

OCSS Options for Sea Link

Independent Review of OCSS
Qualifying Coordinated Project:
OCSS_01 North Falls, Five
Estuaries & Sea Link

Executive Summary

Executive Summary (1/5)

As part of the Offshore Coordination Support Scheme (OCSS) launched by the Department for Energy Security & Net Zero (DESNZ), Arup has been tasked by the consortium of North Falls, Five Estuaries and Sea Link, to perform an independent assessment of two selected alternative options for the Suffolk-Kent point to point HVDC link, known as Sea Link. This is to assist the feasibility study of an offshore coordinated proposal that will explore the connection of two offshore wind farms, North Falls and Five Estuaries, into the bootstrap GB grid reinforcement - Sea Link.

These options have been evaluated against the baseline design (Figure 1) of these otherwise separate projects, which comprise of Sea Link, a two-ended offshore HVDC point-to-point link of 2.0 GW Converter Stations, and separate wind farms connections to shore with a combined capacity up to 1.8 GW. The options currently under evaluation are as follows:

- Option 1 (Figure 2): Sea Link will be initially built and commissioned (Stage-1) as a two-ended HVDC link with an ‘Omega loop’ (an excess bight of cable). At a future date when an offshore converter platform is built near the bight of cable, Sea Link would be taken out of service, cut, and recovered at the bight. It would then be connected into the offshore converter platform to form a three-ended HVDC link (Stage-2) before connecting the offshore wind farms (Stage-3).
- Option 2 (Figure 3): Sea Link is initially built and commissioned as a two-ended HVDC link with an HVDC switching platform in the middle (Stage-1). At a future date when an offshore converter platform is built, Sea Link would be taken out of service to connect the switching platform with the offshore converter platform. This would form a three-ended HVDC link (Stage-2) before connecting the offshore wind farms (Stage-3).

Our assessment shows that the two options are technically feasible, however both will require longer overall delivery programmes, significant outage periods for the construction and commissioning between stages as well as additional capital costs and technical, commercial and programme risks. Furthermore, the both options need to be designed and procured as 3 ended HVDC system to minimise the construction and commissioning risks.

