MSIP South Wales Pathfinders: Cilfynydd, Upper Boat & Swansea North

National Grid Electricity Transmission
Medium Sized Investment Project

January 2025

Contents

Investment Summary

Project Names	Cilfynydd Pathfinder Swansea North Pathfinder Upper Boat Pathfinder	**Delivery years**	Cilfynydd: 2026 Swansea North: 2026 Upper Boat: 2027
SpC 3.14.6 Category	(f) a system operability, constraint management or 0MW connection project National Energy System Operator (NESO) driven		
Drivers for the Investments	**To provide 3 new 0MW demand connections for network stability projects.** South Wales substations identified to deliver the grid stability services in Pathfinder Phase 3 are: Cilfynydd 400kV, Swansea North 400kV and Upper Boat 275kV substation.		
Key considerations & challenges	Key considerations and challenges in delivering these investments include: • **Delivery Timescales:** Enabling the contracted customer connection dates to facilitate an accelerated transition to net zero whilst addressing network operability challenges, • **Land & Consent:** Working within land constraints in extending substation site layouts. • **Technology Choice:** National Grid Electricity Transmission's (NGET) policy to favour Air Insulated Switchgear (AIS) over Gas Insulated Switchgear (GIS) technology, where possible, based on considerations of cost effectiveness and environmental impact. • **Stakeholder Views:** NESO led industry engagement supported the development of cost-effective solutions to enhance grid capacity by increasing network inertia/short circuit level.		
Optioneering	NGET assessed options across five overarching categories including: • Three option categories (do nothing, whole system solution, and market-based solutions) which could not provide the required physical connection to customers • One option for the construction of a new substation, which was considered excessive • Multiple options to extend existing NGET substations (with a variety of technology types) Options considered within the category of extending existing NGET substations included: • Cilfynydd: seven options including AIS and GIS • Swansea North: four options • Upper Boat: six options		
Proposed Solution	**Cilfynydd**: **AIS Extension to the East with Two User Bays.** Double AIS Busbar extension of 400kV substation to the east to provide space for two user bays. Welsh Power synchronous compensator and Bute Energy wind farm. Installation of bay equipment Earth Switches (ESW), civil works, associated Protection and Control (P&C), land remediation and extension of the fence line boundary.	**Swansea North**: **Single Tee Connection.** Installation of new disconnector at a tee point on the outgoing Swansea North - Pembroke two circuit (A80M), Installation of a 400kV circuit breaker at Swansea North 400kV, Installation of a 400kV disconnector at Swansea North 400kV, Installation of current and voltage transformers, Protection and Control (P&C) modifications and associated civils work.	**Upper Boat**: **Extension of mesh corner one and mesh corner four.** Includes installation of the following associated bay equipment: Disconnecting Circuit Breaker ((DCB), with integrated earth switch), Capacitive Voltage Transformer (CVT), Current Transformers (CT), Cable Sealing End (CSE). civil works and associated Protection & Control (P&C).
Outputs of the Investment	Deployment of synchronous compensators across all regions in stability Pathfinder Phase 3 will procure 7.5 Giga Volt Amperes (GVA) of Short Circuit Level (SCL) and 15 Giga Watt seconds (GW.s) of inertia. NESO estimates that, without the integration of Pathfinders across all regions, consumers in England and Wales may incur an additional £14.9bn in constraint actions to manage stability between 2025-35. Addressing grid stability will also enable greater integration of low carbon technologies on to the network.		
PCD Primary Output	Substation extensions accommodate stability service connections at Cilfynydd 400kV (by September 2026), Swansea North 400kV (by July 2026, although a Modification Application is in place to change the ACL date to May 2026), & Upper Boat 275kV substations (the fist by April 2027).		
Estimated Cost (price base 2018/19)	**The current total cost of projects are:** Cilfynydd: [redacted] Swansea North: [redacted] Upper Boat: [redacted]	**The direct costs (and funding allowance being sought) is:** Cilfynydd: [redacted] Swansea North: [redacted] Upper Boat: [redacted]	
Spend profile	**T2 (FY2022 - FY2026):** Cilfynydd: [redacted] Swansea: [redacted] Upper Boat: [redacted]	**T3 (FY 2027 - FY2031):** Cilfynydd: [redacted] Swansea: [redacted] Upper Boat: [redacted]	**T4+ (FY 2032+):**
Reporting Table	Annual RRP – PCD Table	**PCD Modification Process**	Special Condition 3.14, Appendix 1
Historical funding	No existing funding in RIIO-T1 or RIIO-T2.		

1. Executive summary

1.1 Context

This paper summarises NGET's proposed investment to extend the Cilfynydd 400kV substation, Swansea North 400kV substation, and Upper Boat 275kV substation, and seeks to demonstrate the consumer interest in the associated investment.

This Medium Sized Investment Project (MSIP) seeks approval of the need for the investment, as well as approval of the proposed solution and requested funding allowances for efficient spend on the project. The funding is required by NGET to deliver works in response to the NESO Stability Pathfinder Phase 3 project and to enable the delivery of projects in line with contracted customer connection dates [redacted]

1.2 What is the background to this Investment?

As part of their role, NESO is responsible for ensuring the security, operability, and reliability of the electricity system during the transition to net zero. Recent developments in decarbonisation, decentralisation, and digitalisation are driving considerable changes within the electricity network, impacting the operation of the transmission system. By 2030, it is anticipated there will be a significant increase in low carbon generation and interconnection, both of which will pose operability challenges.

Grid stability, which has traditionally been supplied as an inherent by-product of traditional generation (coal and gas plants), represents one of those challenges. As traditional generation is phased out, there is a decline in the inherent stability of the system with inertia and short circuit levels falling. A power network operating without required levels of mechanical inertia is unstable, suffers from issues of power quality and is susceptible to blackouts.

In 2021, NESO identified South Wales as a region requiring stability solutions for the transmission system. NESO issued a tender to procure services to deliver sustainable solutions at a low cost, known as the Network Options Assessment (NOA) Stability Pathfinder Phase 3[1]. Following this assessment, it was determined that the following substations in South Wales have connection bays available to accommodate the Pathfinder Phase 3 solution:

- Cilfynydd 400kV substation (two available connection bays)
- Upper Boat 275kV substation (two available connection bays)

In both cases, the customers were successful in their tender to provide stability services to NESO. NGET has a contractual obligation to provide a connection for both of these customers.

For Swansea North 400kV substation, the approach to delivering stability services for Pathfinder Phase 3 differed as it was not a reserved site in NESO's 'regions of need' document. However, after a successful application to deliver stability services under the first contract, the customer (Statfkraft) applied for a second connection and has been awarded the contract for Phase 3. The customer has a Final Investment Decision (FID) in place. NGET has a contractual obligation to provide a connection to the customer.

NESO in collaboration with NGET identified these sites as appropriate Grid Supply Points (GSPs) with adequate capacity to support the stability pathfinder scheme, thereby reserving capacity at these locations. As the owner of the transmission system, NGET is tasked with ensuring that stability solutions are integrated safely and effectively within the network, in accordance with the Security and Quality of Supply Standard (SQSS). Although the customers were granted the contract to implement the stability scheme via NESO's tender process, the connection of the synchronous compensators to the transmission system necessitates infrastructure modifications at each site, which is the responsibility of NGET.

[1]ESO Transparency Forum, July 2024, Operational Transparency Forum | National Energy System Operator

1.3 What have we considered in developing options for this investment?

NGET assessed a range of solutions to meet the investment drivers in a way that best serves the interest of consumers. For each substation, we considered solutions across five categories. In evaluating these options, we considered the ability to meet the NESO contracted timeline for delivering the network stability solution, costs, technology type, and other factors that are relevant to consumers.

Whilst further detail regarding the optioneering process is provided in sections 4 and 5 of this submission, a brief summary of the options considered is explained below.

In line with the reopener guidance set out by Ofgem, we considered three options as standard: **do nothing (Option A), market based (Option B)**, and **whole system solutions (Option C)**. These were discounted due to their inability to provide a compliant and viable customer connection and because they would not address the grid stability needs identified by NESO, leading to increased constraint costs.

We then considered options to **make use of existing NGET substations (Option D)** or to **build a new substation (Option E)** for each of the three substations. Option E was not shortlisted for any of the substations because it was deemed excessive and inefficient for consumers from a cost and timing perspective given the available capacity at existing substations.

We therefore subsequently focused on options to extend or utilise existing substations (Option D). For each substation, options differed based on configuration and technology type and were shortlisted based on various factors, such as: relative cost (need for additional equipment), procurement lead times, safety, health & security, and the environment.

For **Cilfynydd** substation, we considered seven options, of which three were progressed to detailed options analysis

- **D-2:** AIS extension - maximum customer bays
- **D-5:** GIS extension - building to the west of the substation, using non-SF6 equipment
- **D-6:** GIS extension - building to east of the substation, supplied by east only using non-SF6 equipment

For **Swansea North** substation, we considered four options, of which two options were progressed to detailed options analysis (D-1 and D-2):

- **D-1:** New bays in the GIS hall using SF6 equipment
- **D-2:** Single TEE connection to the Pembroke two circuit

For **Upper Boat** substation, we considered six options,[2] of which two options were progressed to detailed options analysis (D-3 and D-4):

- **D-3:** New Bays with Disconnecting Circuit Breaker (DCB), Three Phase Capacitive Voltage Transformer (CVT), Current Transformer (CT) and Cable Sealing End (CSE)
- **D-4:** New Bays with Disconnecting Circuit Breaker (DCB), Single Phase CVT, CT and CSE

1.4 What is the preferred option and what outputs does it deliver?

The preferred options for the three projects are summarised below. They align with NESO's strategic priorities for enhancing inertia and SCL in the South Wales region, fulfilling the requirements set out in NESO Stability Pathfinder Phase 3. The proposed designs aim to deliver the essential infrastructure to meet the customer's needs, ensuring a reliable and efficient connection while providing the greatest benefit in terms of consumer value.

Key features for each preferred option include:

Cilfynydd: D-2 AIS extension to the east of the substation, with two user bays

[2]For Upper Boat substation, the six options (D-1 to D-6) all propose extending mesh corner one and mesh corner four, differing only in the type of asset technology used.

- AIS substation extension to the east with construction of two AIS customer connection bays to enable Pathfinder 0MW connection for synchronous compensators [redacted]
- Following optioneering, the scope of the [redacted] east extension was decoupled from the overall site strategy to ensure deliverability of the customer connection.
- Decoupled scope and wider site strategy will be managed through a future separate Engineering Justification Paper (EJP) submission.

Swansea North: D-2 Single TEE connection

- Extension to the existing site (through a tee'd connection) to construct a non-standard bay including associated bay equipment to enable Pathfinder 0MW connection for synchronous compensators [redacted].
- Efficiency in design and contract management (lessons learned from Statkraft one project).
- Cost effectiveness - Single Tee connection will avoid the need to extend the GIS Hall.

Upper Boat: D-3 Extension of mesh corner one and mesh corner four.

- New bays with Disconnecting Circuit Breaker (DCB) Three Phase CVT, CT, and CSE to enable Pathfinder 0MW connection for synchronous compensators in 2027.
- Proposed works (extension of the bays) is already on land owned by NG.
- Option meets required control, protection and electrical clearances.
- Configuration/design of equipment is the best option in terms of space constraints at site.

