink transmission asset are presented in [3]

**Figure 5: Murraylink Historic and Forecast Utilisation[3]**




Approximately 780 GWh of electricity flowed across the Murraylink transmission asset in the 2022/23 financial year. This is an increase from the 2019/20 financial year, which saw an overall transfer of approximately 650 GWh.

This increase is expected to be due to the connection additional renewable energy generators and the need to share power between states to account for the retiring fossil fuel generation prior to commissioning of PEC [1].

# 4. The Changing Energy Landscape

In June 2024, AEMO published an Integrated System Plan (ISP) [1] which forecasts changes to the power system as a result of retiring thermal generation and an increase in connection of renewable energy generation and energy storage.

To further understand changes to the electricity transmission system, Murraylink has engaged in planning discussions that also considered emergency control and protection system design with AEMO, AusNet and ElectraNet over the preceding year. No material outcomes have resulted from these discussions. Further need for investment in the transmission network is anticipated in order to support the development and connect the projected portfolio of geographically dispersed renewable generation. The ISP identifies that increasing the interconnection of the grid will provide various benefits including flexibility and security as well as being able to take full advantage of the new and existing generation throughout the NEM.

Interconnectors provide a range of benefits, in particular:

- Enabling the lowest cost generation in the NEM to reach more consumers;
- Mitigating the risk of supply shortfall through imports from other regions;
- Sharing system stability support services, such as frequency and voltage control; and
- Improving system resilience to high impact, low probability events (such as interconnector failures) through a more interconnected NEM.

## 4.1. Impact of Project Energy Connect

AEMO has selected an optimal development path (ODP) that sets out the capacity of new grid-scale generation, firming, storage and transmission needed in the NEM through to 2050. Transmission infrastructure and its development plays a crucial part in the transition from fossil-fuels to firmed renewables and as reported in the 2024 ISP, close to 10,000 km of new transmission would be needed by 2050 under the Step Change and Progressive Change scenarios.

The ODP contains largely the same major transmission projects as in the 2022 ISP. Five committed and anticipated projects are well underway for delivery. Five previously actionable projects remain actionable and are advancing, including the Project Energy Connect (PEC).

Project EnergyConnect will be a new 330 kV high-voltage power line between South Australia at Robertstown and New South Wales at Wagga Wagga, together with a spur line linking to Victoria at Red Cliffs. It will be jointly constructed and operated by ElectraNet (South Australia) and TransGrid (New South Wales).

The first stage of PEC is anticipated in the 2024 ISP to be in service by September 2024 and to be at full capacity by December 2024. AEMO in a letter to APA have advised that following the commissioning of PEC, total utilisation of Murraylink is expected to be reduced, although the role of Murraylink will still be an important one as described in the following section.

## 4.2. Role of the Murraylink Interconnector

Murraylink's primary role in the National Electricity Market is that it enables the transfer of cheaper electricity between South Australia and Victoria. Additionally being an HVDC interconnector provides Murraylink with greater flexibility in operation than traditional AC systems.

As advised by AEMO in [2], there is an important and ongoing need to maintain the Murraylink interconnector, for the below reasons as stated in the letter:

*"Based on our studies for the 2022 ISP, we have observed an important and ongoing need to maintain the Murraylink interconnector, including:*

- ***Resource firming** – As the proportion of variable renewable energy (VRE) increases across the NEM, Murraylink will play a role in sharing firm generation and surplus resources between regions. Following the commissioning of Project EnergyConnect (PEC), total utilisation of Murraylink is projected to decline, but the full capacity is projected to be utilised in both directions.*
- ***Supporting peak demand** – At times of peak demand, particularly in South Australia, our modelling shows that Murraylink improves the capability to deliver a reliable supply of electricity to consumers. This role is particularly clear during periods of high demand, low VRE, network outages or generator outages, and*

*continues following the commissioning of PEC. Without Murraylink, additional capital investment (e.g. battery storage) would likely be required to meet the NEM reliability standard.*