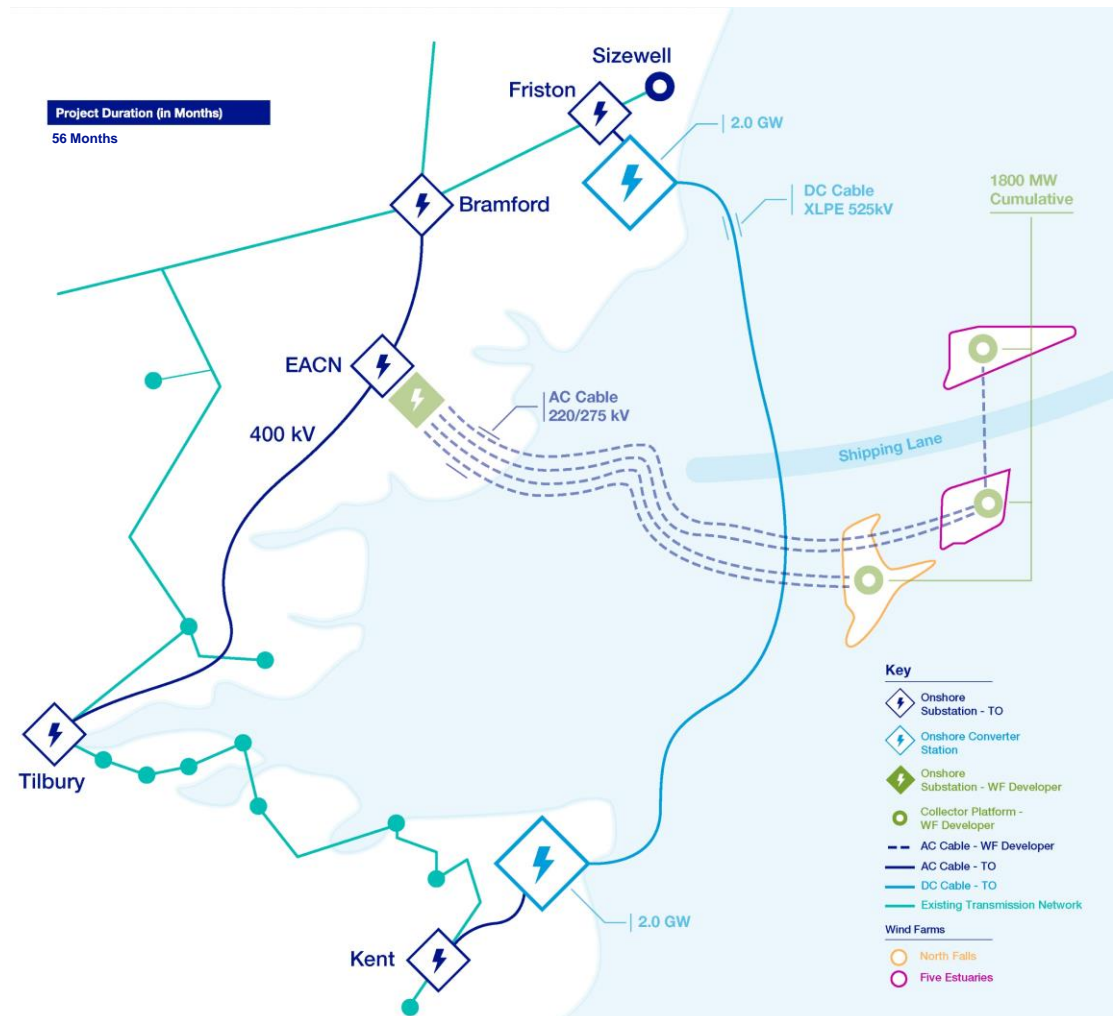


Figure 1. Stylised representation of the Baseline – Sea Link, North Falls and Five Estuaries

Executive Summary (2/5)

Overall Programme

High-level overall programmes comprehensive of the development of the wind farms has been defined for all the three options, the grant of the Sea Link’s DCO has been identified as the start of the delivery phase of each of the programme. The estimate for the time to fully build and commission each of the options are:

- Baseline: total minimum 4 Years and 8 Months, for Sea Link (point to point HVDC system) to be in-service by **December 2030**. By this time both the North Falls and Five Estuaries Wind Farms (awarded as separate projects) would also be operational.
- Option 1: total minimum 8 Years and 8 Months to deliver the whole scheme by **Q4 2034** (earliest). This covers the Sea Link (3-terminal HVDC system) to be in service, followed by modification to allow the connection of the windfarms and for North Falls and Five Estuaries to start operation.
- Option 2: total minimum 8 Years and 5 Months to deliver the whole scheme by **Q3 2034** (earliest). This covers the Sea Link (3-terminal HVDC system) to be in service followed again by modification to allow the connection of the windfarms and for North Falls and Five Estuaries to start generating energy.

Please note the above estimates are the minimum for each option, the programmes may be delayed due to the identified risks. The duration of the planning process is difficult to predict due to its complexity, but it is assumed to be the same for all three options. However, Option 1 and Option 2 may involve in separate public consultations and marine licence applications etc., which may make their planning process longer than that of the baseline. The programmes may also be affected by the ModApp process of the windfarm Grid connection for the alternative options as a significant risk.

