Control and Protection System Upgrade -

Business Case

29/8/25

Document Control

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Table 1.1: Revision Record

Version	Date	Updated By	Changes Made
0.1	*12/05/2023*	*James Turnley, JT Economics*	*Initial draft*
0.2	*16/08/2023*		*Feedback received from group discussions*
1	*15/09/2023*		*Final*
1.1	*29/08/2025*		*Update for changes since final*

Table 1.2: Review and Distribution

Name	Role	Action	Sections
Greg Mather	*Senior HVDC Systems Engineer*	*Input*	*All*
Jamie Horwood	*Asset Lifecycle Manager*	*Input*	*All*
Tom Slee	*Senior Feasibility Engineer*	*Input*	*All*
Prasoon Premachandran	*Team Asset Engineering*	*Input*	*All*
Mark Allen	*Senior Regulatory Manager*	*Review*	*All*
Shan Paramasibam	*Head of Power Engineering*	*Review*	*All*

This document requires the following approvals. Approvals are inserted as an object in the table below (preferred) or stored with the approved document in electronic version on the Project Site in Project Server.

Table 4: Approvals

Name	Role	Approval	Date Approved
Gab Avens (Acting)	*Head of Power On Grid*		

Other project specific approvers can be added if required.

Delegation Policy

Contents

1. Executive Summary

1.1. Action Requested

This business case seeks approval of $90.6 million ($2026) to undertake the project. This project will replace of the Basslink control and protection system. This includes the control and protection systems for station control (AC feed and filters), pole control (thyristor firing pulses, DC yard, converter transformers and valve cooling), communication equipment (COM), Human Machine Interface (HMI) and valve cooling control systems.

This project will result in the lowest lifecycle costs to ensure ongoing safe and reliable operational of Basslink.

The project is due to commence 2026 and is scheduled to be completed by June 2030.

1.2. Alternatives Considered

Option 1 – Control and Protection System replaced by 2030. (recommended option)

Option 2 – Control and Protection System replaced by 2032.

1.3. Project Overview

Basslink is the HVDC interconnector which connects the Tasmanian and Victorian AC grids. Commissioned in 2006, Basslink is critical to the electricity networks in Tasmania and Victoria, protecting against the risk of energy shortages and providing peak load power.

The control and protection system is the 'brain' or 'supercomputer' which ensures safe and reliable operation, and seamless integration with the existing AC grids. The HMI is the system which allows the Control and Protection System to be controlled.

At the time of the revenue reset proposal Basslink expected the Control and Protection system to become obsolete in line with some preliminary announcements by Siemens and international experience with Control and Protection Systems.

Operating obsolete systems beyond their design life escalates the risk of failure, brings challenges around spare part availability, and risks more frequent and more prolonged outages. Bearing this additional risk doesn't deliver any material benefits. Extending the life of the initial system directly shortens the operational (and economic) life of its successor, given its life is limited by the life of the thyristor valves.

Relevant considerations include:

- Basslink's design which assumes a replacement of the control and protection equipment midway through the design life of the thyristor valves and again when the thyristor valves are replaced.
- CIGRÉ (the International Council on Large Electric Systems) recommends that these systems are refreshed midway through the design life of the thyristor valves.
- Due to the criticality of HVDC interconnectors, global practice is to replace these systems at around 20 years.

In turn, optimisation of lifecycle costs requires balancing:

- the replacement of the control and protection system close to the midpoint of its design life to maximise the economic value of both the initial and the replacement system and to reduce the risk of failure, and
- replacing the system at the beginning of a new product life cycle to ensure the system is in place for the longest period before becoming obsolete.

Since the revenue reset proposal Siemens has clarified the extent and nature of the obsolescence and has outlined the platform that it intends to move to as the successor to the current Control and Protection System and Valve Based Electronics.

Given the importance of this decision, we have engaged our customers through multiple deep and broad channels to understand their views on when to replace the Control and Protection System. Most customers – between 68% and 77% depending on customer location – told us that they supported replacement of the system 2025-30 to avoid the potential negative impacts of a Basslink failure. About one quarter considered that we should wait to ensure access to newer technology while a smaller proportion supported delaying investment due to current cost-of-living pressures.

We have also considered increasing market pressures due to a forecast bow-wave of Control and Protection System replacements and new HVDC system. Given the limited number of vendors available, delaying the replacement of the Control and Protection System is likely to reduce our bargaining power increasing prices and risking availability.

Given these factors, replacing the control and protection system by 2030 is the preferred approach as it:

1. is consistent with consumer preferences to replace system by 2030 to reduce reliability risks.
2. enables the transition to the next generation of control and protection systems (also consistent with feedback from consumers).
3. reduces the difference in economic life between first and second control and protection system.
4. reduces market pricing and availability risks.
5. Reduces the risks of outages of the network

1.4. Consistency with the National Electricity Rules

The forecast capital expenditure for this project is required to achieve the capital expenditure objectives, specifically, in relation to the requirements on Basslink under the Basslink Operating Agreement (BOA) (between Basslink and the Tasmanian Government) to comply with Good Electricity Industry Practice[1] and to maintain the operation of Basslink.