- ***Network controllability** – The dispatchability of Murraylink is projected to improve network utilisation and reduce congestion by actively controlling flows parallel to PEC and Heywood. While PEC is expected to have some degree of controllability, through the use of phase-shifting transformers, Murraylink can much more actively follow a precise dispatch target. Murraylink's dispatchability will help balance flows on the network between South Australia, New South Wales and Victoria. This capability is particularly valuable in the event of high coal and gas prices.*
- ***Outage management** – During both planned and unplanned outages, Murraylink improves the capability of the grid to provide consumers with reliable and secure electricity supply. Importantly, the presence of Murraylink is expected to increase the duration of outage windows that are critically needed to maintain the surrounding network – including Heywood and PEC.*
- ***Voltage management** – The STATCOMs at both ends of Murraylink improve voltage management at Red Cliffs and Monash by providing dynamic voltage support. This improves the resilience of the grid in these areas.*

*Importantly, our studies have found that PEC and Murraylink will be able to simultaneously import or export at their combined maximum transfer levels during some conditions. Amongst other factors, the actual dispatch of Murraylink and PEC will be optimised in combination with bids from local generation and storage."*

Murraylink's asset management process does not forecasting any new asset de-ratings, constraints or inability to meet network performance requirements over the next 5-years.

Murraylink is working with AEMO on implementing an approach to implement dynamic real time limits to optimise dispatch and asset utilisation during high temperature periods over Summer.

# 5. Looking After Our Assets

EII has an Asset Management Plan (AMP) [6] that identifies the actions required for optimal management of its assets. A long-term consideration of the integrity of assets is necessary to ensure that they continue to provide the required services.

The purpose of the AMP is to:

- Provide a comprehensive understanding of the current management approach relating to the asset, its condition and utilisation;
- Identify strategic recommendations for future utilisation;
- Provide a platform for approval of work programs; and

- Identify specific issues affecting the assets and the proposed remediation for budget consideration.

The objective of this AMP is to ensure that a strong focus on safety and reliability is maintained in relation to the operation and management of the Murraylink assets. In developing the operating and maintenance procedures incorporated within the AMP, APA Operations EII Pty Limited (as Operator) has considered the approved policies and procedures of APA Group.

Suitable safety management systems are in place and operating to ensure that the risks relating to the operation of all EII assets are effectively managed to keep risks as low as reasonably possible. The APA Group HSE management system is called ‘Safeguard’ and provides a framework by which the processes relating to EII’s HSE activities are written, approved, issued, communicated, implemented and controlled. Additionally, the management system is also subject to review and improvement to ensure objectives and obligations are continually satisfied.

EII management systems are subject to review and improvement to ensure objectives and obligations are continually satisfied. The AMP is reviewed each year to ensure that the content is current.

The AMP describes the applied asset management processes, which requires the asset maintenance history, condition and service performance of each component to be monitored.

Functionally, the equipment at Murraylink, at a high-level, can be divided into two groups:

- Main circuit equipment – These include power transformers, power electronic equipment, filtering equipment and underground cables. These have a standard design life of 40 years or more with some of these now beyond the mid-period of their useful service lives; and
- Ancillary equipment – Equipment necessary for the operation of the converters, notably uninterruptable power supplies, building ventilation, air conditioning, cooling water pumping and treatment systems and control and protection systems. The ancillary equipment generally has shorter service lives (between 15 and 25 years) with elements of the equipment currently at various stages in their service life.

The principal challenges associated with the interconnector relate to maintaining the electrical installation, with its many components, to meet high reliability and availability standards. Even so, components need to be replaced or refurbished when:

- The service performance of the equipment deteriorates, to the point where it jeopardises the reliability and availability performance of the link;
- Maintenance costs escalate, to the point where it becomes economic to replace or refurbish the equipment; or

- Equipment associated with auxiliary systems becomes obsolete, with the potential to jeopardise the availability performance of the link due to unavailability of spare parts.

Some of the equipment will require refurbishment or replacement during the 2023-2028 [6] regulatory control period. Section 8 and 9 or this TAPR provides a summary of the projects that are either underway or have been proposed.