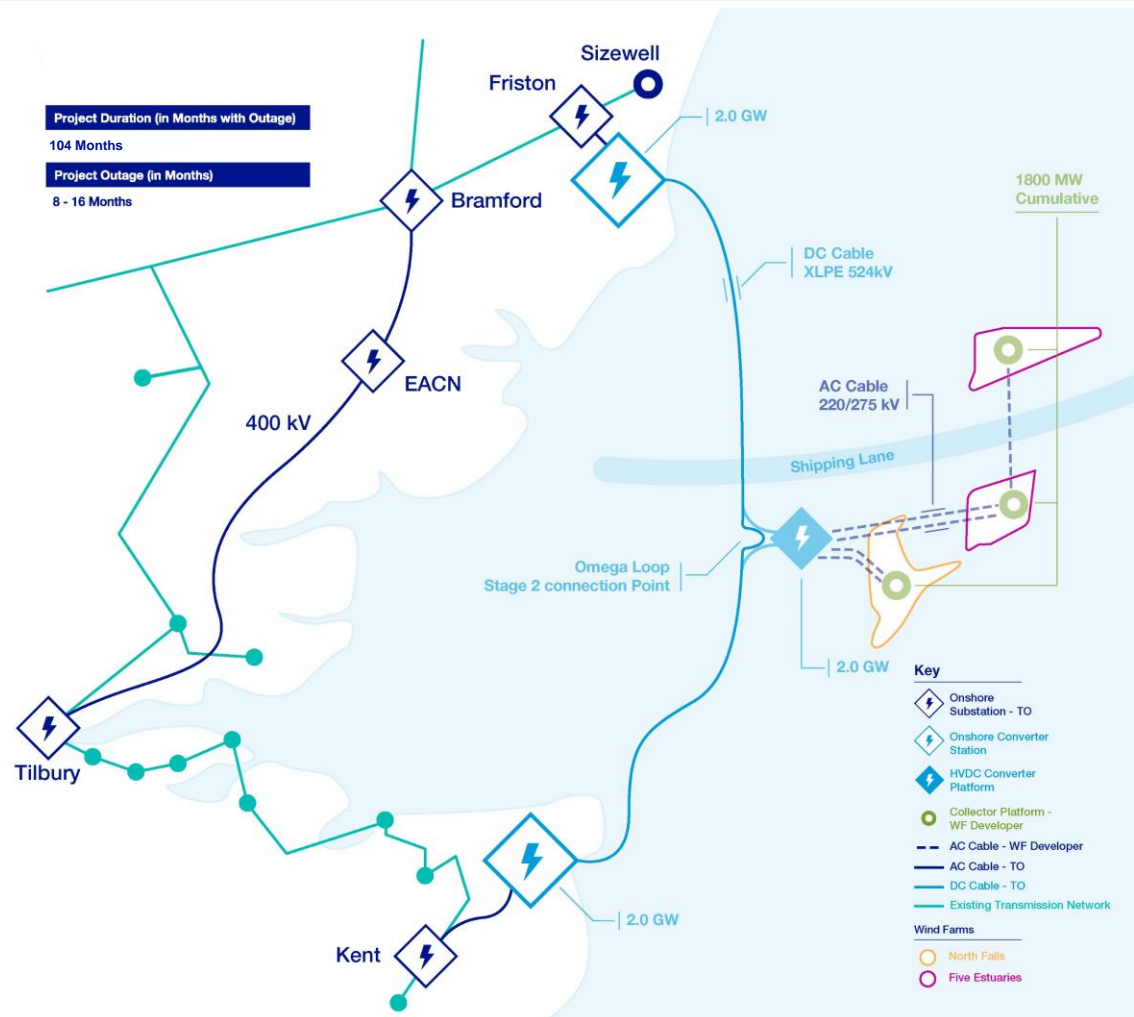


Figure 2. Stylised representation of the Option 1 – Omega Loop

Executive Summary (3/5)

Outage

It has been estimated that an outage on Sea Link would range from 33 weeks (~8 months) (contains no contingency) up to 66 weeks (~16 months) for Option 1, and 27 weeks (~6 months) to 54 weeks (~12 months) for Option 2, to cater for offshore construction works as well as testing and commissioning activities required to turn the two ended HVDC link into the three ended system depending on what each OEM proposes for their system.

The duration range given above allows for a contingency used in the current industry of 100% for the HVDC offshore commissioning activities which make up the outages described. This accounts for weather, market and logistics risks.

The duration is estimated assuming all construction activities that can be done prior to the outage which has been exhausted with overlapping commissioning and testing works, representing the absolute minimum duration to take the Sea Link out of service as an interconnector.

Please note:

- Once the three ended HVDC link has been energised, it is estimated that additional period of time is needed for the suite of works to commission the wind farms although Sea Link can remain in service but with “risk to trip”.
- A second outage period of around 8 weeks will be required to complete the final full load testing and commissioning of the three terminal HVDC system with the wind generation in operation.