[1] see description in Attachment 7 of the Original Proposal

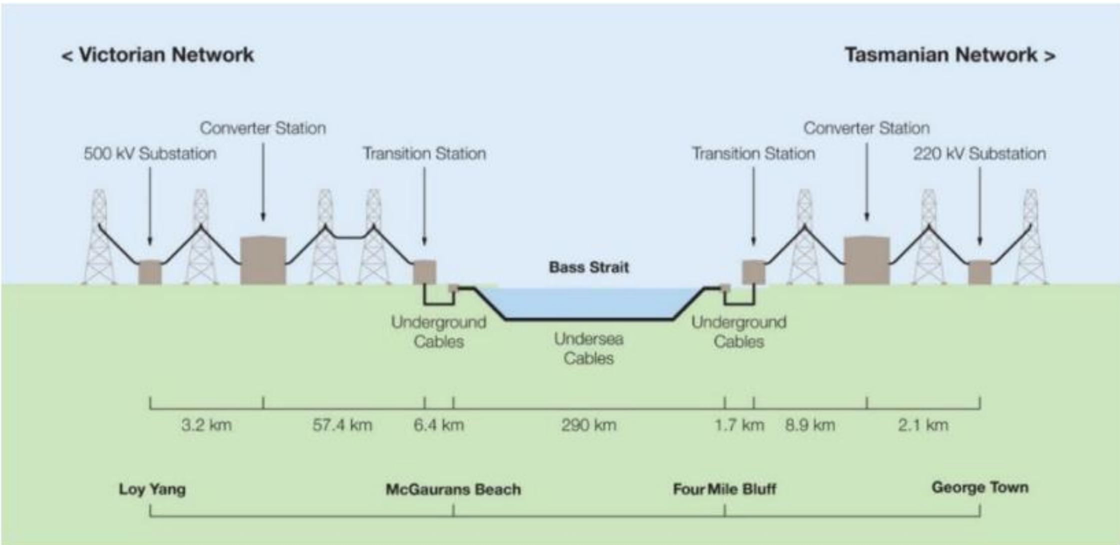
2. Background

2.1. Basslink

Basslink is a 370 km high voltage direct current (HVDC) electricity interconnector between Loy Yang Victoria and George Town Tasmania. Basslink enhances security of supply on both sides of Bass Strait; protecting Tasmania against the risk of drought-constrained energy shortages and protecting Victoria and southern states against the shortage of peak load power.

Basslink is comprised of several major components including overhead transmission lines, underground cables, undersea cables, transition, and converter stations.

Figure 2.1 Basslink Network Overview (including substation connection points)



2.2. HVDC interconnectors

HVDC interconnectors are complex, integrated systems with several components and advanced sub-systems. Many elements are common to other infrastructure, such as breakers, disconnectors, transformers, reactors, capacitors etc – which can have a relatively long-life expectancy.

However, HVDC interconnectors have several unique elements that differ to typical AC infrastructure such as the valves and the sophisticated control and protection system. These components are specialised and subjected to unique electrical stresses requiring highly specialised design and materials. Compared to AC systems, there's limited data on failure modes for HVDC interconnectors – especially when operated beyond their design life – due to factors such as the:

- Small number of HVDC interconnectors in operation.
- Diverse range of HVDC technologies (due to differences in vendors and advances over time).
- High levels of criticality. HVDC interconnectors are the backbone of many electricity systems which leads to proactive renewals and limited in service failures.
- Unique electrical and harmonic stressors (such as high voltage gradients) requiring highly specialised design and materials. In turn this requires increased insulation requirements and higher thermal management requirements and the associated cooling systems.

Figure 2.2 Basslink's Thyristor Valve Hall

Implications of LCC and VSC Technologies in HVDC Interconnectors for Control and Protection Systems

There are two main technologies adopted across different HVDC interconnectors:

- Line Commutated Converters (LCC) technology – also referred to as Current Source Converters (CSC) or simply 'HVDC classic.' This technology is more mature and was originally used with mercury arc valves in the 1950s and 1960s, before the development of thyristors in the late 1970s. Basslink is based on LCC technology.
- Voltage Source Converters (VSC), also referred to as either 'HVDC plus' (Siemens) or 'HVDC light' (Hitachi), was initially introduced in the late 1990s. Murraylink and Directlink employ VSC technology.

There are capability, functionality, and technology differences between LCC and VSC systems. In the context of a control and protection system, a key difference to note is that LCC-based HVDC systems rely on the AC system for the commutation, or switching, of the current direction, a process which can introduce harmonics into the AC system. This requires the use of AC harmonic filters. VSC based systems can switch the current direction independently of the AC system reducing or eliminating the need for AC harmonic filters. Consequently, the scope of the control and protection system of a LCC based HVDC system is broader – as it also needs to monitor the harmonics and continuously operate the AC filters.

Figure 2.3 Basslink's AC filters

2.3. Role of Control and Protection System

HVDC interconnector control and protection systems are the ‘supercomputers’ or ‘brains’ which ensure their safe and reliable operation. The control and protection systems maintain the integrity of the system and prevent any incidents that could cause harm to people or equipment damage.

Broadly, control and protection systems perform two major functions:

- Controlling the AC/DC conversion process, managing the power flow and voltage levels (ensuring that the power is transmitted at the required voltage in the right direction) and ensuring the seamless integration of the HVDC system with the existing AC grids. The system monitors various parameters (such as the temperature and voltage levels), runs sophisticated algorithms extremely quickly and continuously sends signals to control key components such as the valves, cooling system, AC filters etc.
- Protecting the system by detecting and isolating faults that may occur. Faults can occur due to various reasons, such as lightning strikes, equipment failure, or human error. The system operates various devices, including circuit breakers and relays, to detect and clear faults before they can cause damage. The system is critical to ensuring the safety of the system and preventing damage to equipment or people and the connected AC grids. As with the control system, the protection system must operate extremely quickly.

Accordingly, the control and protection system for a HVDC interconnector is materially different to conventional AC protection and control equipment.

Function and scope of the Basslink control and protection system

Basslink’s control and protection system consists of:

- Station control – the control and protection functions for the AC feeder and AC harmonic filters.

- Pole Control – the control and protection functions for thyristor firing pulses, DC yard and converter transformers as well as valve cooling.

The control and protection systems enable the link to operate autonomously at a continuous transfer rating of 500 MW.

A schematic overview of the Basslink Control and Protection system is set out in Figure 2.4.