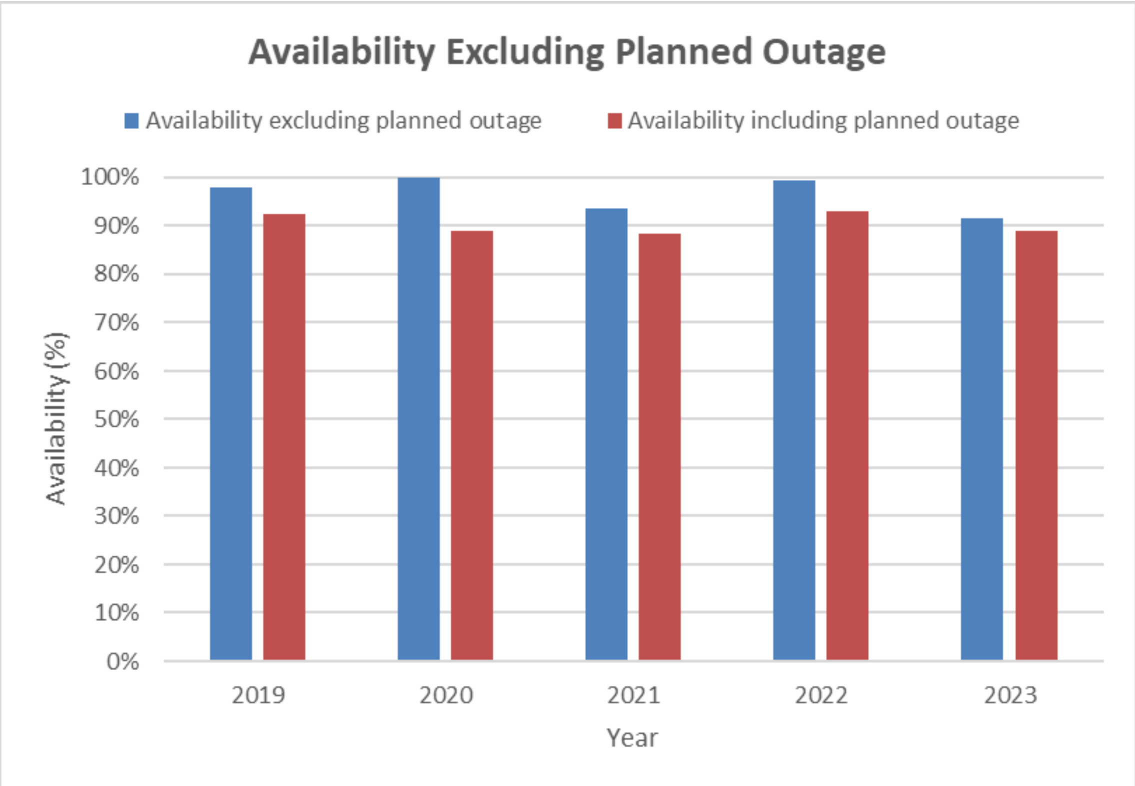
# 6. Asset Availability and Reliability

The following sections provide a high-level assessment of the Murraylink availability based on historical data over the five-year period of operation from 2019 to 2023. This data is used by EII to review the asset performance and development of strategies for maintenance or improvement of the interconnectors in accordance with the EII AMP.

## 6.1. Murraylink Availability

Murraylink is now in its 23rd year of operation. Murraylink is a reliable facility which has displayed an annual average of 96% circuit availability over the last five-year period, which excludes planned outages as shown in Figure 6.

**Figure 6 – Murraylink Annual Availability**




While the main circuit equipment has a long-life span, ancillary equipment necessary for Murraylink operation have shorter life spans. Some of this equipment is or will be undergoing replacement or refurbishment during the 2022-26 regulatory control period in order to make sure that the link remains in a highly reliable state of operation.

# 7. Completed Projects

This section presents the major projects which were recently completed for the Murraylink HVDC interconnector.