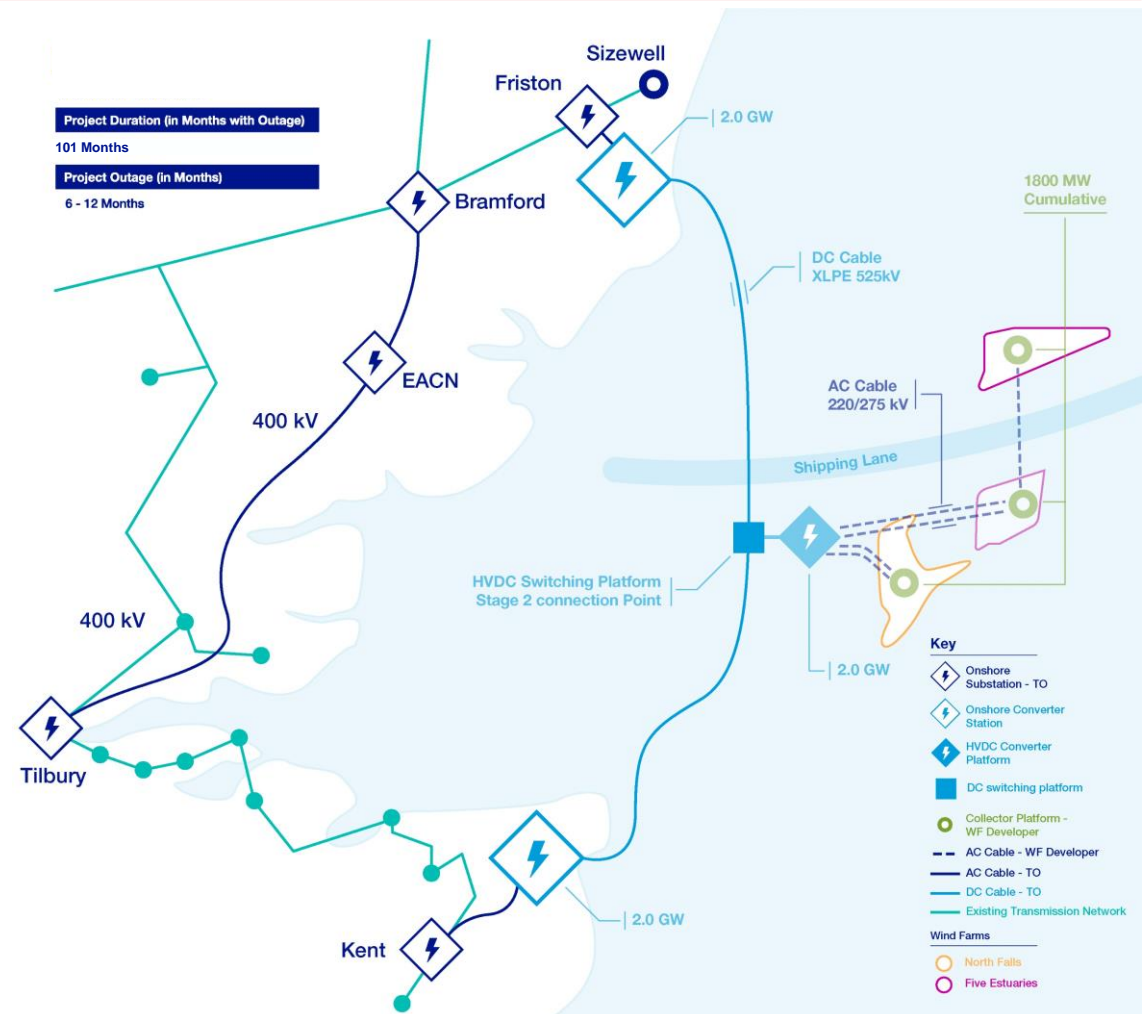


Figure 3. Stylised representation of the Option 2 – HVDC Switching Platform

Executive Summary (4/5)

Costs

The following costs have been estimated based on the building blocks defined for all the options of the Sea Link design, with the key assumptions made about the components that comprise the designs. Please note, the windfarm costs are **not** included in the estimates below.

- Baseline option: [REDACTED]
- Option 1: [REDACTED]
- Option 2: [REDACTED]

Please refer to Figure 5 for a cost comparison of each option. Details of the cost build up are shown further down in this report.

It is understood that the Electricity System Operator (ESO) is producing their East Anglia Network Study which considers any impact to the existing transmission system in the region in the event North Falls and Five Estuaries connects to Sea Link.

If reinforcements are required to be in service prior to the windfarms connecting to Sea Link, any outage associated with the construction is likely to have a different cost profile than the counterfactual depending on the specific design and timing of any chosen reinforcement. Therefore, this report identifies the duration of outages associated with the connection options but not the cost of any outages as these will be reflected in the high-level economic evaluation of options considered by ESO.

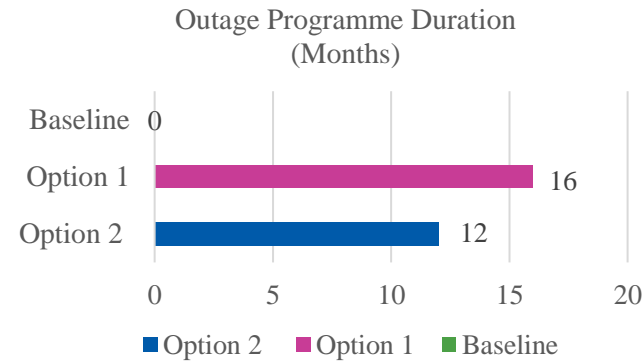


Figure 4. Baseline, Option 1 and Option 2 Outage Programme Duration Estimate

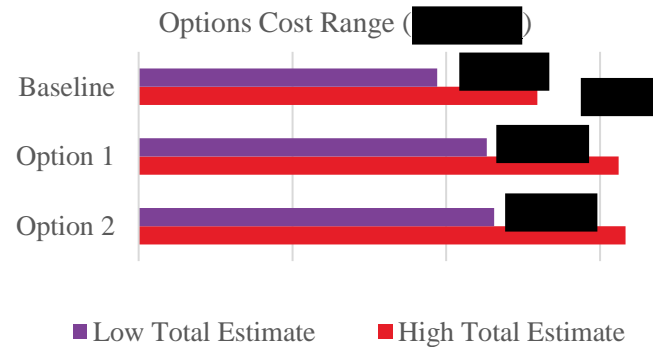


Figure 5. Baseline, Option 1 and Option 2 Cost Estimate

Executive Summary (5/5)

Risks

Risks have been assessed qualitatively, using a 5x5 scoring system for each risk; the two variables being probability and impact. These include risks on technology, construction, operations as well as procurement, programme and commercial/contractual etc. The scores for each risk are aggregated for each option.

Figure 7 shows the overall risk differential between option 1, 2 and the baseline. For a detailed view of the key risks, with the risk type identification (Commercial, Technical or Programme).

Key Facts

Figure 4 and 6 provide a comparison of the programme and outage durations associated with the baseline and Options 1 and 2. Table 1 summarise some key facts for the sea Link baseline versus the OCSS options at a glance.