Funding allowances are sought as part of this MSIP submission. The direct costs for this investment are [redacted] (18/19 prices). Further details related to the makeup of these requested allowances are detailed within the cost model available alongside this submission.

1.5 How has future proofing been considered in the proposed investment?

The primary driver for the project is to deliver customer connections for NESO's Pathfinder Phase 3. The preferred option for Cilfynydd includes provision for an extra bay for Bute Energy (wind farm connection). Additionally, a comprehensive site strategy is being formulated at Cilfynydd to allow for expansion to the west of the substation, future proofing the site to allow for pipeline of future connections.

Similarly, Swansea North also has a wider site strategy in development to cater for pipeline of future customers. These strategies are still in the initial phases of development and will consequently not meet the NESO contracted timeline for delivering the network stability solution.

For Upper Boat 275kV substation due to space constraints, outage restrictions and the site reaching its capacity focus has placed on delivery of contracted customer connection for the pathfinder solution.

1.6 What are the uncertainties and how have they been accounted for?

The following risks and uncertainties to the successful delivery of this project include:

- **Land & Consent:** Working within land constraints in extending substation site layout.

[redacted]

- **System Outages:** High demand for outages on the South Wales network over the next three years [redacted], or the need for additional work to manage network resilience. Ongoing liaison with NESO

[redacted]

- **Unforeseen Ground Contamination (Cilfynydd), unforeseen discovery of asbestos and underground obstructions and services (Upper Boat):** have been identified as

possible risks at the sites. Further investigations and Ground Penetrating Radar (GRP) surveys to be undertaken.

Following a NESO-led investment driver to enhance grid stability in South Wales, NGET will implement infrastructure works to connect synchronous condensers at Cilfynydd, Swansea North, & Upper Boat. NGET's proposed solution for each substation is shown below.

- **Cilfynydd 400kV substation:** AIS Extension to East with Two User Bays
- **Swansea North 400kV substation:** Single TEE Connection
- **Upper Boat 275kV substation:** Extension of Mesh Corner One & Mesh Corner Four

The designs will provide the necessary infrastructure for the customer connection requirements and ensure a reliable and efficient connection; with the greatest benefits in terms of consumer value.

2. Introduction

2.1 Project background

This paper presents the investment case and associated efficient costs for our preferred solution for delivering stability services at Cilfynydd, Swansea North and Upper Boat substations, as identified through the NESO Pathfinder Phase 3 project.

The grid stability projects at these substations are essential to supporting the UK's decarbonisation goals and achieving a net-zero economy by 2050. As the transition to renewable energy accelerates, there is an increasing demand for innovative stability solutions to ensure grid reliability, as the stabilising properties traditionally provided by transmission connected synchronous generation is gradually phased out.

NESO commenced a Network Options Assessment (NOA) Stability Pathfinder Phase 3 project to find the most cost-effective way to address stability issues. This scheme focuses on increasing system inertia at short circuit level (SCL) in England and Wales. Ultimately, these solutions support a more affordable, reliable, and sustainable electricity system while advancing the transition to a low-carbon energy future.

The substations selected to provide the stability services are illustrated in Figure 1.

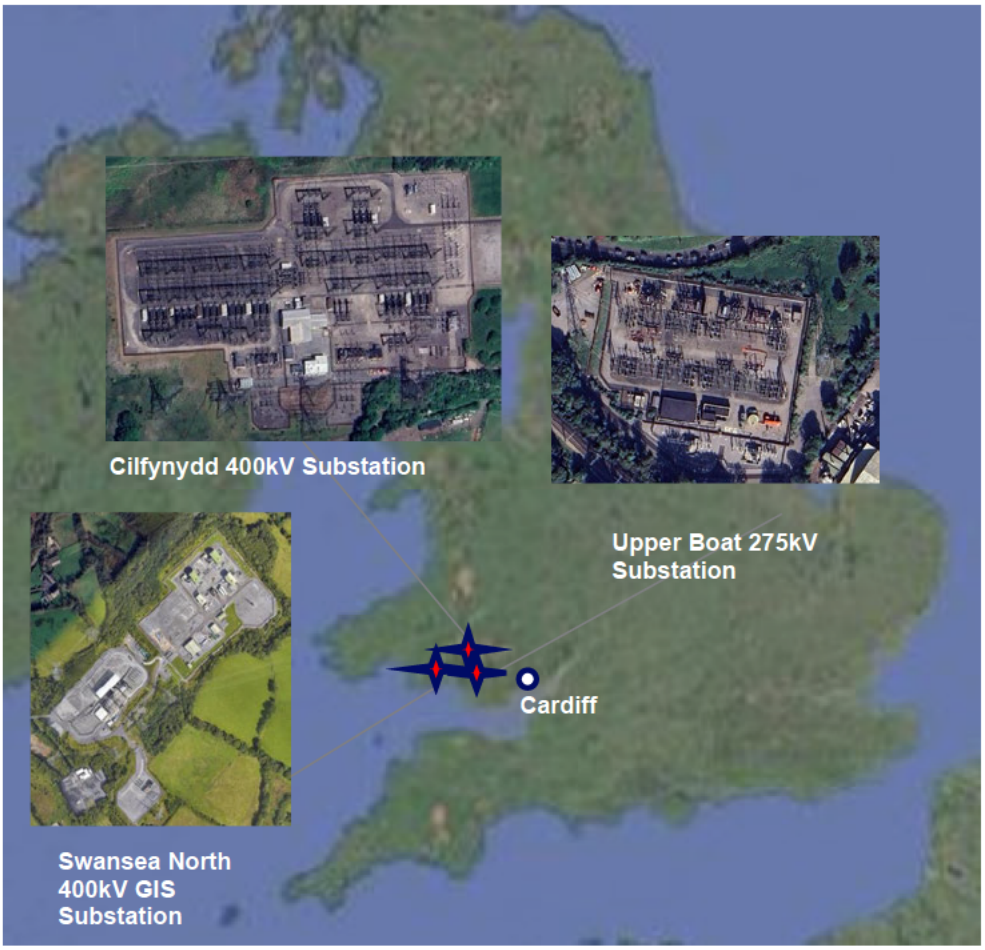

Figure 1: Cilfynydd, Swansea North, and Upper Boat locations

2.1.1 Chronology to the request

The National Energy System Operator (NESO) is responsible for ensuring the security, operability, and reliability of the electricity system. In 2019, NESO announced a pledge to operate a 100% zero carbon national electricity transmission network by 2025. To deliver this, NESO established Stability

Pathfinders[3] to support the development, adoption, and delivery of new technologies to generate important system characteristics, such as system inertia. Pathfinder Phases were determined by the following regional groupings:

- Phase One: GB Wide - Inertia and dynamic reactive power (0MW synchronous compensators only)
- Phase Two: Scotland - Inertia, SCL, and dynamic reactive power
- Phase Three: England and Wales - Inertia, SCL, and dynamic reactive power (0MW synchronous compensators only)

NESO's Stability Pathfinder Phase 3 project sought to address grid stability challenges through a competitive tender process for the procurement of inertia and SCL across five regions in England and Wales. South Wales was highlighted due to the forecasted growth in renewable energy technologies seeking to connect to the grid. Resulting in a significant increase in the demand for regional stability. NGET, in collaboration with NESO, identified Cilfynydd, Swansea North, and Upper Boat as suitable substations with available connection bays to address the requirement for network stability.

NESO - Identification of GB Stability Needs (January 2021 - September 2021)	• NESO's System Operability Framework highlighted the operability risks associated with declining traditional generation, driving the need for stability solutions. • NESO requested NGET to complete an initial analysis to confirm which substations within each region of need could accommodate a new connection for stability solutions
Pre-Tender Consultation and Expression of Interest (EOI) (September 2021 - November 2021)	• NESO published draft tender documents, including technical specifications. Market participants were invited to express their interest in the tender. • NESO reserved a number of connection points (bays) on the network, based on tehnical effectiveness and connection opportunities, for tender participants to implement solutions including Cilfynydd 400kV & Upper Boat 275kV substations
Tender Launch (December 2021 - June 2022)	• Registered participants submitted technical and commercial proposals. • NGET feasilibily studies report was produced for the reserved connection points at substations to inform tender submissions. • The tender submission deadline was 6 June 2022.
Pathfinder Contract Awards (November 2022)	• NESO awarded contracts [redacted] to six companies for solutions providing 7.5 Giga Volt Amperes (GVA) of Short Circuit Level (SCL) and 15 Giga Watt seconds (GW.s) of inertia across all regions in England & Wales[#]

2.1.2 Consumer Benefit

Stability services are essential to support the UK's broader decarbonisation targets. Traditional fossil fuel generation provides grid stability as generation is synchronous. Renewable generation, such as wind and solar, are non-synchronous and therefore require synchronous compensation to maintain grid stability. Synchronous compensators are therefore used to help maintain grid stability when renewable energy sources are increasing.

The connection of stability services at Cilfynydd, Swansea North, and Upper Boat substations will thus enable further renewable integration into the grid at South Wales. This in turn benefits the UK's

[3]ESO Transparency Forum, July 2024, Operational Transparency Forum | National Energy System Operator

Net-Zero commitments while maintaining quality of supply in line with the Security and Quality of Supply Standards (SQSS). These projects will improve SCL during system faults, enhancing the grid's ability to manage disturbances and maintain stability.

NESO estimates that failing to address stability requirements throughout England and Wales through Pathfinder Phase 3 will cost an additional £14.9 billion for system inertia management from 2025 to 2035.[4] This figure represents the cost of maintaining fossil fuel generation as a stabilising strategy, which would be evident in consumer energy bills and would also fail to meet the UK's Net Zero commitments.

2.2 Regional and strategic context

Meeting Net Zero will require a fundamental change in how the Welsh energy system is developed, integrated, and operated. In response to energy decarbonisation targets, Wales is experiencing rapid development of non-synchronous renewable energy projects. Non-synchronous generation reduces system inertia, necessitating significant electricity network reinforcement. NGET's system will need to adapt to the needs of the distribution networks and accommodate the large generation and demand customer connections pipeline in the region.

By focusing on necessary network upgrades and ensuring the system can manage the increased demand, the Pathfinder project supports Wales strategic goals for a sustainable and resilient energy future.