## 7.1. Murraylink Recently Completed Projects

### 7.1.1. Murraylink Control and Protection Replacement

The Murraylink control and protection system was designed and manufactured in 1999 and some of the control system hardware utilised (processors, electronic chipsets, circuit boards) would have become obsolete circa year 2020. Due to the unavailability of hardware spare parts and manufacturer support for the software, a replacement of these systems and equipment was carried out.

The project activities started in early 2018 which included the replacement of the main control computer, control cards and operator HMIs, as the hardware and software reached the end of its serviceable life cycle. The replacement of the obsolete hardware and software is expected to extend the serviceable life of these components by a further 20 years from when it was commissioned in 2020.

### 7.1.2. Cooling Water Drive Replacement

Pumping systems for cooling water circulation are essential to the operation of the Murraylink asset by ensuring adequate cooling of the IGBTs. A component of this system are the AC variable speed drives which regulate the flow of water. The OEM had advised that the original drives were in their obsolescence phase and required replacement.

### 7.1.3. Cable Protection

The works included in this project improved the security of the cables by improving the cable protection and increasing public awareness of the cable location. The scope included:

- Reviewing the cable route to ensure development along the cable route has not compromised the original cable design requirements.
- Any other necessary proactive relocation of the cable route.

### 7.1.4. Enhanced Cooling Systems

This project addresses the negative impact of high summer ambient temperatures on power flow. The project scope was to implement secondary cooling systems to enhance the heat rejection of the existing cooling equipment. Also included in the project were upgrades to the deioniser, nitrogen supply and cooling towers to enhance the cooling system.

#### 7.1.5. Control Room SCADA

This project was to implement SCADA infrastructure to allow control room services for Murraylink from the APA Integrated Operations Centre (IOC) as the contract between ElectraNet and Murraylink, for providing control room services, was set to expire in September 2022. APA now provides control room services for Murraylink from the IOC.

# 8. Committed Projects

This section presents the major projects which are currently underway for the Murraylink asset (APA).

## 8.1. Murraylink Committed Projects

#### 8.1.1. Power Supply Upgrade

The battery chargers in the converter station have reached the end of their economic life and a failure of a battery charger could result in a significant outage. New battery chargers were purchased for the Berri Converter Station in 2018 creating spare components for the older chargers located at Red Cliffs. The remaining obsolete chargers in Red Cliffs are to be replaced in FY25 at an approximate cost of $0.8m.

#### 8.1.2. Essential Spares

To maintain the high level of plant integrity, an amount for critical spares has been allocated. This category of expenditure procures spare parts essential for the ongoing operation of the converter stations. The items include capacitors and other spares facing obsolescence and requiring long-lead times to acquire APA is working to procure 2 x dry-HED capacitors and working with Hitachi to lock in a production run.

#### 8.1.3. Test Equipment

The test equipment replacement project is intended to address the obsolete test equipment and systems for the ongoing reliable operation of the converter stations. The items included for procurement under this project are listed below:

- Cable Hi-pot tester and cable fault locator (‘thumper”) replacement at $1.7m

#### 8.1.4. Reliability

The projects listed below enhance and/or maintain the service provided by Murraylink to the National Electricity Market and are undergoing options evaluations this financial year:

- Flood mitigation measures.
- Critical infrastructure security enhancements.
- Power Quality Metering

# 9. Proposed Projects

Murraylink has progressed initial investigations into the available and viable options for extending the life of the Murraylink HVDC facility. An approach for managing the converter station to reach its operational design life of up to (and possibly beyond) 40-years has been considered.

This section incorporates outcomes from the Extension of Life Assessment and presents the major projects which are proposed for the Murraylink HVDC transmission assets over the next 10-year period. The OEM is the sole provider of equipment and replacement spare parts, of which some components are obsolete. Options are being investigated with the OEM into how this equipment can be replaced. These projects in this section do not all have practical estimated costs at this stage.

There are no proposed or planned augmentation works to enlarge the system or to increase its capacity.

## 9.1. Reliability Improvement and Lifecycle Replacement Works

The following projects have been identified for Murraylink based on a need to either increase the reliability of the asset, maintain emergency controls or to replace the identified component(s) to maintain reliability and/or for lifecycle replacement reasons.