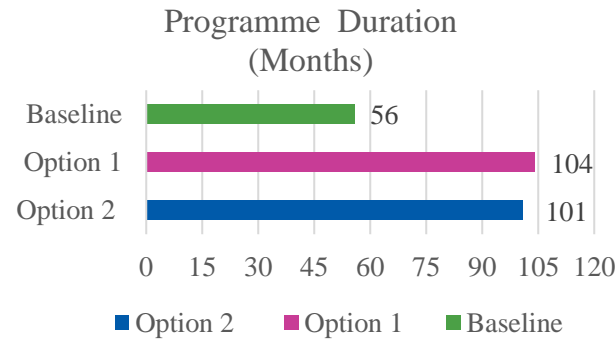


Figure 6. Baseline, Option 1 and Option 2 Programme Duration Estimate

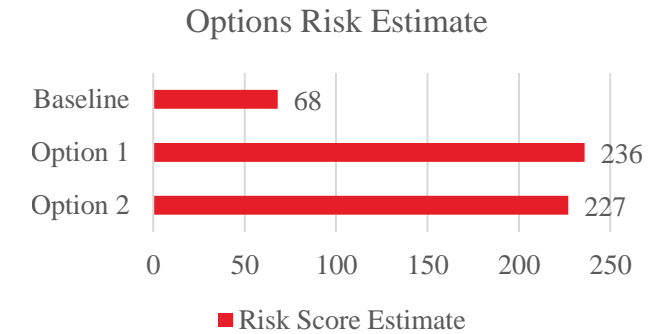


Figure 7. Baseline, Option 1 and Option 2 Risk Estimate

	Baseline	OCSS (Option 1 and 2)
Windfarm capacity	Up to 2.1 GW	Up to 1.8 GW
Windfarm connection date	Oct 2030	Q3/Q4 2034 (earliest)
Sea Link Outage post 2030 to connect windfarms	Not applicable	Up to 66 weeks
Additional Network reinforcement	None	Yes (9 options considered by ESO)
Sea Link CAPEX	Baseline CAPEX	[REDACTED]
Risks (Technical, constriction, commercial & programme etc.)	Existing Baseline Risk	Significant increase and more unknowns

Table 1. Key facts for Sea Link baseline vs. the OCSS options

Introduction

Introduction - Background

The Offshore Coordination Support Scheme (OCSS) is a program announced in the British Energy Security Strategy in April 2022 and aims to provide grants to offshore energy projects to develop coordinated projects for offshore transmission infrastructure. The main goal of the OCSS is to enhance the coordination and scale of the qualifying projects through grants. This scheme is a strategic move by the government to support the growth and efficiency of offshore infrastructure projects and take a step towards the net zero goals. The North Falls, Five Estuaries and the Sea Link projects have been identified as potential candidates to the scheme and could benefit from the coordination enhancement the scheme brings.

The three projects, North Falls, Five Estuaries and Sea Link are planned to be individual projects.

The North Falls project (Figure 8), awarded by the Crown Estate to The North Falls Offshore Wind Farm (RWE and SSE Joint Venture) in Autumn 2020, plans to build up to 72 wind turbines within the Outer Thames Estuary, in the southern North Sea and an onshore substation to connect into the National Grid's network at the EACN (East Anglia Connection Node). The project is planned to be operational by October 2030.

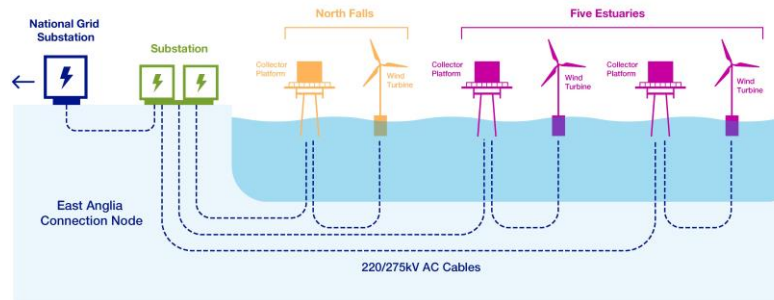


Figure 8. Illustration of the Baseline – North Falls and Five Estuaries

The Five Estuaries project (Figure 9), awarded by the Crown Estate to RWE in Summer 2020, plans to build up to 79 wind turbines within the Southern North Sea and an onshore substation to connect into the National Grid's network at the EACN. The project is planned to be operational October by 2030.

The Sea Link project (Figure 2), is a National Grid project initially proposed as a point-to-point offshore HVDC link between Suffolk and Kent, as part of the Accelerated Strategic Transmission Investment (ASTI) framework to reinforce the GB onshore transmission system. It would

provide 2GW of Grid capacity between Suffolk and Kent with the Earliest In-Service Date (EISD) of December 2030.