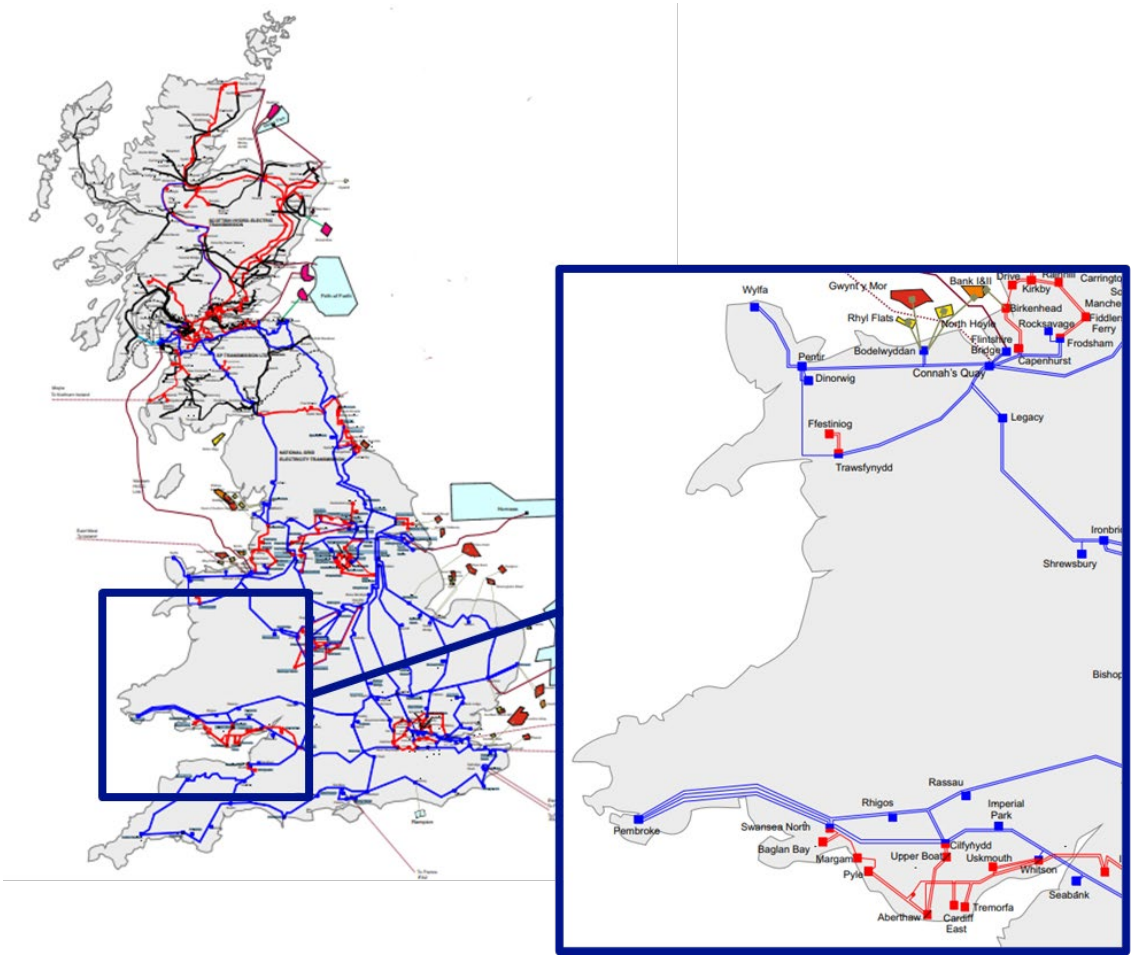

Figure 2: Overview of the Welsh network region

[4]2022, NESO, ESO announces new contracts to deliver over £14 billion in savings, https://www.neso.energy/news/eso-announces-new-contracts-deliver-over-ps14-billion-savings

2.3 MSIP Eligibility

Cilfynydd, Swansea North and Upper Boat projects meet the MSIP criteria under Special Condition (SpC) 3.14.6 (f) a system operability, constraint management or 0MW connection project (NESO driven).

2.4 T3 interactions

While this MSIP is being submitted under the RIIO-T2 price control period, it links to initiatives outlined in our RIIO-T3 Business Plan. As outlined in our RIIO-T3 Regional Report *Wales: Future Network Blueprint*, we are enhancing existing networks to ensure adequate capacity for electricity transmission in the region.[5] [redacted]

The Cilfynydd, Swansea North and Upper Boat substation grid stability Pathfinders align with the ambitions set out in our RIIO-T3 business plan to facilitate the shift towards a clean and sustainable energy network for the future. These investments are critical for aligning with Ofgem's T3 consumer outcomes (see Table 1).

Table 1: Alignment with Ofgem T3 consumer outcomes

Infrastructure fit for a low-cost transition to net zero	Supports the Pathfinders project, which is required for ensuring system stability as low-carbon technologies are integrated into the grid, which is a key element of expected new generation in South Wales over the T3 period.
System efficiency and long-term value for money	The Pathfinders project avoids increased constraint costs as the network would otherwise rely on costly balancing measures.

[5] Wales: Future Network Blueprint

3. Establishing Need

3.1 Overview

This section sets out the key driver of the investment need. This is summarised in Table 2 below.

Table 2: Summary of Investment Drivers

Summary of Primary Drivers			Date
	Pathfinder Phase 3	NESO requested NGET to conduct a high-level analysis to assess which substations in the region have capacity to accommodate a new connection. Cilfynydd 400kV, Swansea North 400kV[6] and Upper Boat 275kV substations in South Wales were identified as each having available connection bays to accommodate the Pathfinder Phase 3 solution.	[redacted]
Customer Connections	**Pathfinder**	This investment is driven by signed customer connection requests. The customers who were successful in their tender to provide stability services to NESO have been awarded contracts to deliver these solutions. NGET is obligated by our licence to provide connections for these customers. A formal application was submitted, forming the basis of the needs case for the proposed investment works, detailed in this submission. • **Cilfynydd 400kV Substation:** Welsh Power • **Swansea North 400kV Substation**: Statkraft • **Upper Boat 275kV Substation:** Pulse Clean Energy	
	Other Customers	Cilfynydd includes an additional signed customer connection for Bute Energy 107.8MW wind farm (funded by T2 Generation uncertainty mechanism).	

3.2 Load related drivers

Table 3 provides further details on the proposed customer connections.

Table 3: Details of Load drivers

Project Name	Customer Name	MVA Demand	Available for Commercial Load (ACL[7]) Date	Customer Status
Cilfynydd	Welsh Power	2 x 50 MVA User Synchronous Compensators	[redacted]	There is a signed customer contract to deliver the Pathfinder project.
Swansea North	Statkraft	2 x 42.5 MVA User Synchronous Compensators		There is a signed customer contract to deliver the Pathfinder project. The customer has gained planning permission and

[6] This connection is part of the stability pathfinder, although Swansea North is not a reserved site

[7] The Available for Commercial Load (ACL) date, refers to the date recorded as the first commercial use of the connection

Project Name	Customer Name	MVA Demand	Available for Commercial Load (ACL[7]) Date	Customer Status
			[redacted]	Final Investment Decision (FID).
Upper Boat	Green Frog Venture (now Pulse Clean Energy)	2 x 42.5 MVA User Synchronous Compensators		There is a signed customer contract to deliver the Pathfinder project.

3.2.1 Grid Stability

The national electricity networks are a complex system that must meet engineering needs for reliable power flows. These needs include inertia, SCL, voltage control, and system restoration. Traditionally, system needs have been met by synchronous generation sources such as coal, gas, and nuclear plants[8]. When synchronous sources are running in most cases they have a stabilising effect on the system. However, the rapid increase and integration of variable renewable technologies (wind, solar and other technologies) means there is a reduction in synchronous generation on the network. Non-synchronous generation does not have the same stabilising effect which means additional actions are required to maintain system reliability.

The NESO Operability Strategy Report December 2021[9] outlined plans on how NESO will look to address the stability challenges by incorporating the use of new synchronous assets such as synchronous compensators. These assets can provide stability to the network with minimal impact on the electricity market. Unlike traditional generation sources, synchronous compensators require only a relatively small demand and do not need to export large volumes of power to provide stability capability. This will ensure the system remains stable, even when network conditions are changing. By exploring new sources of stability such as synchronous compensators, the electricity system can continue to deliver safe and reliable electricity and move towards a sustainable and resilient future.

NESO identified 5 regions of need: North-East England, East of England, South Coast, South-West England and South Wales. These were chosen because Phase 3 needs to procure SCL which is highly locational in nature, with effectiveness reducing as the electrical distance increases. NESO has found from prior pathfinders that SCL solutions can also provide the required level of inertia, eliminating the need to procure inertia outside of the regions in need. NESO identified regional grid stability requirements across all regions, these are highlighted in Table 4.

[8] https://nic.org.uk/app/uploads/Operability-of-HRES-February-2021.pdf
[9] https://www.neso.energy/document/227081/download

Short Circuit Level (SCL)

SCL measures the system's ability to manage faults (such as those resulting from weather, equipment failure, or lightning) ensuring there is adequate fault current for protective devices, like circuit breakers, to operate effectively.

A high (SCL) enhances voltage stability, minimising significant fluctuations during disturbances and aiding in quicker recovery of the grid. Conversely, operating a system with a low SCL may result in a longer recovery time following a disturbance.

Inertia

Electricity for the grid is generated by machines that have large rotating components. These components rotate at the appropriate frequency to maintain a balance between supply and demand. The kinetic energy stored in parts is referred to as inertia. In the event of a sudden change in system frequency, these components will continue to rotate and mitigate that change, thereby assisting in stabilising the grid following disturbances.

Table 4: Regional grid stability requirements determined by NESO

Region	SCL and Inertia Need
North-East England	500 MVA
East of England	2000 MVA
South Coast	2000 MVA
South-West England	500 MVA
South Wales	2500 MVA
Total Inertia across all these regions	**15 GW**

In NESO document Network Options Assessment (NOA) Stability Pathfinder Phase 3 - Regions of Need and Network Diagram Details[10]," NESO's model identified the threshold that distinguishes substations inside and outside the regions of need. Additionally, NESO requested NGET to conduct a high-level analysis to determine which substations in South Wales had the capacity to accommodate a new connection. Following NESO's assessment, it was concluded that the following substations could support the pathfinder phase 3 solution:

- **Cilfynydd 400kV Substation:** Customer - Welsh Power
- **Swansea North 400kV Substation**[11]**:** Customer - Statkraft applied for a second connection and were successful in their tender
- **Upper Boat 275kV Substation:** Customer - Pulse Clean Energy

The outcome of the Stability Pathfinder Phase 3 tender assessment was published by NESO in November 2022[12]. NGET is obligated by our licence to provide connections for these customers. A formal application was made, forming the needs case for the works proposed in this submission.

3.2.2 Other Customer Connections

Other customer connections were considered for the sites as part of the optioneering process to ensure futureproofing of the network. [redacted] A renewed interest in solar, onshore wind and storage has seen the pipeline increase significantly in recent years.

Solar generation, coupled with battery storage facilities, are more prevalent in the South Wales transmission connection applications. Most offshore wind connections have applied to connect into North Wales. Both Swansea North and Cilfynydd substations are popular sites with several

[10] https://www.nationalgrideso.com/document/227121/download

[11] This connection is part of the stability pathfinder, although Swansea North is not a reserved site

[12] nationalgrideso.com/pathfinders/stability-network-services-procurement#Phase-3

contracted connections.

Cilfynydd 400kV substation has multiple customer connection schemes which have driven the need to extend the operational boundary and extend the busbar to facilitate the new 400kV connection bays. These connections include a combination of generation and storage projects for wind and solar generation and Battery Energy Storage System (BESS). The most notable customer is the Bute Energy 107.8MW wind farm connection (funded by T2 Generation Uncertainty Mechanism).

3.3 Existing and planned future network

3.3.1 Overview of the network today

South Wales is generally a net exporter whereby excess power on the transmission network flows out of this region towards the South-East in times of high wind and solar generation. The Welsh transmission infrastructure is rated for the existing import and export requirements. However, due to the volume of connections and Holistic Network Design (HND) proposals, significant infrastructure upgrades are required to securely transfer power between Wales and England.