### 9.1.1. Extension of Life Project

The extension of life assessment has raised three major components that require replacement. IGBT Positions, DryHED Capacitors and Phase Reactors. The project is currently in options assessment and estimates are not yet established. OEM engagement is occurring to refine cost estimates and practical options. Sections below consider each of these replacement components and initial options considered.

Further options analysis and detailed cost estimates will be provided throughout the related RIT-T process for this project that is scheduled to commence by July 2025.

IGBT Positions

Prompted by the Hitachi notice on the ceasing of OEM support/production for the IGBT positions and limited available spares, Amplitude Consultants were engaged in June 2022 and presented the outcomes of an assessment on options available to APA to ensure continued operation of the plant to meet a 40-year design life [5].

A summary of the key background information and options assessment outcomes is as follows:

- Murraylink uses Hitachi's (previously ABB) Generation 2 IGBT positions, with approximately 3,000 IGBT positions in each converter station.
- The total spares holding is estimated at 165 units, with the population presently failing at a rate of 24 per year.

- It is projected that the available spare IGBT positions will be exhausted circa 2028, assuming a constant failure rate.

The options considered are to allow for a replacement of the IGBT positions or alternatively the entire valve system so that the facility can support the newer generation of IGBT positions or new generation IGBT submodules that are expected to be continued to be supported over the coming years or decades.

A summary of the valve replacement options assessed are listed below [5]:

1. **Continued operation with existing valves (i.e., do nothing):** Based on the current stock of IGBT positions available, it is estimated that there will be only 4-5 years of operation possible, assuming the current rate of failure of IGBT positions. If the failure rate were to increase, which is possible, this will shorten the operational life to even less – after which there will be insufficient spare parts to allow the Murraylink facility to be restarted.

2. **Replace existing IGBT positions with a newer generation of IGBT position:** This option would entail replacement of the existing Generation 2 IGBT positions with a newer IGBT positions (Generation 3) from the same supplier (Hitachi).

   These IGBT positions will not be compatible, from a physical and electrical perspective, with the Generation 2 IGBT positions, and as such the minimum amount that can be replaced is expected to be a single phase at one converter station.

   The balance of serviceable IGBT positions from the replaced phase would be recovered, retained and stored as spare parts to be used on the remaining (not upgraded) valves. This solution would increase the stock of spare Generation 2 IGBT positions, however it will not reduce the rate of failure and it is likely that significant planned outages in the future to replace failed IGBTs will be required. There is also concern that even the Generation 3 IGBTs (the ones used to replace the Generation 2) are near or at the end of its support life by the OEM.

3. **Replace one converter with VSC MMC valves:** The replacement of the existing valves with VSC modular multi-level converter (MMC) technology would address the IGBT obsolescence issues. MMC technology has been around for almost 15 years, and all new VSC HVDC systems being installed today and over the coming years are all utilising MMC technology. It is expected that replacement with these MMC valves will increase the life of the valve at one converter by at least 25 years. For the other converter, the removed Generation 2 IGBT positions will increase the stock of spare parts, however the same issues raised in item 2 (rate of failure, continued planned outages, support life of the Generation 3 IGBTs) would apply for this converter.

4. **Replace both converters with VSC MMC valves.** This is the preceding option as described, however with both converter stations replaced. This will have a much higher capital cost, although the replacement of both converter stations could be done in parallel to minimise the overall impact on the outage of Murraylink – and therefore the expected outage would be about the same as for the single-converter

replacement option. The reduction in losses and improvements in reliability and thermal performance, would be realised at both converters. In addition, the option will result in the futureproofing on the entire HVDC system, without any need to retain and use existing Generation 2 IGBT positions or to rely on the Generation 3 IGBT positions, with an extension of at least 25 years for both converters.

At this stage of the assessment, these options are to be considered as a high-level estimate only with key assumptions as defined in our earlier report [5]. Further information and detailed cost estimates will be provided throughout the related RIT-T process for this project that is scheduled to commence by July 2025.