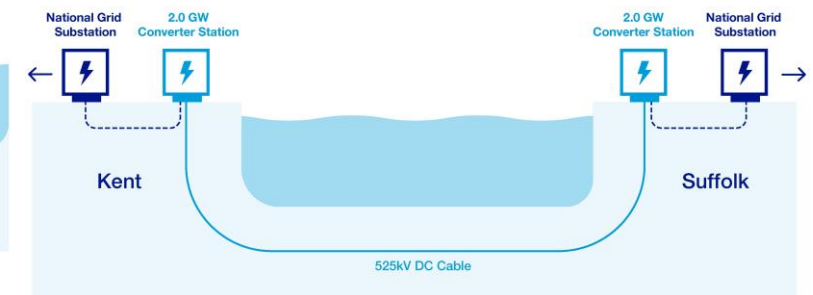


Figure 9. Illustration of the Baseline – Sea Link

The Department for Energy Security and Net Zero (DESNZ) and the Department for Business Energy & Industrial Strategy (DBEIS) initiated the Offshore Coordination Support Scheme (OCSS) in December of 2022.

On the 5th of December 2023 DESNZ and DBEIS announced that the consortium of North Falls, Five Estuaries and Sea Link, have been successful in receiving the grant funding.

Introduction - Background

In the OCSS funding application the consortium submitted two alternative designs to the baseline designs (Figures 1 and 2).

In the first alternative design, Option 1 (Figure 10), Sea Link is initially built and commissioned as a two-ended HVDC link connecting two onshore 2.0 GW converter stations with an excess bight of cable (known as the ‘Omega Loop’) as Stage 1.

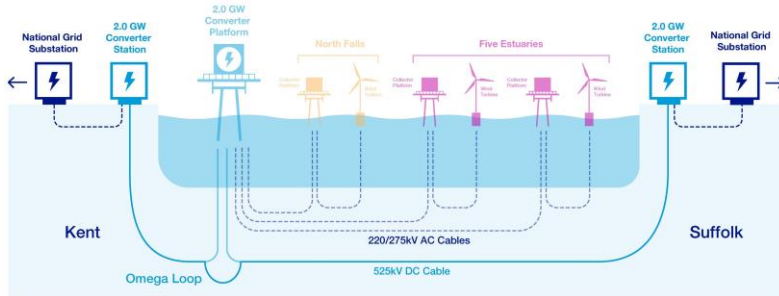


Figure 10. Illustration of Option 1

In Stage 2 when a 1.8 GW offshore converter station is installed near the Omega Loop, Sea Link would be taken

out of service, the cable cut, and recovered at the bight. The cable would then be connected into the converter platform to form a three-ended HVDC link for the connection of the offshore wind farms.

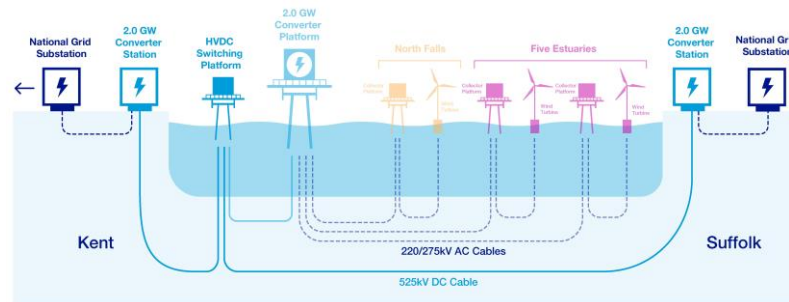


Figure 11. Illustration of Option 2

In the second alternative design, Option 2 (Figure 11), Sea Link is built and commissioned as a two-ended HVDC link connecting two onshore 2.0 GW converter stations, with a DC switching platform installed in the middle as Stage 1. In Stage 2, a 1.8 GW offshore converter platform would be built, Sea Link would be taken out of service, and a connection between an offshore converter platform and the switching platform would be made resulting in a three-

ended HVDC link for the connection of the offshore wind farms.

Note, the offshore converter platforms are described as 1.8 GW due to the infeed limits imposed by National Grid Security and Quality of Supply Standard, however they are rated at 2.0 GW as a standardized industrial design.

This report aims to produce an impartial view on the two proposed alternative options through the analysis of multiple factors such as technical feasibility, capital cost, programme schedule and risks. This report is not to provide a preferred solution.

The output of this report should support an assessment of the deliverability of a coordinated project.

Several key assumptions have been made, including defining sufficient technical details for each option to enable Arup to detail cost, schedule, technical feasibility and the risks related. These assumptions and contents will be summarized in the later part of this section .

Introduction - Organisation of the Report

The report includes the following topics in the assessment of the alternative proposals:

The Building Blocks

This section delves into the concept of “Building Blocks” a term used to denote the major functional blocks that constitute each of the options.

This section covers the key attributes of each building block such as size, weight, quantity, operating voltage, power, capacity and material type. It also provides a list of key components/equipment assumed within for each of the building locks.