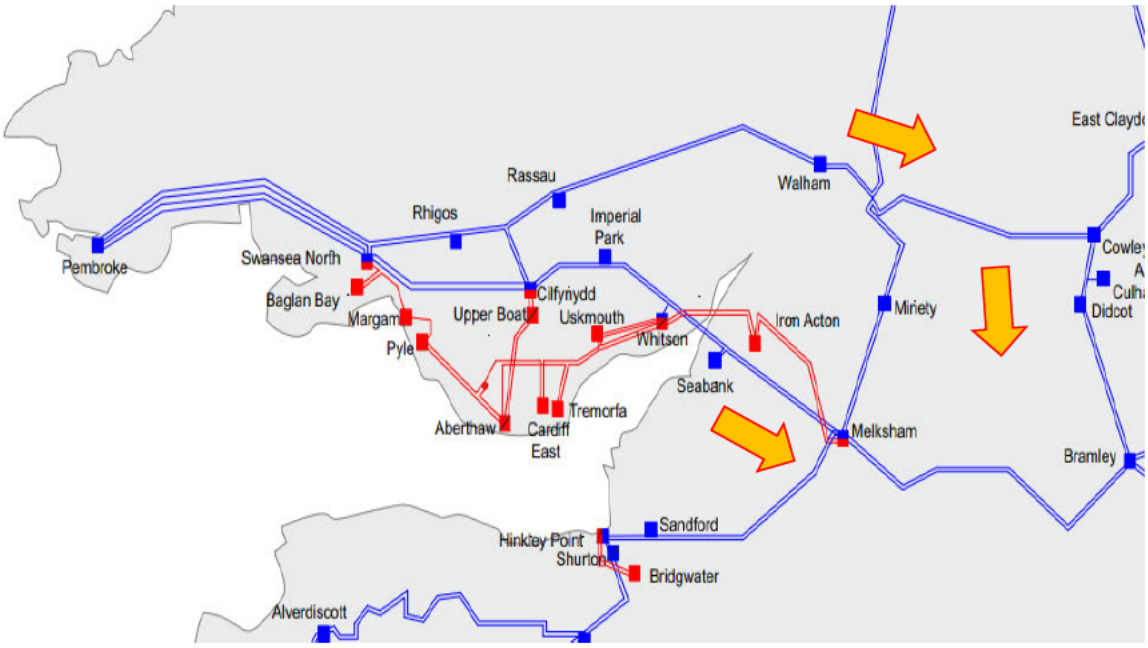

Figure 4: NGET South Wales Network & Powerflow direction.

3.3.2 Strategic outlook of the network changes

The Pathfinder Phase 3 addresses a growing need to maintain network stability while accommodating the rising demand from renewable generation. NESO's 'Leading the Way'[13] suggests that 45 GW of new connections are required across all of England & Wales by 2031. As of February 2024; customers have contracts for new connections that would deliver a total of 17GW generation connections in this region.

Following 2030, Wales is expected to primarily export electricity owing to the integration of offshore wind projects. Furthermore, new High Voltage Direct Current (HVDC) connections arriving from Scotland in combination with new generation in Wales will significantly increase flows in the region. These connections drive the need to enhance power transfer capability within Wales to enable power export.

[redacted]

3.3.3 Asset Health

The main driver for this investment is to implement NESO's Stability Pathfinder Phase 3 solution, and as a result, site asset health has been given limited consideration during the project's development. High-level overview of each site suggests that most of the assets are low risk (in good condition). It is important to highlight that this assessment is based on primary health drivers, such as family condition, age, and obsolescence. and does not consider other factors such as visual condition assessment, oil/SF6 top-ups, maintenance compliance, plant status issues, or open defects.

Any asset health-related works at Pathfinder sites will be efficiently managed through programmes of work or asset health intervention windows as part of T2, or through T3. Therefore, NGET are not seeking additional funding to address any asset health issues through the Pathfinder MSIP.

[13] https://www.futureenergyscenarios.com/2023-FES/

4. Optioneering

4.1 Overview

This section summarises the options we considered to address the needs case established in the previous section, in a way that best serves the interest of current and future consumers. In line with our optioneering process, for each project (Cilfynydd, Swansea North and Upper Boat) we identified the following high-level options:

A. A do-nothing option as the counterfactual option.

B. A market-based solution.

C. Non-transmission, whole system solution.

D. Making use of existing NGET substations.

E. A new substation.

In summary:

- **Options A-C** were discounted in all three projects because they risk NGET's licence obligation to provide a customer connection. The grid stability needs identified by NESO would also remain unaddressed without action, leading to increased constraint costs, reliance on costly balancing measures, and operational risks to the grid. Optioneering was therefore focused on site-specific solutions to ensure the successful delivery of the Pathfinder Phase 3 solution.

  Options B & C in particular were ruled out in early optioneering stages as NESO's advanced planning, supported by NGET's feasibility studies during the tender process, assessed the appropriateness of Cilfynydd, Swansea North and Upper Boat substations and reserved the required connection bays at each location.

- Options that **make use of existing NGET substations (Option D)** were then considered. These extend and utilise the existing infrastructure at Cilfynydd, Swansea North, and Upper Boat substations to connect the Pathfinder solution. Various options were evaluated at each site to ensure optimal site layout and technology solution:

  - **Cilfynydd:** evaluated seven site-specific options to extend the substation. The options differed in terms of technology type (AIS or GIS extension), the location of the extension, and the supply location. Option D-2 was the selected as the preferred solution.
  - **Swansea North:** evaluated four site-specific options to accommodate the Pathfinder 3 connection. These options varied in technology type. Option D-2 was the selected as the preferred solution.
  - **Upper Boat:** considered six site-specific options to extend the substation, varying only in technology type. Option D-3 was selected as the preferred solution.

- We then considered options to **construct new substations (Option E)**. This approach would construct entirely new substations or consider alternative sites to connect the Pathfinder solution. This was not shortlisted for any of the substations because it was deemed excessive due to the technical feasibility and sufficient capacity of Cilfynydd, Swansea North and Upper Boat substations to accommodate the stability solutions identified by NESO. Constructing a new substation or utilising an alternative location may incur substantial costs, entail planning challenges, and result in prolonged timelines, which would conflict with the operational objectives of the Pathfinder programme. This would lead to higher expenses for consumers and a potential risk to the quality of supply.

4.2 Cilfynydd

4.2.1 High-level options analysis

An assessment of the high-level options is undertaken for each site to meet the customer need. Each is assessed against the following criteria:

- Capacity and future development potential
- Design and technical complexities
- Operation and maintenance
- Safety, health and security
- Planning, land and consent
- Third party impact and network coordination
- Environment and Sustainability
- Timing of programme and resources
- Cost

A summary of our initial options assessment is detailed for Cilfynydd in Table 5 below.

Table 5: Summary of initial options assessment, Cilfynydd 400kV Substation

Option	Option title	Option description	Taken Forward to Detailed Optioneering?	Rationale
D-1	AIS extension - with reactive compensation	The required customer connection is facilitated by extending the substation with 7 new bays (2x east - 2025, 5x west - [redacted]).	**Not taken forward** - does not include spare bays in design for peak local connection demand.	Demand for connection to substation not met.
D-2	AIS extension - maximum customer bays	The required customer connection is facilitated by extending the substation with 9 new bays (2x east - 2025, 7x west - [redacted]).	**Taken forward to detailed assessment** - Customer connection delivered with AIS solution.	Additional spare bays included in design to meet local substation connection demand.
D-3	AIS extension - with reactive compensation - PRRs between feeders	As per D-1, but with increased distance between feeders (no change to number of bays)	**Not taken forward** - does not include spare bays in design for peak local connection demand.	Demand for connection to substation not met.

Option	Option title	Option description	Taken Forward to Detailed Optioneering?	Rationale
D-4	AIS extension - maximum customer bays but with PRRs between feeders	As per D-2 but with increased distance between feeders and 1 less user bay to the west i.e. 8 new bays (2x east - [redacted], 6x west - [redacted]).	**Not taken forward** - does not include spare bays in design for peak local connection demand.	Increased distance between bays used in design reduces substation capacity and risks peak local connection demand not being met.
D-5	AIS extension to East with GIS extension - building to the west	The required customer connection is facilitated by an AIS extension of 2 new bays to the east, and a GIS building to the west using non-SF6 equipment.	**Taken forward to detailed assessment** - smaller footprint/visual impact than AIS solution. Most new assets indoors & hidden from view	Potential to extend GIS in future, to accommodate additional customers.
D-6	GIS extension - building to the east - supplied by east only	The required customer connection is facilitated by an AIS extension of 2 new feeder bays to the east, and a GIS building extension to the east using non-SF6 equipment.	**Taken forward to detailed assessment** - no new land purchase required - extension is entirely within current land boundary.	Potential to extend GIS in future, to accommodate additional customers.
D-7	GIS extension - building to the east - supplied by east & west	The required customer connection is facilitated by an AIS extension of new bays - 1 east, 1 west - and a GIS building extension to the east using non-SF6 equipment.	**Not taken forward** - High cost and GIS equipment complexity excessive for connection requirements.	Design and equipment are costly, and solution offers only neutral benefits in other key areas. West supply cable route is complex leading to high associated risk and cost.

The conclusion of the high-level options assessment shown in the above table is that Options D-2, D-5 & D-6 were taken forward for detailed options assessment, as the timeline for contracted customer connection could be achieved (D-1), GIS solution has a smaller footprint than AIS (D-5), and GIS extension would entirely be within the current land boundary (D-6).

4.2.2 Qualitative options analysis

Table 6 below provides a summary of our detailed qualitative assessment of the relevant technical, environmental, planning, and socio-economic considerations pertaining to the shortlisted options at Cilfynydd.

Table 6: Summary of qualitative analysis of shortlisted options, Cilfynydd 400kV Substation

Option #	D-2	D-5	D-6
Option title	**AIS Extension - Maximum Customer Bays**	**GIS Extension - Building to West**	**GIS Extension - Building to East - Supplied by East Only**
Capacity & future development potential Preferred option: D-2	• Extension exceeds the number of customer connections and therefore provides spare bays/capacity for additional demand in the future.	• Potential to extend GIS in future, to accommodate more customers.	• Potential to extend GIS in future, to accommodate additional customers.
Design & technical complexities Preferred option: D-2	• Conventional extension, meeting requirements / obligations of project. • Can be built offline with final connection to existing substation towards end of construction period. • Expansion either side of bus section, security of supply. • No new technology or type registration required. • NG land fully utilised (no room for further expansion at a later date). • Non-standard PRR location. • Potential requirement for additional bus coupler(s) / section(s) following Power System Engineer (PSE) input, at the cost of user bays.	• Can be built offline with final connection to existing substation towards end of construction. period. • Supply from only one side of existing bus section. • Non-SF6 solution required, associated uncertainty.	• Can be built offline with final connection to existing substation towards end of construction period. • Supply from only one side of existing bus section. • Non-SF6 solution required, associated uncertainty.