Figure 2.4 Basslink control and protection system schematic overview

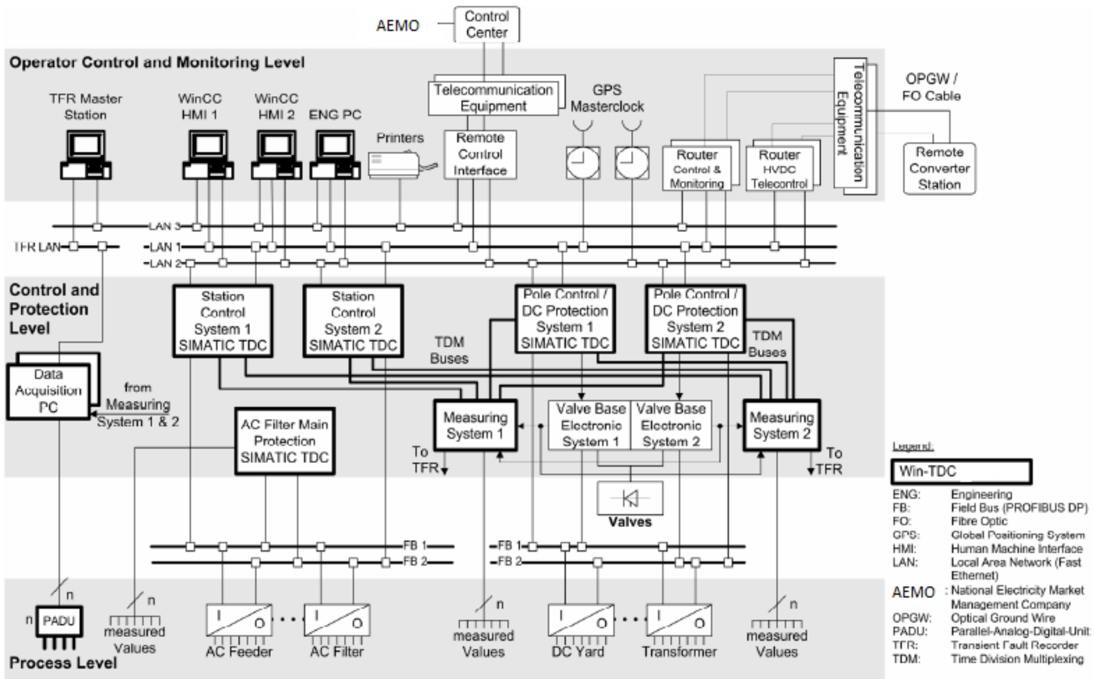


Figure 2.5 Basslink's Control and Protection System

3. Timing of replacement

3.1. Lifecycle planning

There are two key considerations in determining the optimal replacement of a control and protection system for a HVDC interconnector:

1. The lifecycle of the HVDC interconnector.
2. The lifecycle of the control and protection system technology.

This section outlines the key factors for each and the key considerations in considering the timing of replacing a control and protection system.

3.1.1. Lifecycle of a HVDC interconnector

General lifespan of a HVDC interconnectors

The overall lifespan of a subsea HVDC interconnector is determined by the longevity of its key components, including the submarine cable and converter stations. Converter stations[2] are typically designed for a 40-year life.

We note that Transpower has found that the three cables commissioned in 1991 have differing life expectancies due to variations in submarine environmental exposure. One cable has an expected lifespan of 34 – 44 years, while the remaining two are projected to last over 40 years.[3] Transpower is currently reviewing options to replace these cables, also noting that the Cook Strait submarine cables are not buried for protection like the Bass strait cables.[4]

3.1.2. Control and Protection System lifecycle

The core of the control and protection systems is the computer hardware and software which operates the closed loop systems which control the interconnector.

The non HMI layers (control and protection, and process) are made up of high-performance specialised, real-time computers and digital signal processors. Rapid improvements in technology, design, hardware and software, as well as changes in system requirements (for instance with respect to cyber security) make the life of these systems relatively short. There has been no change to these systems on Basslink since commissioning in 2006.

Broadly, there are several drivers to refresh these systems:

1. Ongoing access to support and spares. As vendors shift to new platforms, they often reduce or halt the production of spare parts and withdraw support.
2. Compatibility with other parts of the HVDC interconnector (importantly the valves given the interconnectedness of the control and firing system).
3. Obtain additional functionality and reliability unlocked by the latest platform and software.

In the case of Basslink the key driver relates to the need for ongoing access to support and spares. Siemens indicate that a refresh of the control and protection system should occur after 15 years. Without access to new spares reliability will decline.

[2] CIGRE 2016, *Guidelines for life extension of existing HVDC systems*, p.11
[3] Synergies Economic Consulting and GHD 2018, *Independent Verification Report – Transpower's RCP3 Expenditure Proposal (2020-25),* p.193
[4] See here.

Human Machine Interface Lifecycle

The HMI layer is based on computers with modern operating systems (such as Windows or Linux). These systems have a design life of between 2 and 8 years due to modern software and computer development timeframes to maintain support, functionality, and updates to reflect the latest security patches etc.

Basslink's HMI was last replaced in 2011 and is now 12 years old. The HMI uses obsolete and unsupported software and hardware (such as Windows XP) and is incompatible with the latest version of Siemen's HMI software.

An upgraded ISO 27001 (Information Security Management Systems standard) certified HMI system which implements a protected zone concept is now available. This new system includes the newest security patches latest software and deploys a virtualisation solution (allowing the abstraction of physical hardware from the operational system). The new HMI system is required to meet Australian Energy Sector Cyber Security Framework (AESCSF) requirements.

The virtualisation option also breaks the Microsoft Windows update cycle. Currently a change to hardware requires a new operating system, application software and bespoke drivers (not available off the shelf). Virtualisation enables hardware upgrades to occur seamlessly without software changes.

At the time of the revenue proposal the delays to the design of the successor control and protection system led to Basslink exploring a separate earlier upgrade of the HMI. However, at that time discussions with Siemens indicated that a HMI level only upgrade prior to the design of the control and protection system was highly likely to not be compatible with the new control and protection hardware platform.

Figure 3.1 Basslink's Human Machine Interface

3.1.3. Siemen's announcement of obsolescence

At a Siemens Interconnectors Owners Group (IOG) meeting in 2022, Siemens advised attendees that the family of control and protection systems that includes the Basslink system will be obsolete and support will be removed, most likely in 2030.