For the purpose of this report, this section is of vital importance as it lays the groundwork for the feasibility study of the construction and commissioning activities and provides a structure for the estimation of the capital costs and the estimation of a delivery programme.

The building blocks are the basis from which this report is able to provide an objective comparison of the Baseline, Option 1 and Option 2.

Several key assumptions and considerations have been made to determine the building blocks. These assumptions are mainly based on Arup’s internal knowledge derived from industry wide project experiences.

The Cost

The cost section presents the major high-level costs for the baseline, Option 1 and Option 2 from both capital investment and engineering perspectives. The costs are estimated using the unit costs in Arup’s database for the key components and equipment identified in the building blocks as defined in this report. It includes the costs directly influencing Sea Link and those associated with the Wind Farm connections.

However, to make a full cost comparison, it is necessary to consider all the costs associated with each of the options, not only the capital and engineering costs as estimated in this report, but also the network constraint costs due to the outages required for the alternative options as well as additional transmission reinforcements to compensate for the capacity used by the Wind Farms with Option 1 & 2. In this report no constraint or additional reinforcement cost has been considered.

The Programme

This section of the report aims to provide an overall high-level programme, focussing on the major estimated milestones, including Sea Link installation commissioning,

outages and project completion etc. The programme comparison will highlight the impact of the Option design on the project durations.

Apart from Sea Link, the development of the wind farms has also been included in the overall programme for all the three options. The duration of the planning process is difficult to predict due to its complexity, but it is assumed that the planning duration would be the same for all three options. However, Option 1 and Option 2 may involve in separate public consultations and marine licence applications etc., which may make their planning process longer than that of the baseline. The programmes may also be affected by the ModApp process of the windfarm Grid connection for the alternative options as a significant risk.

Introduction - Organisation of the Report

The Construction, Commissioning & Outage

This section addresses three important aspects of the alternative options: construction, commissioning and the outages, of which the activities are closely linked and intertwined. These three aspects play a key role in the transformation of the two-ended HVDC circuit into a three-ended circuit.

The discussion of construction and commissioning methodology specifically focus activities of the alternative options after the 2-ended HVDC link has been commissioned and in service. These include pre-outage work, activities during the outage as well as windfarm connections and final full load tests when the 3-ended HVDC system and windfarm generators are fully operational.

In addition, some overall considerations are also discussed in this section to ensure feasibility of the construction and commissioning of the schemes, including procurement, design, factory testing etc.

The outage focus on the activities to be conducted during

the Sea Link “out of service” period to allow the appropriate connections and testing to be carried out.

Outage durations for the alternative options are worked out based on the construction activities and commissioning requirements as discussed in this report. These include the activities on cable, offshore platform, HVDC systems as well as wind farm connections and final full load testing.

The Risks

This section explores the overall risks for both the baseline and the alternative Option 1 and 2, with an aim to make a comparison between the options.

Building Blocks

Building Blocks - Introduction

This section delves into the concept of “Building Blocks” a term used to denote the major equipment pieces that constitute each of the options.

This section covers the key attributes of each building block such as size, weight, quantity, operating voltage, power, capacity and material type. It also provides a list of components for each of the option.

For the purpose of this report, this section is of vital importance as it lays the groundwork for the feasibility study of the construction and commissioning activities and provides a structure for the estimation of the capital costs and the estimation of a delivery programme.

The building blocks are the basis from which this report is able to provide an objective comparison of the Baseline, Option 1 and Option 2.

Several key assumptions and considerations have been made to determine the building blocks. These assumptions are mainly based on Arup’s internal knowledge derived from industry wide project experiences.

To cater for the required sea link transmission capacity and maximise future potential of wind farm connections, the following building blocks are assumed for the options:

➤ **Baseline:**

- Offshore Windfarm Collector Platforms: 1 for North Falls and 2 for Five Estuaries, with an assumed combined capacity up to 1.8 GW
- 2 Onshore Substations for offshore Windfarm connections rated 2.0 GW
- 2 Onshore HVDC Converter Stations rated 2.0 GW
- Offshore HVDC Cable rated 525 kV
- HVAC Cables rated 220/275kV

➤ **Option 1:**

- Offshore Windfarm Collector Platforms: 1 for North Falls and 2 for Five Estuaries, with an assumed combined capacity up to 1.8 GW
- 2 Onshore HVDC Converter Stations rated 2.0 GW
- 1 Offshore HVDC Platform and Converter Station rated 2.0 GW
- Offshore HVDC Cable rated 525 kV
- HVAC Cables rated 220/275kV

➤ **Option 2:**

- Offshore Windfarm Collector Platforms: 1 for North Falls and 2 for Five Estuaries, with an assumed combined capacity up to 1.8 GW
- 2 Onshore HVDC Converter Stations rated 2.0 GW
- 1 Offshore HVDC Platform and Converter Station rated 2.0 GW
- 1 HVDC Switching Platform rated at 2.0 GW
- HVDC Cable rated 525 kV
- HVAC Cables rated 220/275 kV

In the next few pages of this section provide further details on these building blocks with reasonings for the assumptions made.