Option #	D-2	D-5	D-6
Option title	**AIS Extension - Maximum Customer Bays**	**GIS Extension - Building to West**	**GIS Extension - Building to East - Supplied by East Only**
Operations & maintenance (O&M) Preferred option: D-2	• Conventional O&M possible. • Short outages due to offline build. · Continued use of existing amenities building (limited). • Equipment is close to access road due to limited space. • All AIS bays are oriented southwards due to restricted land availability. A number of cables exiting the site to the south following the extension.	• GIS marketed as 'maintenance-free'. • AIS O&M conventional. • Continued use of existing amenities building (limited). • Equipment is close to access road due to limited space.	• GIS marketed as 'maintenance-free'. • AIS O&M conventional. • New amenities and facilities at GIS site. • Equipment is close to access road due to limited space.
Safety, health & security Preferred option: D-6	• Temporary road to avoid vehicle traffic through existing site during construction. • Access to user bays will require third parties to use main gate and travel through the existing substation.	• Temporary road to avoid vehicle traffic through existing site during construction. • Access to user bays will require third parties to use main gate and travel through the existing substation.	• Temporary road to avoid vehicle traffic through existing site during construction [redacted] • Entrance to a separate compound must be managed/controlled.
Planning, land & consent Preferred option: D-5	• No new land purchase required – extension is entirely within current land boundary.	• Land remaining to west after extension. • No new land purchase required – extension is entirely within current land boundary.	• No new land purchase required - extension is entirely within current land boundary. • Space remains to west of site for further extension at a future date. • Unknown feasibility and cost of groundworks to east. • Potential easements/consent issues for cable laying.

Option #	D-2	D-5	D-6
Option title	**AIS Extension - Maximum Customer Bays**	**GIS Extension - Building to West**	**GIS Extension - Building to East - Supplied by East Only**
Third party impact & network coordination Preferred option: D-2	• Already well-established outdoor AIS substation. • Rural/sparsely populated area, lower chance of objections from local residents. • Outdoor switchgear is arguably more visually intrusive.	• Already well-established outdoor AIS substation. • Rural/sparsely populated area, lower chance of objections from local residents. • Smaller footprint/visual impact than AIS solution. Most new assets indoors & hidden from view.	• Rural/sparsely populated area, lower chance of objections from local residents. • Smaller footprint/visual impact than AIS solution. Most new assets indoors & hidden from view. • GIS compound built on currently unused land - development may be unpopular/unexpected. • Potential visual impact of GIS on hill to east is unknown. May be possible to mitigate this through design / positioning of new development.
Environment & sustainability Preferred option: D-2	• Largest land take and therefore potential disruption to environment. • All new equipment (aside from circuit-breaker replacements) so limited risk of disposal issues. • Potential reuse of parts of existing access roads and fence line (modification will be required). • Environmental surveys may highlight issues with expansion. • Potential requirement to import material to create a level site to west.	• Smallest land take and potential disruption to environment. • All new equipment (aside from circuit-breaker replacements) so limited risk of disposal issues. • Potential reuse of parts of existing access roads and fence line (modification will be required). • Environmental surveys may highlight issues with expansion.	• Smaller land take on existing site. • New GIS compound on hill to east. Currently appears to be a field, will be disturbed. • All new equipment (aside from circuit-breaker replacements) so limited risk of disposal issues. • Potential reuse of parts of existing access roads and fence line (modification will be required). • Potential requirement to import material to create a level site to east/west. • Surveys may highlight issues with expansion to east/west.
Timing of programme & resources	• Land to east already level, easier to meet 2025 deadline of 2 new user bays. Then have until 2028 for more	• Land to east already level, easier to meet 2025 deadline.	• Less groundwork to west • Groundworks to west must be completed by 2025 - significant.

Option #	D-2	D-5	D-6
Option title	**AIS Extension - Maximum Customer Bays**	**GIS Extension - Building to West**	**GIS Extension - Building to East - Supplied by East Only**
Preferred option: D-2	significant expansion to west (and associated groundworks). • Fully AIS solution, reduced cost versus GIS. • Availability of hill to east as potential Construction, Design & Management (CDM) area. • Significant groundworks, cut and fill required to west. Feasibility and cost of groundworks yet to be estimated and likely to be significant.	• Less groundwork to west than other options, shorter timeframe, and reduced cost of cut & fill. • Non-SF6 solution required, associated uncertainty. • GIS bay manufacture and testing off-site, less on-site construction work. • Availability of hill to east as potential CDM area. • Lead time for non-SF6 GIS can be long	• Non-SF6 solution required, associated uncertainty. • Cable lay required, and costs associated. • GIS bay manufacture and testing off-site, less on-site construction work. • Possible long lead time for non-SF6 GIS. • Potential high cost of groundworks to east (yet to be estimated). • Cost of establishing a new compound vs. expanding an existing site. • GIS equipment is more expensive than AIS, p us cost of GIS building.

The assessment in the above table demonstrates the comparative analysis between the shortlisted options against key criteria including technical, environmental, planning, and socio-economic considerations. The assessment highlights strengths and weakness for the shortlisted options.

Option D-2 was selected as the preferred option for the investment driver.

4.2.3 Quantitative options analysis

The multi-criteria process summarised above for selecting the preferred option did not require a detailed Cost Benefit Analysis (CBA) in line with Ofgem's guidance. We have concluded it would not be proportional to scale and cost of the investments proposed [redacted] to undertake a CBA process for this submission.

Our evaluation of the options indicates that the preferred solution provides the best value for consumers, the earliest connection date for the customer, and an appropriate level of technical and project risk.

4.2.4 Preferred solution

The preferred solution is **Option D-2**, AIS Extension - Maximum Customer Bays.

Site Solution: Option D-2 involves an extension to the Cilfynydd AIS substation, which includes the addition of two AIS customer connection bays to the east of the substation in 2025 for the Pathfinder connection. The proposed extension fits within land currently owned by National Grid.

Followed by seven AIS customer connection bays to the west of the substation [redacted] The number of bays provides futureproofing for current forecast customer connection demand (further details are provided in the establishing need section 2.2.2). The initial optioneering included two bays to the east for the connection of the National Energy System Operator (NESO) Pathfinder and an additional bay for Bute Energy ([redacted]). Meanwhile, the seven-bay extension to the west ([redacted]) is intended to accommodate a pipeline of customer connections. [redacted]

Technology Solution: Option D-2 proposes the installation of AIS, free-standing earth switches, pantograph disconnectors and high and low-level post insulators.

[redacted]

Figure 5: Cilfynydd - Option D-2 Layout Drawing

4.3 Swansea North

4.3.1 High-level options analysis

A summary of our initial options assessment is detailed for Swansea North in Table 7 below.

Table 7: Summary of initial options assessment, Swansea North 400kV Substation

Option	Option title	Option description	Taken Forward to Detailed Optioneering?	Rationale
D-1	Extending the existing substation with new bays	The required customer connection is facilitated through accommodating 10 additional bays at Swansea North GIS Hall using SF6 equipment.	**Taken forward to detailed assessment** - demand for future connections at Swansea north exceed can be met	Known technology, low risk of design faults. Compact design.
D-2	Single TEE connection on Pembroke 2 circuit at Swansea North	The required customer connection is facilitated through providing a connection point to be tee'd off Pembroke two circuit to connect the new Swansea North Greener Grid connection.	**Taken forward to detailed assessment** - this option provides the customer with connection which considers wide site strategy aimed at connecting multiple customers to Swansea North.	Additional consideration given to the volume of customer connection applications at Swansea North.
D-3	Connect at Remote Ends	The required customer connection is facilitated through connection to another substation in the region.	**Not taken forward** - This option is not suitable for the customer connection.	Next closest substation to customer location is more than 25km away, infeasible to ask customers to connect there due to increased risk and cost. Additionally, the existing sites do not have the capacity to facilitate the connection.
D-4	Rebuild Existing Site	The required customer connection is facilitated by reconstruction and asset replacement at existing substation.	**Not taken forward** - This option provides the customer with connection but considered excessive for the size of works required.	Existing site only commissioned in 2010 - equipment not in need of replacement.

The conclusion of the high-level options assessment shown in the above table is that Options D-1 & D-2 were taken forward for detailed options assessment, as demand for future connections can be accommodated with a GIS extension (D-1) and the timeline for contracted customer connection could be achieved (D-2).

4.3.2 Qualitative options analysis

Table 8 below provides a summary of our detailed qualitative assessment of the relevant technical, environmental, planning, and socio-economic considerations pertaining to the shortlisted options at Swansea North.

Table 8: Summary of qualitative analysis of shortlisted options, Swansea North 400kV Substation

Option #	D-1	D-2
Option title	**GIS Bay Extension**	**Single TEE connection Pembroke 2 Circuit at Swansea North**
Capacity & future development potential Preferred option: D-2	• Demand for future connections at Swansea north exceed capacity of a GIS extension (max 10 additional bays) and thus an expansion is expected in the coming years. • Reduces capacity for future connections.	• Tee connection considers wider site strategy aimed at efficiently connecting multiple customers to Swansea North.
Design & technical complexities Preferred option: D-2	• Known technology, low risk of design faults. • Compact design.	• Already designed for initial Greener Grid connection so can be replicated efficiently for second customer connection. • Meets customer's needs. • Known technology, low risk of design faults.
Operations & maintenance Preferred option: D-2	• Leaves space in corner of the substation as laydown in future. • GIS expansion has greater complexity, require multiple outages and greater safety challenges due to proximity of live circuits.	• Utilises space in substation corner which may have been used as laydown area for future works. • Can have percentage of works completed offline without the requirement of outages.
Safety, health & security Preferred option: D-2	• Known technology, health and safety procedures are well known. • GIS expansion would require multiple outages and working near multiple live circuits • Access to the GIS hall would be confined. Different working parties/plant on top of each other	• Known technology, health and safety procedures are well known. • Working required near to a live circuit. • Working outdoors enables greater construction footprint which is preferred for people/plant interface.
Planning, land & consent Preferred option: D-2	• Option may require planning permission for building extension.	• Permitted development.

Option #	D-1	D-2
Option title	**GIS Bay Extension**	**Single TEE connection Pembroke 2 Circuit at Swansea North**
Third party impact & network coordination Preferred option: D-2	• All works within National Grid compound. • Would require multiple outage co-ordination. May require DNO outages.	• All works within National Grid compound. • Only required NGET outages.
Environment & sustainability Preferred option: D-2	• SF6 Intensive solution.	• Limited use of SF6.
Timing of programme & resources Preferred option: D-2	• Not possible to meet the customers connection date. • Requires costly GIS hall extension.	• Meets customer contracted connection date. • Time & resource efficient - Lessons learned from delivery of Statkraft one project will allow design and contract management to be optimised, enabling straightforward implementation and minimising potential delays. • Cost effectiveness - Single Tee connection will avoid the need to extend the GIS Hall.

The assessment in the above table demonstrates the comparative analysis between the shortlisted options against key criteria including technical, environmental, planning, and socio-economic considerations. The assessment highlights strengths and weakness for the shortlisted options.

Option D-2 was selected as the preferred option for the investment driver.

4.3.3 Quantitative options analysis

The multi-criteria process summarised for selecting the preferred option at each site did not require a detailed Cost Benefit Analysis (CBA). See discussion in Section 4.2.3.

4.3.4 Preferred solution

The preferred solution is **Option D-2**, Single TEE connection on Pembroke 2 Circuit.

Site Solution: Option D-2 involves an extension through a Tee'd connection off the incoming Pembroke two circuit. The connection will be located in the North-West corner of the existing substation. The proposed connection mirrors the initial Statkraft one connection at Swansea North and fits within the existing substation boundary.

Technology Solution: Installation of a new disconnector at a tee point on the outgoing Swansea North - Pembroke two circuit, including 400kV circuit breaker**,** 400kV disconnector**,** current and voltage transformers**,** protection and control modifications and associated civils / minor works for both infrastructure and one-off works.