This is broadly consistent with the life of control and protection systems (see table 2.1). At the time this obsolescence was understood to cover the actual control system (not the valve-based electronics) as this was considered primary plant integral to the valve (converter).

However, the parts that have been used on Basslink have been receiving obsolescence notices since 2018. Continued operation is possible with expenditure provided the obsolescence includes identification of a working upgrade. However, components are being removed from support and manufacture with no identified working upgrade.

In October 2022, Siemens provided obsolescence notification for the valve-based electronics (i.e. all the control interfacing with the thyristors). Siemens did not recommend stand-alone replacement of the valve-based electronics, rather that they should be evaluated for replacement at the time the control and protection system is replaced.

Bathtub Failure Rate Curve

The Control and Protection system spare parts experience a bathtub shaped failure curve. A Bathtub failure curve is called that because of the shape of a graph of the failure rates per year of life of the asset looks like a bathtub. This is because there is a relatively higher failure per year either shortly after installation or grouped around a specific end of life with a low failure rate experienced in between.

Figure 2: A diagram of a bathtub curve

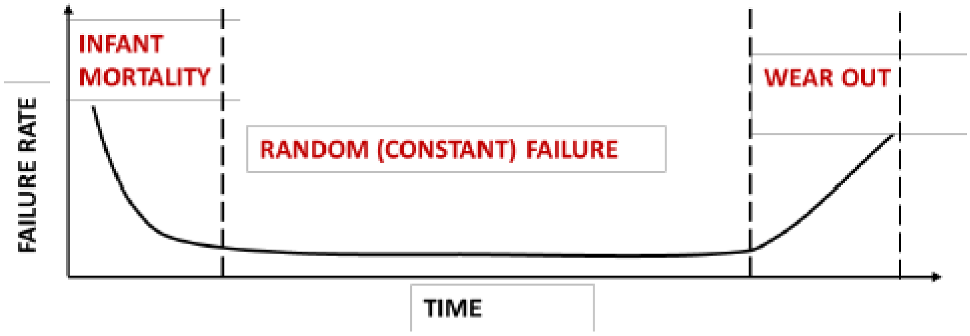


Figure 1: Example of a bathtub curve [5]

An acceleration in failures combined with a finite number of spares, in some cased there are no existing spares, means that at some point a critical component of Basslink will fail taking Basslink offline until the control and protection system is upgraded. An emergency upgrade will take more time and cost more than a planned upgrade.

The reason for the control and protection system being included in the three key issues for specific stakeholder consultation is there are no relevant older systems that can be used to understand the likely failure profile of the Basslink Control and Protection System. This combined with standard industry practice to replace prior to failure means we don't know with certainty when the failure rate on critical spares will accelerate.

Specifically for the Control and protection system that at some point in the future the failure rate of the components will escalate quickly (end of asset life). We don't know when end of asset life will occur. We know that the further we delay the upgrade of the Control and Protection System the more likely the end of life will be reached prior to the new upgrade being in place, resulting in an extended outage in breach of the Amended Basslink Operating Agreement.

In the absence of a quantifiable expected life, Basslink will follow good industry practice with regards to the replacement of the Control and Protection System. We will plan the replacement of the Control and Protection in line with the replacement benchmarks.

[5]Thomas Heiser and James P. Hofmeister, BATHTUB, FAILURE DISTRIBUTION, MTBF, MTTF, AND MORE: THEY ARE RELATED, October 2019, p2

3.1.4. Benchmark replacement timeframes

Table 1.1 lists a set of control and protection system replacements for HVDC programs around the world, as reported by Siemens, Hitachi and in trade media for HVDC interconnectors commissioned in the 1990s and 2000s.

Note that not all the links may have originally been installed with digital controls (for instance, Hitachi's MACH control system was first installed with Skagerrak 3, commissioned in 1993). We have also excluded Control and Protection System upgrades which we understand to be limited to the HMI layer such as the 2018 upgrade to the Transbay Cable (commissioned in 2010).[6]

Consistent with CIGRE findings, this data indicates Control and Protection Systems are generally replaced between 15 and 20 years following commissioning – with more recent links being replaced at shorter intervals. Given international good electricity industry practice is to replace these systems, 'no replacement' was not considered to be a feasible option.

Table 3.1 HVDC control and protection system upgrades 1990s and 2000s[7]

Table 0.1 HVDC control and protection system upgrades
Description of the table

HVDC System	Power rating	Country	Initial commissioning	Upgrade commissioned	Age at replacement
		Initial commissioning 2000s			
Al-Fadhili	3 x 600 MW	Saudi Arabia	2009	2026	17
BorWin1	400MW	Germany	2009	2022	13
Rapid City	2 x 100MW	USA	2003	2020	17
Cross Sound Cable	330MW	USA	2002	2022	20
Murraylink	220 MW	Australia	2002	2020	18
Moyle Interconnector[8]	2 x 250MW	United Kingdom	2001	2022	21
Directlink	3 x 60MW	Australia	2000	2019	19
Swepol link	600 MW	Sweden-Poland	2000	2024	24
		Initial commissioning 1990s			
Gotland Light	400 MW	Sweden	1999	2024	25
Welsh HVDC Station[9]	600 MW	USA	1995	2017	22
Kontek	600 MW	Denmark - Germany	1995	2016	21

[6] See here

[7] Based on public data released by major suppliers. Most identified upgrades undertaken by Hitachi (previously ABB) as outlined here. Upgrades undertaken by other suppliers are referenced separately with a link to a news release or article.
[8] See here.
[9] See here.

Jeju Island link 1[10]	300 MW	South Korea	1994	2020	24
Baltic cable	600 MW	Sweden	1994	2019	25
Skagerrak 3	440MW	Norway - Denmark	1993	2014	21
Inter-island Connector Pole 2	1,200	New Zealand	1992	2013	21
Quebec – New England Transmission	2,000MW	Canada / USA	1990-1992	2015-2016	24-26
Rihand - Dadri	1,568 MW	India	1990	2021	31

For completeness, we also report on the control and protection system replacements for HVDC interconnectors commissioned in the 1970s and 1980s. The life of the control and protection systems in these links is generally longer due as they operate using customised analogue systems.[11]

3.1.5. Control and Protection system timing trade-offs

Given that a midlife control and protection system replacement is going to be required, the challenge is determining the optimal timing for this to occur. We need to consider Technology refresh cycles. Ideally the control and protection system would be replaced at the beginning of a product lifecycle:

Replacing a system that has a platform close to its end of life risks the installation of a system which is obsolete before the end of its economic life. Replacing the system too early could also forgo the benefits of additional functionality and reliability from newer technology.