Previous economic analysis has identified that the most likely cost efficient approach is for the replacement of a single phase of Generation 2 IGBTs with Generation 3 IGBTs [8], although this does not consider the expected drawbacks of this solution when compared to the MMC valve replacement options, including:

- No change to or increasing rate of failure (reliability).
- Continued planned outages to replace failed IGBT positions (availability) and concerns on the support life of the Generation 3 IGBTs (technical obsolescence).
- Potential to avoid other projects e.g. capacitor and phase reactor replacement.

The final decision on the preferred approach is still to be determined with further economic analysis, refinement of options, risk assessment and ongoing engagement with suppliers.

DryHED Capacitors

The DryHED capacitors experienced a failure at the Berri Converter Station in September 2023. APA have been in consultation with Hitachi with regards to replacement spare parts and have been advised that this equipment is no longer being manufactured and supported by Hitachi. Available options are being investigated of how to manage the risks, with some of the proposed options presented below:

- Hitachi to restart manufacturing of the same DryHED capacitors.
- Replacement of the current type of capacitors with a smaller DryDCap capacitors.
- Using larger quantities of smaller capacitors as an alternative replacement strategy.

The DryHED capacitor replacement would not be required if both stations were to be upgraded to VSC MMC technology.

Phase Reactors

Typically for high voltage reactors, regular condition assessment and monitoring can be applied to achieve a 30-year useful operating life. However, the OEM has advised APA that these water-cooled reactors are now obsolete and this poses a potential risk to the asset, as failure of this equipment may remove the converters from operation for a substantial amount of time while waiting for a redesign and replacement of a bespoke reactor.

The options that may be considered for the phase reactors are as follows:

1. Replace the water-cooled reactors at both stations with an air-core type and associated forced cooling (preferred).
2. Replace the reactors at one station but retain the removed water-cooled reactors as spares for the second station, noting there are current concerns on condition and coolant leakage.

The above-mentioned options are expected to positively influence the useful life expectancy of the Murraylink facility and minimise the risk of extended outages in the case of a reactor failure. The selected option will depend on a techno-economical assessment or this activity.

Note that if both converter valves were to be replaced with MMC technology (as described in Section 9.1.1), these phase reactors will be replaced with smaller, air core reactors that have  relatively less onerous cooling requirements, which allows for the removal of the water-cooled reactors and associated cooling equipment from the system completely.

#### 9.1.2. Cooling Systems

The outdoor components of the cooling system will need to consider its current condition and corrosion level and any further deterioration to ensure that a 30-year useful operating life can be achieved.

CIGRE reports that the valve cooling equipment should have a useful operating life of 25 years ±5 years, however this is on the premise that the equipment has been well maintained and not stressed beyond its design parameters [7].

While replacement of the valve cooling system on its own (without replacing the valves) has been performed on other projects, it is often the case that the valve cooling system is replaced when a valve replacement is undertaken [7].

The options that may be considered for the life extension plan for this asset are as follows:

1. Perform a complete replacement of the cooling systems contingent on a valve upgrade project being undertaken, which would add an additional 25 years (±5 years) to the life of this equipment.
2. Assuming that the current design of the cooling system is compatible with the either of the proposed IGBT upgrade approaches, keep the original valve cooling system and conduct a detailed assessment to determine its condition. If the assessment does not return with any significant concerns, increase the condition assessment and testing maintenance cycles to ensure that the equipment is not degrading rapidly with age. Noting, the reactor cooling system can be de-commissioned should MMC valves be installed.

3. If the valve upgrade project is not implemented, increase the testing and maintenance frequency to ensure that the equipment is not degrading rapidly with age. Additionally, undertake any remedial maintenance activities as required to ensure serviceability.

#### 9.1.3. Fibre Optic Cables (Valves)

Fibre optic cables are installed within the IGBT valves to communicate information from the valve control unit (VCU) to each IGBT. A gradual deterioration over time in the performance of these fibre optic cables has been identified at Directlink, being an older project to Murraylink, which has had an impact on its availability. This necessitated a program of work to replace the fibre optic cables with new cables in Directlink and it is expected the same could be required to be performed in Murraylink to ensure that the reliability of the Murraylink facility is maintained.