4.4 Upper Boat

4.4.1 High-level options analysis

A summary of our initial options assessment is detailed in Table 9 below.

Table 9: Summary of initial options assessment, Upper Boat 275kV Substation

Option	Option title	Option description	Taken Forward to Detailed Optioneering?	Rationale
D-1	Extending the existing substation with new bays - standard with CB	The required customer connection is facilitated through extension of the 275kV substation with 2 New Bays with Circuit Breaker with Standard Bay Arrangement.	**Not Taken forward** - the option provides the customer with connection however after strengths, weaknesses, opportunities threats (SWOT) analysis other options were identified as having a higher level of benefit.	Space restrictions on bay pose operational challenges for construction and maintenance.
D-2	Extending the existing substation with new bays - standard with DCB	The required customer connection is facilitated through extension of the existing 275kV substation with 2 New Bays with DCB with Standard Bay Arrangement.	**Not taken forward** - the option provides customer with connection however identified as one of the least beneficial options.	Space restrictions on bay pose operational challenges for construction and maintenance. Relative cost of technology high and risk of fault in isolation.
D-3	Extending the existing substation with new bays - three phase with DCB	The required customer connection is facilitated through extension of the existing 275kV substation with 2 New Bays with DCB - Three Phase CVT, CT and CSE.	**Taken forward to detailed assessment** - This option provides the customer connection and is the second most beneficial following the SWOT analysis in terms of benefits, compared to other options.	Cost saving solution by combining three devices into one (disconnector, circuit breaker and earth switch).
D-4	Extending the existing substation with new bays - single phase with DCB	The required customer connection is facilitated through extension of the existing 275kV substation with 2 New Bays with DCB, Single Phase CVT, CT and CSE.	**Taken forward to detailed assessment***- this option provides customer with connection with the greatest number of benefits compared to all other options.	Greatest number of benefits including configuration of equipment and combining disconnector, circuit breaker, and earth switch - saving cost and space availability.

Option	Option title	Option description	Taken Forward to Detailed Optioneering?	Rationale
D-5	Extending the existing substation with new bays - single phase with disconnector switch	The required customer connection is facilitated through extension of the existing 275kV substation with 2 New Bays with Disconnector Switch - Single Phase CVT, CT and CSE.	**Not taken forward** - the option provides customer with connection however identified as one of the least beneficial options.	Space restrictions on bay pose operational challenges for construction and maintenance.
D-6	Extending the existing substation with new bays - hybrid switchgear	The required customer connection is facilitated through extension of the existing 275kV substation with 2 New Bays with Hybrid Switchgear and CSE.	**Not taken forward** - this option provides customer with connection however equipment is more costly compared to technologies used in other options. Additional environmental and security detractors identified.	Option cost too high and concerns regarding health, safety, & security.

*Option D-4 (with single phase CVT) was initially selected as the preferred solution due space constraints at site. Upon detailed design it became evident that a three phase CVT could be accommodated, resulting in a decision to move forward with option D-3.

The conclusion of the high-level options assessment shown in the above table is that Options D-3 & D-4 were the top two scoring options and were taken forward for detailed options assessment.

4.4.2 Qualitative options analysis

Table 10 below provides a summary of our detailed qualitative assessment of the relevant technical, environmental, planning, and socio-economic considerations pertaining to the shortlisted options at Upper Boat.

Table 10: Summary of qualitative analysis of shortlisted options, Upper Boat 275kV Substation

Option #	D-3	D-4
Option title	**2 x Sync Comp Bays with Installation of Disconnecting Circuit Breakers, Three phase CVT**	**2 x Synchronous Compensation Bays with Installation of Disconnecting Circuit Breakers, Single phase CVT**
Design & technical complexities	• Compact asset design. • Complex technology.	• Compact asset design. • Complex technology.
Operations & maintenance	• DCB adds complexity to O&M. • Ongoing issues of using a DCB as a point of isolation.	• DCB adds complexity to O&M.
Safety, health & security	• High level of safety with robust mechanical and electrical interlocking for DCB. Lesser-known technology so health safety and operational procedures need to be developed further. • A sizable portion of work will be carried out within the existing substation.	• High level of safety with robust mechanical and electrical interlocking for DCB. Lesser-known technology so health safety and operational procedures need to be developed further. • A sizable portion of work will be carried out within the existing substation.
Planning, land & consent	• The proposed extension work is on land already owned by National Grid. • Cable route also passes through a small section of Railway crossing. • The equipment will be constructed in the existing spare Bay location, potentially an issue if space is limited.	• The proposed extension work is on land already owned by National Grid. • Cable route also passes through a small section of Railway crossing.
Environment & sustainability	• Use of non SF6 CB should be available within the project timescales. • AIS will not require as much SF6 gas compared to hybrid alternative.	• Use of non SF6 CB should it be available within the project timescales. • AIS will not require as much SF6 gas compared to hybrid alternative.
Timing of programme & resources	• Cost saving solution by combining three devices into one (disconnector, circuit breaker and earth switch). • DCBs more costly alone.	• DCB with single phase CVT is the best option if there is an issue of space availability and clearance from adjacent bays. • Cost saving solution by combining three devices into one (disconnector, circuit breaker and earth switch).

Option #	D-3	D-4
Option title	2 x Sync Comp Bays with Installation of Disconnecting Circuit Breakers, Three phase CVT	2 x Synchronous Compensation Bays with Installation of Disconnecting Circuit Breakers, Single phase CVT
		• DCBs more costly alone.

The assessment in the above table demonstrates the comparative analysis between the shortlisted options against key criteria including technical, environmental, planning, and socio-economic considerations. The assessment highlights strengths and weakness for the shortlisted options.

Upper Boat 275kV Substation: Option D-3 was selected as the preferred option for the investment driver.

4.4.3 Quantitative options analysis

The multi-criteria process summarised for selecting the preferred option at each site did not require a detailed Cost Benefit Analysis (CBA). See discussion in Section 4.2.3.

4.4.4 Preferred solution

The preferred solution is **Option D-3**, Substation Extension - Installation of Disconnecting Circuit Breakers, Three-phase CVT, Cable Sealing End with Slipover CTs at National Grid premises and HAM Unit CT and VT at Customer End.

Site Solution: Option D-3 involves extending mesh corner one and mesh corner four to facilitate the customer connection for stability services at the Upper Boat substation. Cabling is required to connect synchronous compensator to the substation. The user will be responsible for the cabling, installation, and ownership of the synchronous compensators.

The site requires new foundations for DCB, ESW, CT, VT, CVT and CSE. The two synchronous compensator feeder bays will be configured to the substation mesh corners as follows: synchronous compensator one will be connected to mesh corner one, while synchronous compensator two will be connected to mesh corner four.

Technology Solution: Option D-3 proposes the installation of Disconnecting Circuit Breakers with Earth switch, three phase CVT, Cable sealing end with slipover Current Transformer, High Accuracy Metering (HAM) unit CT and VT to feed the synchronous compensator bays.

5. Detailed cost for preferred solution

5.1 Introduction

This section provides a high-level summary of the overall costs for the proposed extensions at Cilfynydd, Swansea and Upper Boat substations including an expenditure profile for all regulatory years of delivery. The costs presented in this section represent our latest view of costs for the proposed investment; all costs are presented in 2018/19 prices, unless otherwise stated.

The cost model submitted alongside this document, provides a breakdown of the costs in more detail and should be reviewed alongside this chapter.

5.2 Total Allowance Request - Cilfynydd

Total project costs are [redacted]. NGET requests [redacted] allowance is provided through the MSIP reopener mechanism to recover the direct portion of costs and deliver works described above. The MSIP reopener mechanism is subject to the Opex escalator and therefore indirect costs will be funded under this route.

Table 11: Allowance request - Cost Model tab reference 1.0

	2018/19 price base (£)								
	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	Total
Total project costs (excluding one off contribution)	[redacted]								
CAI									
Allowance Request (Direct Only)*									

*Remainder to be funded via Opex escalator

5.3 Cost Summary - Cilfynydd

The total cost to develop and deliver the Cilfynydd project is [redacted] including indirect costs and costs incurred to date.

The table below shows a summary of total project costs.

Table 12: Cost Summary - Cost Model tab reference 1.1

2018/19 price base (£)		
Element	**Total**	**CAI/Direct**
[redacted]		

5.4 Cost Firmness - Cilfynydd

Table 13 below shows the assessment of cost firmness using the classification outlined in the Ofgem LOTI reopener guidance document published on 29th March 2021. This shows that [redacted] of total costs are in firmness 2 and, whilst they have been agreed, are not yet certain given the contracting arrangements on this scheme.

[redacted]

Table 13: Cost Firmness – Cost Model Tab reference 1.9

Cost Firmness	Total	Notes
[redacted]		

5.5 Total Allowance Request - Swansea North

Total project costs are [redacted]. NGET requests [redacted] allowance is provided through the MSIP reopener mechanism to recover the direct portion of costs and deliver works described above. The MSIP reopener mechanism is subject to the Opex escalator and therefore indirect costs will be funded under this route.

Table 14: Allowance request - Cost Model tab reference 1.0

	2018/19 price base (£)					
	2023/24	2024/25	2025/26	2026/27	2027/28	Total
[redacted]						

5.6 Cost Summary - Swansea North

The total cost to develop and deliver the Swansea North project is [redacted] including indirect costs and costs incurred to date.

The table below shows a summary of total project costs.

Table 15: Cost Summary - Cost Model tab reference 1.1

2018/19 price base (£)		
Element	**Total**	**CAI/Direct**
[redacted]		

5.7 Cost Firmness - Swansea North

Table 16 below shows the assessment of cost firmness using the classification outlined in the Ofgem LOTI reopener guidance document published on 29th March 2021. This shows that [redacted] of costs fall within cost firmness 3.

[redacted]

Table 16: Cost Firmness - Cost Model Tab reference 1.9

Cost Firmness	Total	Notes
[redacted]		

5.8 Total Allowance Request - Upper Boat

Total project costs are [redacted]. NGET requests [redacted] allowance is provided through the MSIP reopener mechanism to recover the direct portion of costs and deliver works described above. The MSIP reopener mechanism is subject to the Opex escalator and therefore indirect costs will be funded under this route.

Table 17: Allowance request - Cost Model tab reference 1.0

	2018/19 price base (£)				
	2023/24	2024/25	2025/26	2026/27	Total
[redacted]					

5.9 Cost Summary - Upper Boat

The total cost to develop and deliver the Upper Boat project is [redacted] including indirect costs and costs incurred to date.

The table below shows a summary of total project costs.

Table 18: Cost Summary - Cost Model tab reference 1.1

2018/19 price base (£)		
Element	Total	CAI/Direct
[redacted]		

5.10 Cost Firmness - Upper Boat

Table 19 below shows the assessment of cost firmness using the classification outlined in the Ofgem LOTI reopener guidance document published on 29th March 2021. This shows that [redacted] of total costs are in firmness 2 and, whilst they have been agreed, are not yet certain given the contracting arrangements on this scheme.

[redacted]

Table 19: Cost Firmness - Cost Model Tab reference 1.9

Cost Firmness	Total	Notes
[redacted]		

6. Deliverability and risk

6.1 Deliverability

This section sets out a summary of the key activities pertaining to the delivery of the project, including the current high-level programme plan, procurement strategy and anticipated risks.