3.2. Market factors

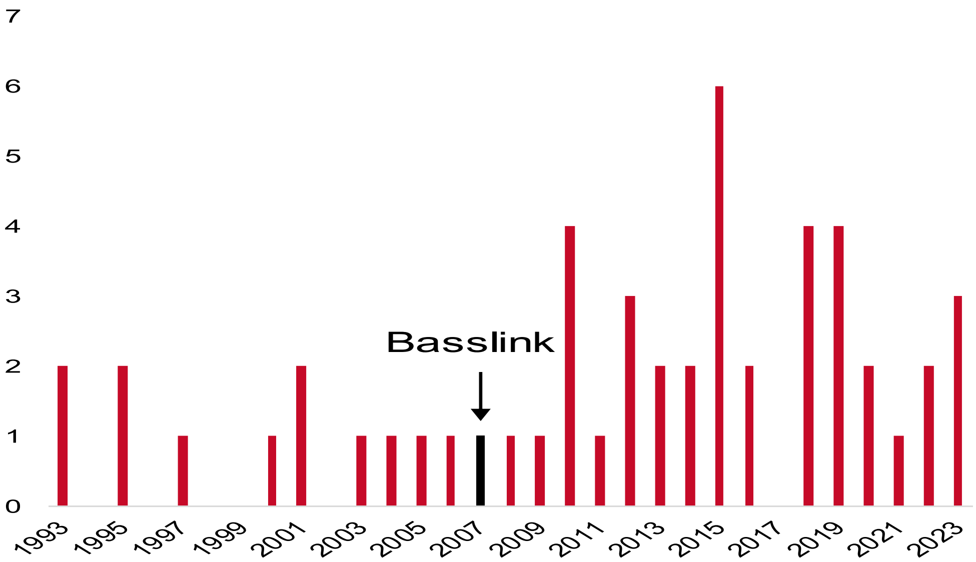
There are several market factors which complicate control and protection system replacement:

- Limited number of HVDC vendors – which limits our bargaining power, particularly given the challenges of vendor switching (outlined below).
- Supply chain shortages, such as those in respect to semiconductors which have affected vendors such as Siemens Energy. Semiconductors are the core components of control and protection systems.
- A bow wave of HVDC interconnectors due for a mid-life refresh of their control and protection systems, see Figure 2.9. Notably Basslink was the first (and therefore the oldest) HVDC interconnector with the Win-TDC control system.
- Increasing demand for HVDC technology with the global trends towards decarbonisation and electrification driving a greater need for transmission. These projects are becoming increasing larger and higher value increasing demand for high voltage electricity projects and putting further pressure on the supply chain.

Discussions with the manufacturer indicate a current lead time of 3 years. This is expected to increase as other HVDC interconnector systems fall due for their Control and Protection System replacement. There is also a significant risk that the overall cost will increase over time.

[10] See here.
[11] Analog systems are no longer installed in modern HVDC interconnectors due to the bespoke engineering requirements, reduced functionality, lower redundancy and high degree of monitoring required (as their many discrete components age and deteriorate over time).

Figure 3.3 Commissioning dates of Siemens HVDC systems over the last 30 years



4. Cost of a Control and Protection System

At the time of the proposal and the stakeholder engagement, Basslink estimated the cost of the Control and Protection System to be $44m.

Siemens Energy reviewed the Basslink Lifecycle Management Plan in 2020 and provided a 'Non-Binding Indicative Estimate' for HVDC refurbishment of 18 million to 22 million Euro. This equated to about $44 million in Australian dollars.

This estimate was also broadly consistent with the upgrade cost of Basslink given the recent experience on the, then, recently upgraded control and protection systems at Murraylink and Directlink.

It was used as it was the best forecast of the cost available at the time of the proposal.

4.1. Update

A number of factors changed between the original proposal and the AER's decision to regulate Basslink. These factors have had a direct effect of increasing the forecast of the cost for the upgrade of the control and protection system. The individual elements contribution to the cost estimate has not been provided by Siemen's energy.

4.1.1. Valve Based Electronics

In October 2022, Siemens provided obsolescence notification for the valve-based electronics (i.e. all the control interfacing with the thyristors). They did not recommend stand-alone replacement of the valve-based electronics, rather that they should be evaluated for replacement at the time the control and protection system is replaced.

The inclusion of replacing the valve-based electronics increased the cost of the replacement project beyond that which had been undertaken on the Directlink and Murraylink replacements as this work was not undertaken on those upgrades.

4.1.2. Beckhoff Automation imbedded PC hardware

Basslink submitted its revenue proposal in September 2023. As noted above, our forecast for the control and protection system upgrade capital expenditure was based on an estimate from Siemens. Without being explicit, the total value of the estimate assumes "version change" upgrade of the Siemen's control and protection system similar to what we had experienced in relation to the upgrade of Murraylink and Directlink by Hitachi.

Our proposal was submitted very shortly[12] after Siemens publicly announced their intention to move to an entirely new platform for the replacement – a Beckhoff platform. No cost estimates or cost indications were provided at the time of the announcement.

A platform replacement like that being proposed by Siemens Energy is a total upgrade of the cubicles (the physical structures in which the control and protection system is housed) and their contents. There is no opportunity to reuse any of the existing equipment or infrastructure, for example it will require a complete control and protection system communications upgrade.

This is in contrast with the "version change" upgrade that was assumed in the original Siemens cost estimate which would have involved a partial upgrade with the focus being on upgrading the smart technology components of the control and protection system.