#### 9.1.4. AC Circuit Breakers

Hitachi has advised APA that the specific circuit breaker model used on site will be obsolete and component level replacements will not be available. It is expected this equipment will need to be replaced in the near future due to technical obsolescence and non-availability of spares.

#### 9.1.5. AC Protection Relays (Red Cliffs)

The AC protection relays at the Red Cliffs Converter Station protect the AC power cables to the Red Cliffs Terminal Station. These relays are now obsolete with one unit having failed in early September 2024 and are being replaced with limited spares. This is not an issue at the Berri Converter Station as the equivalent AC protection relays were upgraded in 2019. Replacement of the Red Cliffs AC protection relays will need to be performed due to technical obsolescence and non-availability of spares.

#### 9.1.6. DC Current Transformers (LEM)

This equipment is used for the current measurement on the DC cables in the DC filter room. These devices are no longer supported by the OEM (obsolete) and APA is investigating options to replace these devices in due time. The options for this replacement are limited and similar equipment may be sourced for complete overhaul in the case of a failure in the future.

#### 9.1.7. Cable Relocation

The Murraylink cable could require relocation to make way for potential developments, or road realignment, along the cable route in the future. The Murraylink cables have non-exclusive rights to occupy road reserves under section 93(1)(d) of the Electricity Industry Act and a licence with Vic Roads in Victoria; and under section 47 the Electricity Act in South Australia. In the event that a future development is planned for an area where the cables are installed, Murraylink is likely to be required to relocate or otherwise protect the cables from damage. This proposal is contingent on a future development that requires the relocation of the Murraylink cables where the estimated cost is $2.2m as outlined in the current revenue submission.

#### 9.1.8. Refurbishment/Replacement

The refurbishment works are planned to ensure the ongoing serviceability of a range of ancillary equipment at the converter stations. This equipment is essential to the continued reliable performance of the converter stations. These items include:

- Valve and reactor cooling system pumps.
- Valve and reactor cooling system electric motors.
- Cooling tower electric motors.
- Motor control centre motor start contactors.
- Motor control centre control relays.
- Motor control centre switches.
- Dehumidifiers.

#### 9.1.9. Other Maintenance Projects

The below works were identified as requiring to be actioned in next 5-year period to maintain safe and reliable operation of the asset:

- **Phase Reactor Cooling Chiller Pump Motor** – surface condition of the externally located pump motor identified as suboptimal due to aging and environmental effects, which will require further assessment and potential replacement.
- **Local Operator Workstation (LOWS)** – LOWS were installed as part of the control and protection system upgraded to Mach III in late 2020, therefore the remaining life of the system is dependent on the support durations form Hitachi. Computers and other equipment relating to the LOWS as part of the control and protection system can be relatively easily acquired in the next 3-5 years to meet the next mandatory replacement interval.
- **Fire System –** re-painting required as part of the maintenance cycle is required for the outdoor piping at the fire system pump house.
- **Transformer Components –** deteriorating surface condition on the transformer surge arrestor insulator requires the component to be replaced to maintain a reliable operation of the transformer.
- **Transformer Body (Red Cliffs)** – surface condition of line three power transformer requires testing and remedial actions.

## 9.2. Future Works Beyond the Next 10-Year Period

From an extension of life assessment conducted in September 2024, there were a number of projects identified that will be potentially required close to or at the end of Murraylink design life of 40 years, as presented in Table 2. These potential works are heavily reliant on the condition of each individual piece of equipment, which are to be monitored and assessed carefully to determine when the replacement will be warranted.