6.1.1 Delivery Programme

The programme for each project is illustrated in Table 20, 21 and 22 below,

Table 20: Cilfynydd Delivery Programme

Activities	Date
[redacted]	

Table 21: Swansea North Delivery Programme

Activities	Date
[redacted]	

Table 22: Upper Boat Delivery Programme

Activities	Date
[redacted]	

6.1.2 Procurement and Contracting Strategy

The procurement and contracting strategy for these projects adheres to the NGET procurement approvals process, ensuring that all projects meet strategic goals and technical requirements. This comprehensive approach involved a thorough assessment of different procurement options for the project, whereby the project has been procured via an established framework.

6.1.3 Risk and Risk Management

A risk management process has been used for managing reasonably foreseeable risks. The process is in line with ISO 31000:2009, Risk Management - Principles and Guidelines. Table 23, 24 and 25 below list the key risks and mitigation strategies for Cilfynydd, Swansea North, and Upper Boat, respectively. A comprehensive risk register for each project is available within the cost model.

Table 23: Delivery risks for Cilfynydd 400kV

Description	Mitigation
Interfacing Works Interface with two customers on site. The customers will be undertaking site works whilst the project is undertaking works. [redacted]	Regular weekly interface meetings and monitoring of progress of all programmes.
System Outages Taking parts of the network offline to complete works can only be done if the remainder of the network is operational and can compensate for the removal of capacity during works. Could cause delays due to inability to complete works within scheduled outage.	Ongoing liaison with NESO.
Unforeseen Ground Contamination Risk that unforeseen contaminants may be encountered during the works. Contamination identified will need to be dug out and removed to a licenced landfill. Clean imported inert fill will need to be introduced to fill voids from the removal. Contaminated ground water will also need to be tankered away.	Further verification boreholes and slit trenches to be undertaken by the main works contractor.
Unforeseen Discovery of Asbestos Recent Ground Investigation (GI) survey output has not indicated presence of asbestos on site. The survey output is based on the top soil. There is the risk of unforeseen asbestos discovery on site. This could lead to additional costs or removal and potential delay to programme. Engagement with a specialist asbestos removal contractor to safely remove the asbestos. Leading to stand down of the contractor work gang.	Further verification boreholes and slit trenches to be undertaken by the main works contractor. The contractor will highlight any asbestos discovered. This will be a National Grid risk.

Table 24: Delivery risks for Swansea North 400kV

Description	Mitigation
System Outages Taking parts of the network offline to complete works can only be done if the remainder of the network is operational and can compensate for the removal of capacity during works. This could cause delays due to inability to complete works within scheduled outage.	Ongoing liaison with NESO.
[redacted]	
Risk Management Hazard Zones (RMHZ) Currently, there are no RMHZs in place. The duration of the works introduces the potential for RMHZ to be imposed at some point if a safety concern arises. There is the risk of access restrictions for the construction activities. This could cause the contractor to stand down and risks programme delay.	Ensure the programme has sufficient float to limit the impact of RMHZ in place. Discuss and implement an action plan to mitigate the delays that RMHZ could impose on the project e.g. by building a temporary blast wall.

Table 25: Delivery risks for Upper Boat 275kV

Description	Mitigation
[redacted]	
System Outages Constraints on the system at Upper Boat dictate the outages required. These outages need to be planned carefully and agreed with NESO. There is a risk that outages may not be available to meet the current programme dates. This could cause delays due to inability to complete works.	Early engagement with the customer's contractor and NG contractor to align programmes of the work required. Early confirmation of outages will enable the contractor to plan resource accordingly and re-sequence works if required.
Unforeseen Discovery of Asbestos Previous site surveys reported known presence of asbestos on site. There is the risk of unforeseen asbestos discovery on site in excess of the known volume. This will lead to additional costs for removal. Potential delay to programme. Engagement with a specialist asbestos removal contractor to safely remove the asbestos. Stand down of the contractor work team who spotted the asbestos during their work activities.	Contractor has trained personnel to manage asbestos disposal. This will limit the standing time.
Unforeseen Underground Obstructions and Services Ground Penetrating Radar (GPR) surveys and trial holes to be undertaken in 2025. Underground services and obstructions to be identified during the surveys. There is a risk that previously unknown services and underground obstructions may be discovered on site during construction. Risks additional costs to divert existing services to accommodate customer cable.	GPR surveys and trial holes are to be undertaken.
[redacted]	

7. Conclusion

This document is the MSIP submission to Ofgem by NGET for the South Wales Pathfinder. It is submitted with reference to Special Condition 3.14.6 (f) of NGET's transmission licence. This paper has demonstrated the need for investment at Cilfynydd, Swansea North, and Upper Boat substations, and the optioneering analysis that led us to our proposed solutions. Table 26 summarises the main drivers, selected options, estimated costs and outputs.

Table 26: MSIP Project Investment Summary

Main drivers	**To provide 3 new 0MW demand connections for network stability projects.** South Wales substations identified to deliver the grid stability services in Pathfinder Phase 3 are: Cilfynydd 400kV, Swansea North 400kV and Upper Boat 275kV substation.		
Selected Option	**Cilfynydd**: **AIS Extension to the East with Two User Bays** Double AIS Busbar extension of 400kV substation to the east, to provide space for two user bays. Welsh Power synchronous compensator and Bute Energy wind farm. Installation of bay equipment Earth Switches (ESW), civil works, associated P&C, land remediation and extension of the fence line boundary.	**Swansea North**: **Single Tee Connection** Installation of new disconnector at a tee point on the outgoing Swansea North - Pembroke two circuit (A80M), Installation of a 400kV circuit breaker at Swansea North 400kV, Installation of a 400kV disconnector at Swansea North 400kV, Installation of current and voltage transformers, Protection Control (P&C) modifications and associated civils work.	**Upper Boat**: **Extension of mesh corner one and mesh corner four**. Includes installation of the following bay equipment: Disconnecting Circuit Breaker ((DCB), with integrated earth switch), Capacitive Voltage Transformer (CVT), Current Transformers (CT), Cable Sealing End (CSE), civil works and associated Protection & Control (P&C).
Estimated Cost	**The current total cost of projects are:** Cilfynydd: [redacted] Swansea North: [redacted] Upper Boat: [redacted]	**The direct costs (and funding allowance being sought) is:** Cilfynydd: [redacted] Swansea North: [redacted] Upper Boat: [redacted]	
Spend Profile	**T2 (FY2022 - FY2026):** Cilfynydd: [redacted] Swansea: [redacted] Upper Boat: [redacted]	**T3 (FY 2027 - FY2031):** Cilfynydd: [redacted] Swansea: [redacted] Upper Boat: [redacted]	**T4+ (FY 2032+):**
Outputs	Deployment of synchronous compensators across all regions in stability Pathfinder Phase 3 will procure 7.5 Giga Volt Amperes (GVA) of Short Circuit Level (SCL) and 15 Giga Watt seconds (GW.s) of inertia. NESO estimates that, without the integration of Pathfinders across all regions, consumers in England and Wales may incur an additional £14.9bn in constraint actions to manage stability between 2025-35. Addressing grid stability will also enable greater integration of low carbon technologies on to the network.		
PCD Primary Output	Substation extensions accommodate stability service connections at Cilfynydd 400kV ([redacted]), Swansea North 400kV [redacted]), & Upper Boat 275kV substations ([redacted]).		

Following a NESO-led investment driver to enhance grid stability in South Wales, NGET will implement infrastructure works to connect Synchronous Condensers at Cilfynydd, Swansea North, & Upper Boat. NGET's proposed solution for each substation is shown below.

- **Cilfynydd 400kV substation:** AIS Extension to East with Two User Bays
- **Swansea North 400kV substation:** Single TEE Connection
- **Upper Boat 275kV substation:** Extension of Mesh Corner One & Mesh Corner Four

The designs will provide the necessary infrastructure for the customer connection requirements and ensure a reliable and efficient connection; with the greatest benefits in terms of consumer value.

8. RIIO-T1 and RIIO-T2 allowances

There were no investments proposed for these projects during either RIIO-T1 or T2 business plans submissions. The projects do not have funding through any other price control mechanism.

9. Assurance and Point of Contact

Provided with the MSIP portfolio submissions is the assurance statement letter, providing written confirmation in line with the assurance requirements set out in Ofgem's Re-opener Guidance and Application Requirements Document, dated 17th February 2023.

This confirmation is provided by the Head of Future Price Controls, Electricity Transmission. They provide the following statements below regarding how this MSIP application has been prepared and submitted in relation to each of the three assurance points requested by Ofgem:

a. It is accurate and robust, and that the proposed outcomes of the MSIP submission are financeable and represent best value for consumers.

b. There are quality assurance processes in place to ensure the licensee has provided high-quality information to enable Ofgem to make decisions which are in the interests of consumers.

c. The application has been subject to internal governance arrangements and received sign off at an appropriate level within the licensee.

NGET's designated point of contact for this MSIP application is Leo Michelmore, Strategic Upgrade Regulatory Manager (leo.michelmore@nationalgrid.com).