Siemen's energy was the only potential supplier of a "version change" upgrade because a partial upgrade requires the installation technology that is compatible with the equipment being retained[13]. Compatibility has to be the exacting standards required given the frequency and speed of the interactions within the control and protection system. Timing of the control and protection system is measured in micro-seconds.

[12] June 2023 IOG
[13] Our understanding is this option was not available to Siemen's Energy as it does not have preferential access to Siemens design and manufacturing infrastuture.

Siemens provided more detail about the new Beckhoff automation hardware platform at an October 2024 IOG conference.

In December 24 Siemen's Energy provided Basslink with a project estimate of the cost replacing the existing Basslink Control and Protection System with a Beckhoff system of $88m. When adjusted for inflation and labour cost escalation, the cost of the project is $90.8.

5. Consumer views

Given the materiality of this project and the difficulty in quantifying the risk (most control and protection systems are replaced in advance of failure given their criticality to electricity grids around the world), we sought out customers views on whether we should replace the system in the 2025-30 or 2030-35 periods.

We engaged consumers through online focus groups, in person workshops and an online quantitative survey.

Online focus groups

The first activity conducted was two online focus groups with Victorian and Tasmanian consumers and small businesses. The objective was to test clarity and comprehension of information provided ahead of the consumer workshops.

We found that consumers understood the topic well and demonstrated their understanding of the key trade-offs between cost and reliability.

Overall, these consumers indicated a preference towards investing earlier. Tasmanian residents questioned the need on the basis that they did not need to reply on electricity from Victoria for their supply needs and were concerned whether the system could become redundant as new technologies develop.

In person workshops

The second activity was in-person workshops in Melbourne and Launceston to inform consumers and understand their preferences.

Most (77% in Melbourne and 69% in Launceston) supported replacing the system earlier. The main reason for this preference was to avoid potential negative impacts on households and businesses – with several participants raising concerns about the flow on effects and cost implications of a disrupted energy supply. Consumers highlighted that investing sooner decreased the risk of the system failure or of APA being unable to acquire a new one before the current system failed.

A quarter of participants preferred to wait to replace the system on the basis that waiting would provide access to future technology (as they had seen with TVs and Laptops). A smaller proportion also noted a preference to delay spending given the current context of cost-of-living pressures.

Online quantitative survey

To test and validate the outcomes from the consumer workshops an online quantitative survey was conducted. The survey found that the majority are willing to pay sooner as they believed that this option is more cost-effective, efficient and presents less risk.

Consumers told us they considered that paying sooner would be cheaper in the long run. Many respondents told us that they believed investing sooner would have a lower risk of electricity outages and could allow Basslink to operate better or more efficiently.

6. Options

6.1. Best Forecast of Future platform

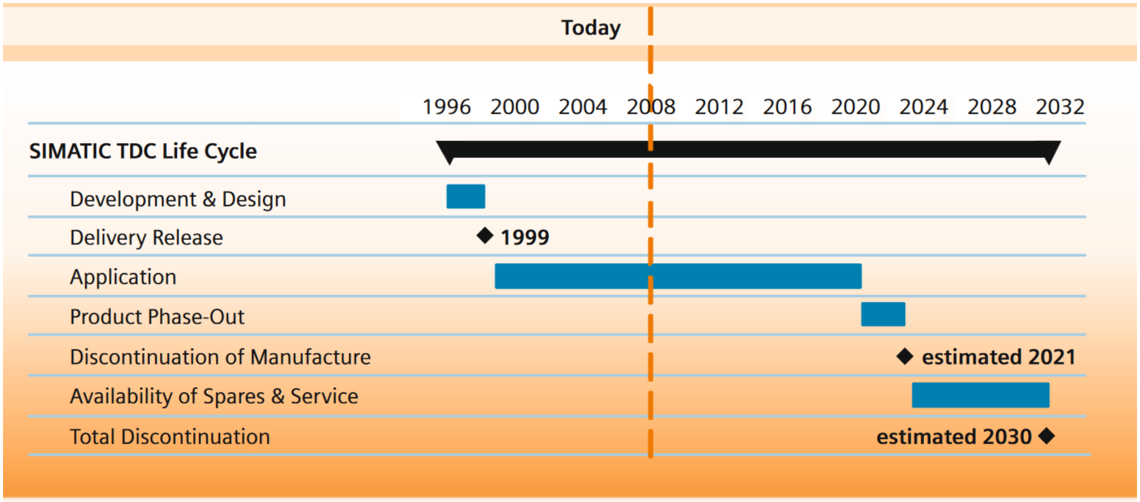
Basslink's control and protection system is currently based on the Win-TDC platform where:

- Win represents the Windows operating system at the operator control and monitoring level.
- TDC is the Siemens Simatic Technology and Drive control system. This system is a digital automation system featuring very high computing power and the ability to process very large programs. The TDC system is typically used in large plant environments such as steel rolling mills but has been adapted for use in HVDC systems.

Basslink was the first commissioned interconnector to use this platform in 2006. Figure 6.1 sets out the product life cycle of Simatic TDC in 2008.

The future platform is Beckhoff Automation imbedded PC hardware and MATLAB modelling software[14] and Siemens have advised there are two factory slots available at present for delivery in 2030 or 2032

Figure 6.1 Simatic TDC Lifecycle in 2008



SIMATIC TDC is a product family that includes individual products with differing lifecycles and successor products are not always direct replacements, APA actively monitor this obsolescence and purchase additional spares when a product is obsolete.

6.1.1. Challenges and Implications of Vendor Switching for HVDC Control and Protection Systems and Valves

The control and protection system and valves of a HVDC interconnector are intricately linked. Moving to another vendor would require either:

- The replacement of the valves in addition to the control and protection system. This option would incur significant additional costs to replace an asset which is currently functional and has significant remaining design life.
- Engineering a bespoke system to adjust a vendors standard control and protection system so that it could work with the Siemens valves. This option would incur additional costs and uncertainty with the replacement project. It would also limit and complicate ongoing support with both the control system vendor and Siemens with the valves.