**Table 2 – Life Extension Approach and Replacement Intervals**

| Component | Life Extension Approach | |
|---|---|---|
| | Procure spares | Replacement |
| Transformer bushings | 2030 | 2035 |
| Transformer tap changer | 2030 | 2035 |
| Transformer cooling system | 2030 | 2035 |
| Valve cooling system (See Note) | 2030 | 2035 |
| DC voltage divider | 2030 | 2035 |
| DC surge arresters | 2030 | 2035 |
| DC insulators (Silicone Rubber) | 2030 | 2035 |
| Instrumentation (current and voltage) | - | 2035 |
| Telecommunication interface / equipment | 2030 | 2035 |
| Fire System – VESDA and fire panels | - | 2035 |
| AC and DC switchgear - disconnectors and earth switches | - | 2040 |
| DC insulators (Ceramic) | - | 2040 |
| AC cable protection relays (Berri) | - | 2040 |
| Control and protection system | 2035 | 2040 |
| *Note: Potential replacement during valve upgrade project if implemented.* | | |

# Appendix A – Abbreviations and Definitions

## Abbreviations

### Table – Abbreviations

| AEMO | Australian Energy Market Operator |
|---|---|
| Hitachi | Company and supplier of the asset HVDC equipment (originally ABB) - main Contractor and OEM for this asset |
| AC | Alternating Current |
| APA | APA Group company and operator of Murraylink |
| DC | Direct Current |
| HV AC | High Voltage Alternating Current |
| HVDC | High Voltage Direct Current |
| IGBT | Insulated Gate Bipolar Transistor |
| NER | National Electricity Rules |
| OEM | Original Equipment Manufacturer |
| VCU | Valve Control Unit<br>VCA – Valve Control Phase A<br>VCB – Valve Control Phase B<br>VCC – Valve Control Phase C |
| AEMO | Australian Energy Market Operator |

## Definitions

In this document, unless the context requires otherwise, capitalised terms have the meanings set out as per below.

a. **Converter** means the special equipment needed to convert electricity between AC and DC, and utilising power electronic devices and associated electrical and auxiliary equipment.

b. **Converter Building** means the structure housing the Converter and associated electrical and auxiliary equipment. The Converter Building consists of a control room, a valve cooling room, a reactor cooling room, 12 valve enclosures, a reactor room, an indoor AC yard and an indoor DC yard.

c. **Converter Station** means the site where the Converters and associated high voltage switchgear are installed.

d. **Murraylink** means the HVDC Transmission System that connects the high voltage power networks at Red Cliffs in Victoria and Monash in South Australia via High Voltage DC cables.

e. **Red Cliffs Converter Station** means the Murraylink converter station located at 716 Woomera Avenue, Red Cliffs, Victoria, and consisting of one Murraylink Converter Station.

f. **Berri Converter Station** means the converter station located at 18903 Sturt Highway in Monash, South Australia, and consisting of one Murraylink Converter Station.

g. **Site** means either or both of the Red Cliff Converter Station and/or the Berri Converter Station.

## 10. References

[1] AEMO. (2024). Integrated System Plan. AEMO.

[2] AEMO Communication. (2022). The future role of Murraylink in the NEM - September 2022. AEMO.

[3] AEMO- NEMWEB - Data_Archive - Wholesale_Electricity - MMSDM. (n.d.). https://nemweb.com.au/Data_Archive/Wholesale_Electricity/MMSDM/. Retrieved October 2024

[4] AEMO Network Visualisation Tool. (n.d.). Retrieved 2024, from http://www.aemo.com.au/aemo/apps/visualisations/map.html

[5] Amplitude Consultants. (2022). Murraylink Valve Replacement, Project Options Assessment. Retrieved October 2024, from https://www.aer.gov.au/system/files/Murraylink%20-%20Attachment%202%20-%20Amplitude%20-%20Report%20on%20IGBT%20Options%20-%20June%202022.pdf

[6] APA. (n.d.). Asset Management Plan CY2022 to CY2026.

[7] CIGRE TB 649, Guidelines for life extension of existing HVDC systems. (2016).

[8] Oakley Greenwood, Economics of Replacing IGBTs on Murraylink, Final Report, November 2022. (n.d.).

[9] Schneider. (2021). Preventive Maintenance / Regular Preventive Maintenance Report. Schneider.