Appendix A: Enlarged drawings of preferred options

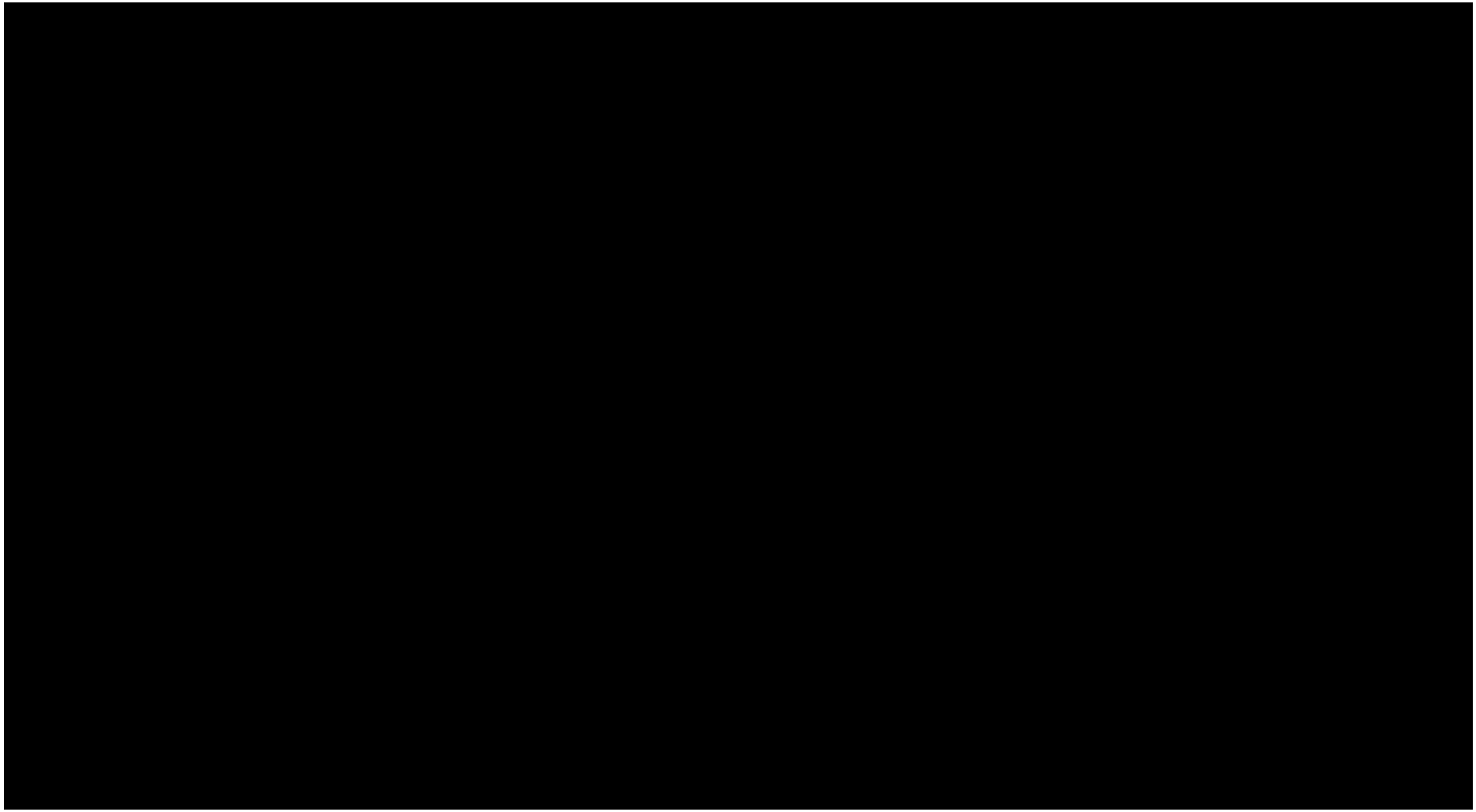

Figure 8: Layout drawing of preferred option for Cilfynydd 400kV substation

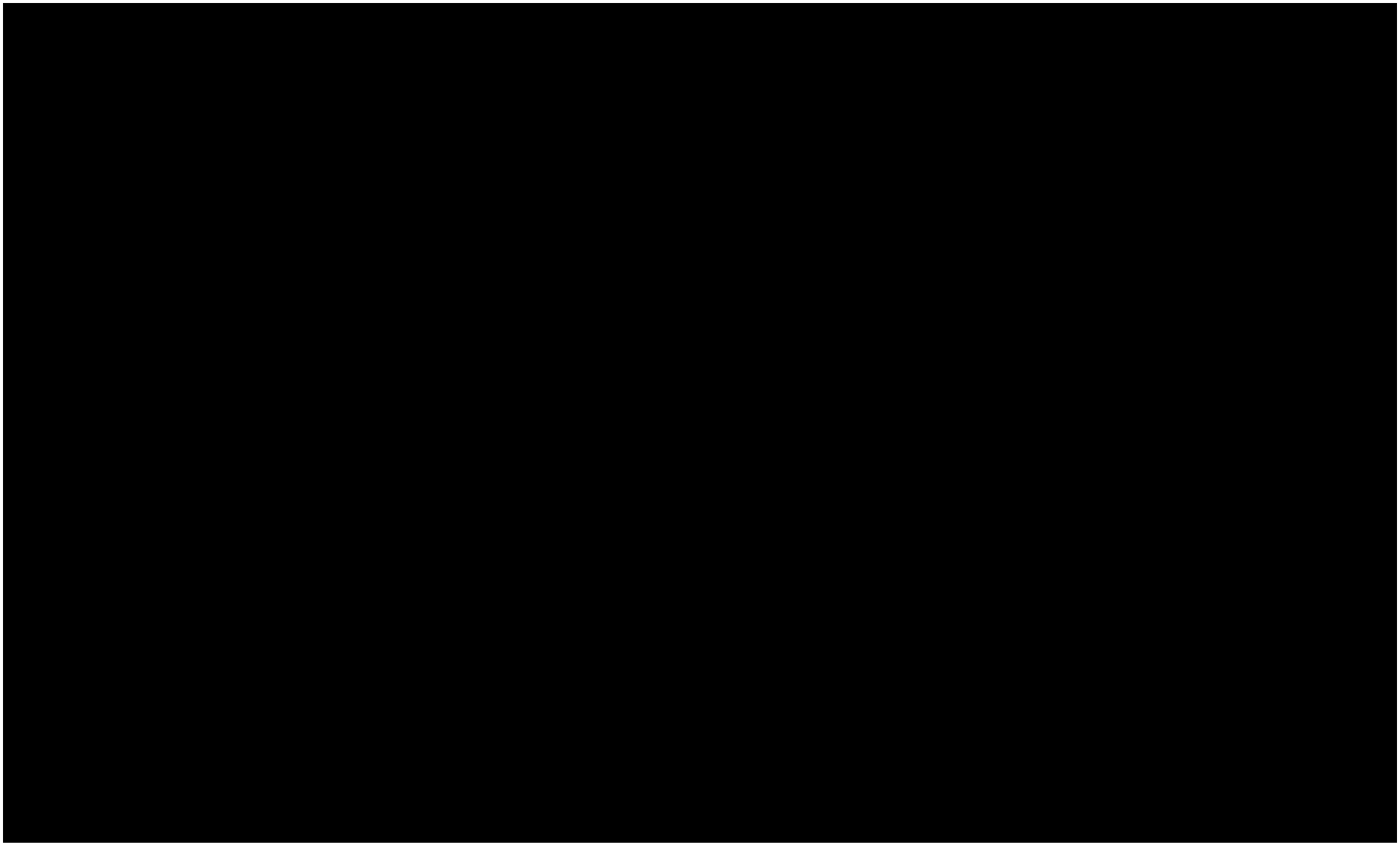

Figure 9: Layout drawing of preferred option for Swansea North 400kV substation

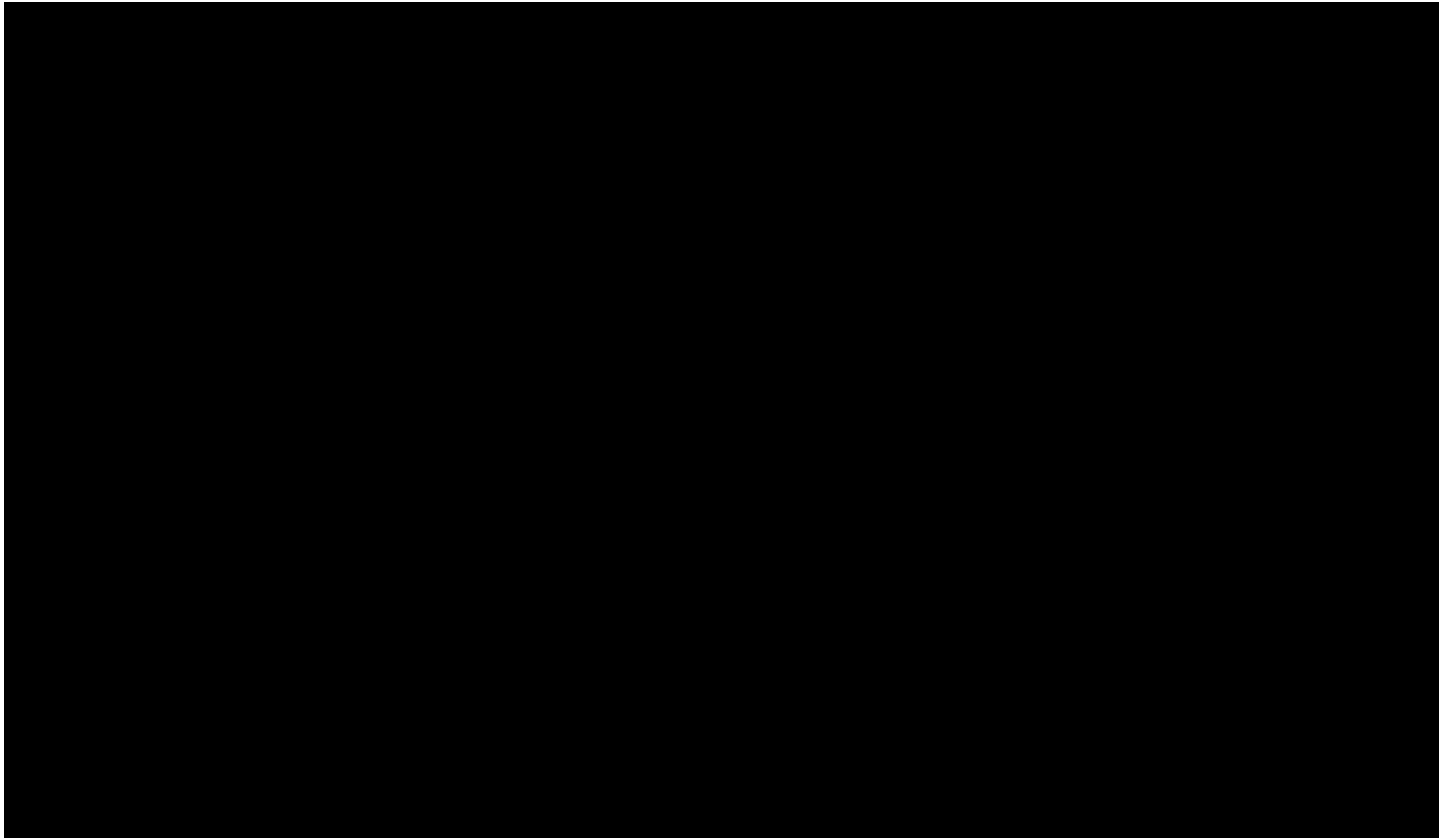

Figure 10: Layout drawing of preferred option for Upper Boat 275kV substation

Appendix B: Glossary

Acronym	Definition
ACL	Available for Commercial Load
AIS	Air Insulated Switchgear
BESS	Battery Energy Storage System
CAI	Closely Associated Indirects
CB	Circuit Breaker
CBA	Cost Benefit Analysis
CILF4	Cilfynydd 400kV Substation
CSE	Cable Sealing End
CT	Current Transformer
CVT	Capacitive Voltage Transformer
DCB	Disconnecting Circuit Breaker
ECI	Early Contractor Involvement
EPC	Engineering, Procurement, Construction
ESO	Electricity System Operator
ESW	Earth Switch
FEED	Front End Engineering Design
FES	Future Energy Scenarios
FID	Final Investment Decision
GIS	Gas Insulated Switchgear
HAM	High Accuracy Metering
HND	Holistic Network Design
HVDC	High Voltage Direct Current
MC	Mesh Corner
MSIP	Medium Sized Investment Project
NESO	National Energy System Operator
NGET	National Grid Electricity Transmission
NOA	Network Options Assessment
O&M	Operation and Maintenance
P&C	Protection and Control
RMHZ	Risk Management Hazard Zones
SAP	System Average Price
SCL	Short Circuit Level
SF6	Sulphur Hexafluoride
Sync Comp	Synchronous Compensator
tCSNP	Transitional Centralised Strategic Network Plan
VT	Voltage Transformer

Appendix C: Cost model

Please see the accompanying Cost Models submitted alongside this MSIP:

- ‘Appendix C Pathfinders South Wales (Cilfynydd) – MSIP Jan 25 – Cost Model’
- ‘Appendix C Pathfinders South Wales (Swansea North) – MSIP Jan 25 – Cost Model’
- ‘Appendix C Pathfinders South Wales (Upper Boat) – MSIP Jan 25 – Cost Model’

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