[14] See here

We are only aware of a single example of the installation of a third-party control and protection system. This occurred as part of the 2013 upgrades to New Zealand's inter-island link which included the installation of Pole 3 and an upgrade of Pole 2 (originally commissioned in ABB in 1992)[15].

There were significant differences between the Siemen's pole control system and valves which required special bespoke hardware modules to be designed to interface between the two systems. This incurred additional cost (relative to implementing complementary systems) and complexity. It also means any issue could be attributed to three different sections (control system, interface, or valves) which complicates support (relative to a single vendor model).

Accordingly, we are unaware of any HVDC interconnector which has attempted or resolved the engineering challenges in installing a third-party control and protection systems on Siemens valves.

We've reached out to multiple alternative Operating Equipment Manufacturers (OEMs) of HVDC interconnected technology (including both GE and Hitachi who run APA's Murraylink and Directlink interconnectors) but, to date, we have not been successful in receiving any offer.

The technical differences between OEMs means any other provider of the C&PS would also have to either replace the converter (as the fibre triggering pulses and optical feedback are unique to the Siemens detailed design) or develop a specific product to interface to the Siemens 12 pulse bridge. This additional scope compared to Siemens, likely outweighs any possible savings from offering a cheaper upfront C&PS and may explain why we have yet to get Hitachi or GE to proceed with any viable alternative offer.

6.2. Current Timing Options

Therefore, the focus on options, and the basis of stakeholder engagement, was the potential timing of an upgrade.

In our original proposal business case, we considered three replacement timeframes for the Control and Protection System: 2026, 2030 and 2035. These were selected to demonstrate the impact of delay on the consumer outcomes.

Due to delays in Siemens producing a design for the Beckhoff Automation imbedded PC hardware Control and Protection System the option of a FY 2026 completion date is no longer a viable option as the timing of delivery and installation is longer than the remaining time available.

Ongoing engagement with Siemens has indicated they have two potential production windows for the Beckhoff Automation imbedded PC hardware Control and Protection System one which would result in the completion of installation in 2030 and one which would result in the completion of installation in 2032,

Waiting beyond FY32 would mean the current Control and Protection System would have been operating for 27 years before being replaced. As can be seen from table Table **3.1** above. Only 1 of 17 HVDC networks has run a control and protection system longer than 27 years, Rihand – Dadri in India. For Basslink this outcome is not consistent with good industry practice.

6.3. Option 1 – Control and Protection System replaced by 2030

6.3.1. The cost of the option

- $90.8 million capital expenditure in $FY2026.

6.3.2. The expected benefit

- Minimises the likelihood of an extended outage due to the control protection ceasing to function before a replacement is in place
- Maximises the economic life of the replacement control and protection system prior to the end of design life of the thyristors.

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- Consistent with the preferences of customers: as this option reduces the risk to their electricity supply by decreasing the risk of a system failure or Basslink being unable to acquire a new system.

6.3.3. Any expected dis-benefits

- The time value of money for the 2 year delay of expenditure compared to the option 2

6.4. Option 2 – Control and Protection System replaced by 2032

6.4.1. The cost of the option

The cost of the project is $90.8 million capital expenditure in $FY2026.

6.4.2. The expected benefit

The time value of money for two years of delay compared to installation in 2030

6.4.3. Any expected dis-benefits

Higher likelihood of failure of a critical component resulting in Basslink going offline for an extended period of time.

The cost of construction for HVDC projects has experienced significant cost increases in recent years. This can be seen in the experience of the construction cost of Marinuslink. A further delay risks additional cost increases to the cost of installing an upgraded control and protection system.

6.5. Option Comparison

Option 1 Replacement by 2030 is recommended as it is consistent with customer preferences and reduces the impact of market risks.

Table 3.1 Option comparison (Present value terms, $millions)

Table 3.1
Description of the table

Option	Description	Capex	Early replacement risk	Reliability risk	NPV
1	Replacement by 2030	90.8	Higher-	Lower	90.8
2	**Replacement by 2032**	**90.8**	**Lower**	**Higher**	**90.8**

The benefit of delaying the installation from 2030 to 2032 is the time value of money. That is the value of paying money in the future rather than now. The time value of money is calculated by taking the value of the expenditure and multiplying it by an appropriate discount factor for each year. The benefit is cumulative. For a regulated business the discount factor is the regulated return (nominal vanilla weighted average cost of capital). Using this methodology the delay from 2030 to 2032 is worth $12.2m.

The cost of delaying the installation from 2030 to 2032 is the expected value of the cost of an outage. This is the probability multiplied by the total cost. For the cost of the outage we have used the market benefits modelled by EY on the step change base case for the period of 2030 to 2032. The market benefits as calculated are $273.5m. This market benefit would be higher in the event that the Marinuslink cable is delayed beyond the end of 2032.

Unfortunately, as noted above the future probability of failure for the Basslink Control and Protection System is completely unknown.

In these circumstances an alternative is to see whether the required probability of failure to make the expected cost of delay less than or equal to the expected benefit of delay, the breakeven failure rate, is a credible outcome. That is, what is the minimum probability of failure at which the expected value of failure is greater than or equal to $12.2m and is it credible to view the potential for failure in the two years between 2030 and 2032 as higher than that value.

Given the 2032 is a fixed date for replacement, the cost of a Basslink control and protection system failure is highest at the start of the two years and is zero at the end of the two years. So based on this the average value of failure over the two-year period is half of 273.5 or 136.7. A probability of 8.9% makes the expected value of the cost of $136.72 to be $12.2m.

It is Basslink's view that, given the age of the control and protection system and the absence of some critical spares, it is reasonable to believe that the probability of failure of the Control and Protection system in the two year period from 2030 to 2032 could be higher than 8.9%.

6.5.1. Balance of risks

There are certain assumptions underpinning the calculation of the breakeven failure rate. The critical ones are:

- Marinuslink is constructed in accordance with the 2022 ISP step change forecast
- Costs of the new control and protection system do not rise quicker than inflation between 2030 and 2032
- The market benefits calculated by EY are non-biased (the real number is as likely to be higher as it is to be lower).

The balance of risks is such that the estimate of the breakeven failure rate is more likely to be lower than it is to be higher:

- A delay to Marinuslink is more likely than the project will be delivered early given the manufacturing timing challenges being experienced in the international market for HVDC converter equipment and cables.
- Given the level of demand for cable and HVDC converters and the limited manufacturing capability internationally it is more likely that the cost of a new control and protection system will rise by more than inflation between 2030 and 2032 that it is it will fall or rise slower than inflation.

7. Recommendation

The risks associated with this

The 2030 replacement is the best option given:

- The realistic prospect of failure higher than the breakeven failure rate
- The balance of risks associated with the breakeven failure rate are on the downside.
- The control and protection will have been operating beyond the design life of 20 years for 6 years
- There are no spares for some of the subcomponents of the system
- In 2030 the Basslink control and protection system will have been in operation longer than 10 of the 17 Control and Protection systems that have been replaced to date.
- Consultation with Stakeholders has revealed a preference for reliability even where costs may be incurred earlier.
- If the fault was to occur more than 30 days from the completion of the upgrade then Basslink would be in breach of the Amended Basslink Operating Agreement.

8. Project Deliverables

8.1. Scope

The project comprises the design, engineering, manufacturing, factory testing, construction, site installation, testing, commissioning and documentation of new control and protection systems.

Specifically, the works will replace the current Basslink control system without changing the current functionality, capacity, performance, harmonics audible sound generation or external interfaces.

The project includes (but is not limited to):

- Communication (COM) systems.
- Human Machine Interface (HMI).
- Pole Control and Protection frameworks, and control system computers.
- Valve Control Unit communication interface modifications.
- Cooling Control and Protection frameworks.
- Engineering Server systems including all necessary maintenance, fault finding and developing tools for supporting the new control system.
- Station Control and Monitoring systems providing persistent storage of all events and transient fault records produced in the control and protection system.
- Obsolete electronic components

Spares to ensure continued operation until 2030.

Siemens are using a Preferred Supplier Agreement (PSA) and APA are in discussion to commit $10 million to perform the following:

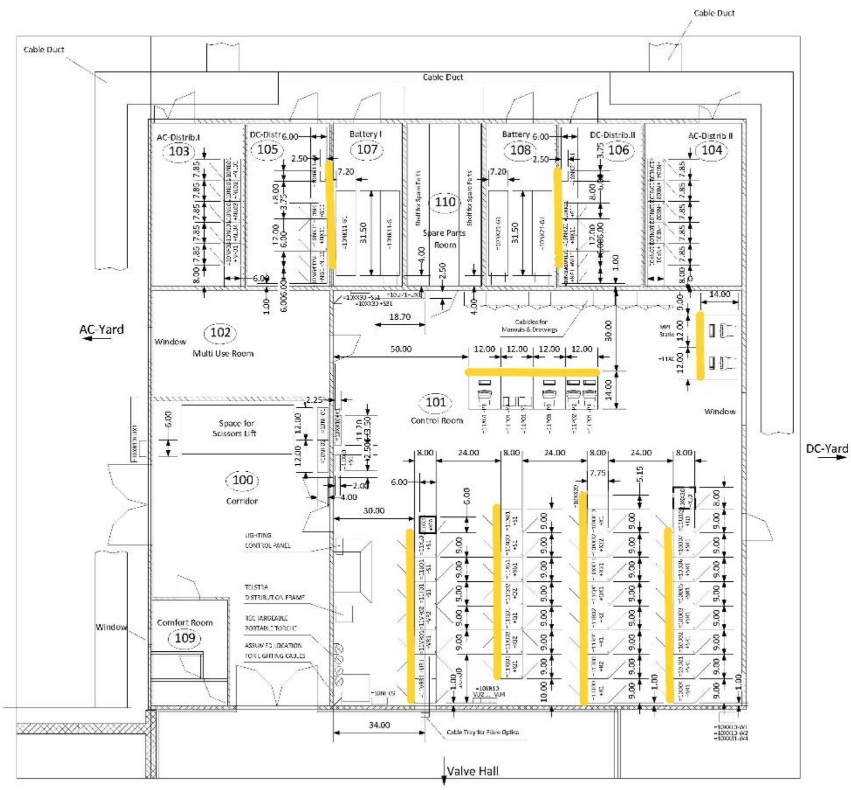
- Feasibility design studies
- Contract and technical specifications
- Financial commitment for a manufacturing slot guarantee

8.1.1. In Scope

The items considered in scope for Control & Protection System Refresh project are:

Table 4.1 In Scope	
1	Assess with OEM Support which components & elements of the control and protection system will no longer be/are no longer supported
2	Procure Spares to enable continued operation through to planned upgrade date
3	OEM to design, fabricate, factory test and install new control & protection equipment in in parallel with the existing, operational equipment at both converter stations
4	OEM & APA to power-up and pre-commission new equipment
5	Outage for ~10-20 days to enable completion of: • Cutover of field wiring from existing C&P System Connections to new C&P System Connections • Complete pre-commissioning and pre-energisation testing • Complete commissioning activities Two commissioning teams required working in tandem, one at each converter station
6	Decommission and remove superseded control and protection equipment

Figure 2.10 Control Cubicles to be replaced at each converter



8.1.2. Out of Scope

The items considered out of scope for project are:

Table 1.1 In Scope	
1	Additional engineering to fit a third-party control and protection system.

8.2. Project Schedule

The estimated costs for the project are set out in Table 4.1.

Table 4.1 Control and Protection Refresh costs ($2026, millions)

Control and Protection Scheme Replacement Capital expenditure ($FY26)						
Year	**FY 26**	**FY 27**	**FY 28**	**FY 29**	**FY 30**	**Total**
Expenditure	**5.3**	**13.3**	**28.0**	**28.1**	**16.1**	**90.8**

A high level- overview of the project schedule and key stages is provided in **Figure 8.1**.

Figure 8.1 Indicative project schedule