Figures 12, 13 and 14 show indicative geographic maps of the three scenarios Baseline, Option 1 and Option 2 respectively, after which a breakdown of the building blocks that form these designs has been detailed.

Baseline

Key

-  Onshore Substation - TO
-  Onshore Converter Station
-  Onshore Substation - WF Developer
-  Collector Platform - WF Developer
-  AC Cable - WF Developer
-  AC Cable - TO
-  DC Cable - TO
-  Existing Transmission Network

Wind Farms

-  North Falls
-  Five Estuaries

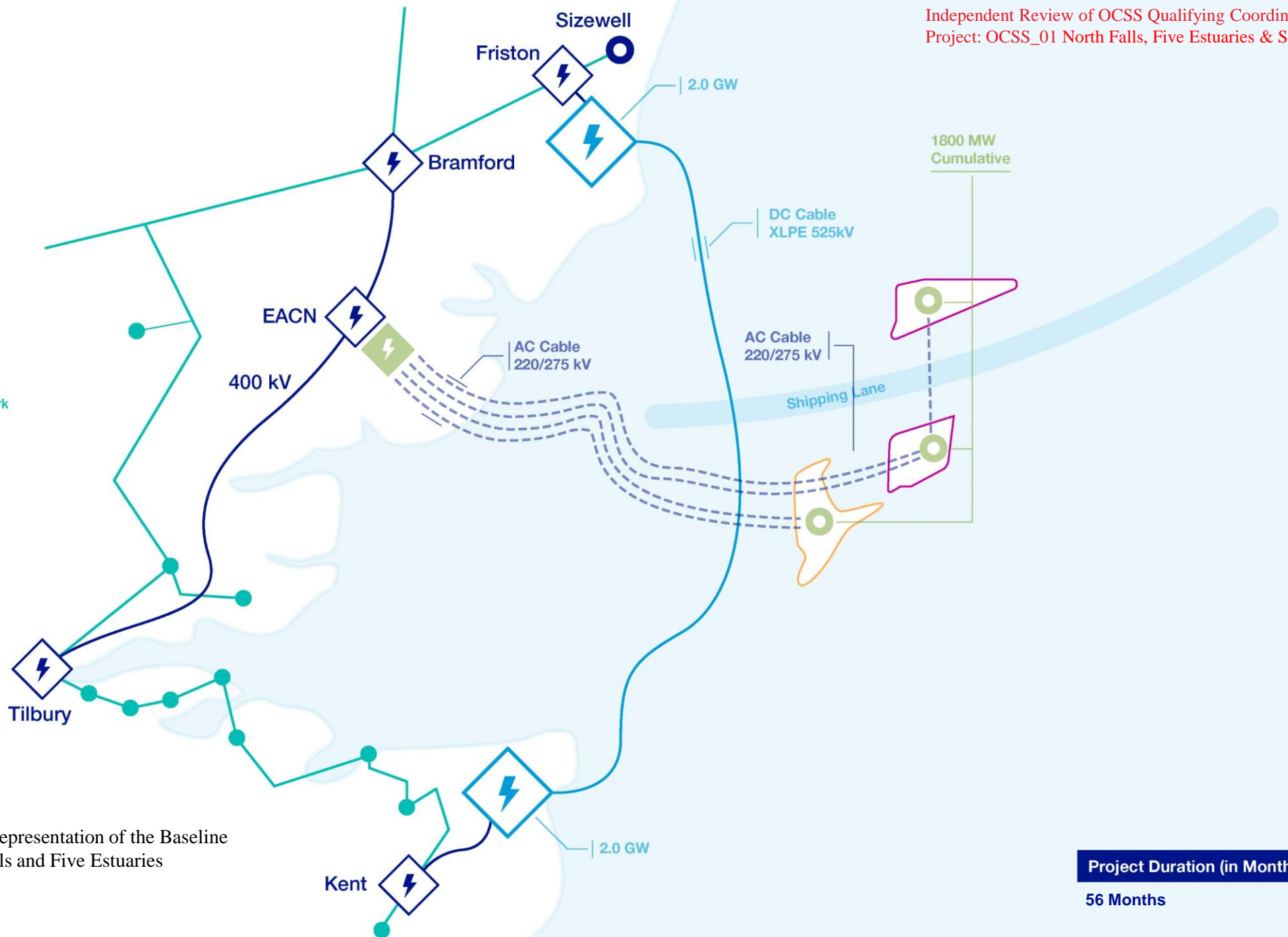


Figure 12. Full page stylised representation of the Baseline
– Sea Link, North Falls and Five Estuaries

Project Duration (in Months)
56 Months

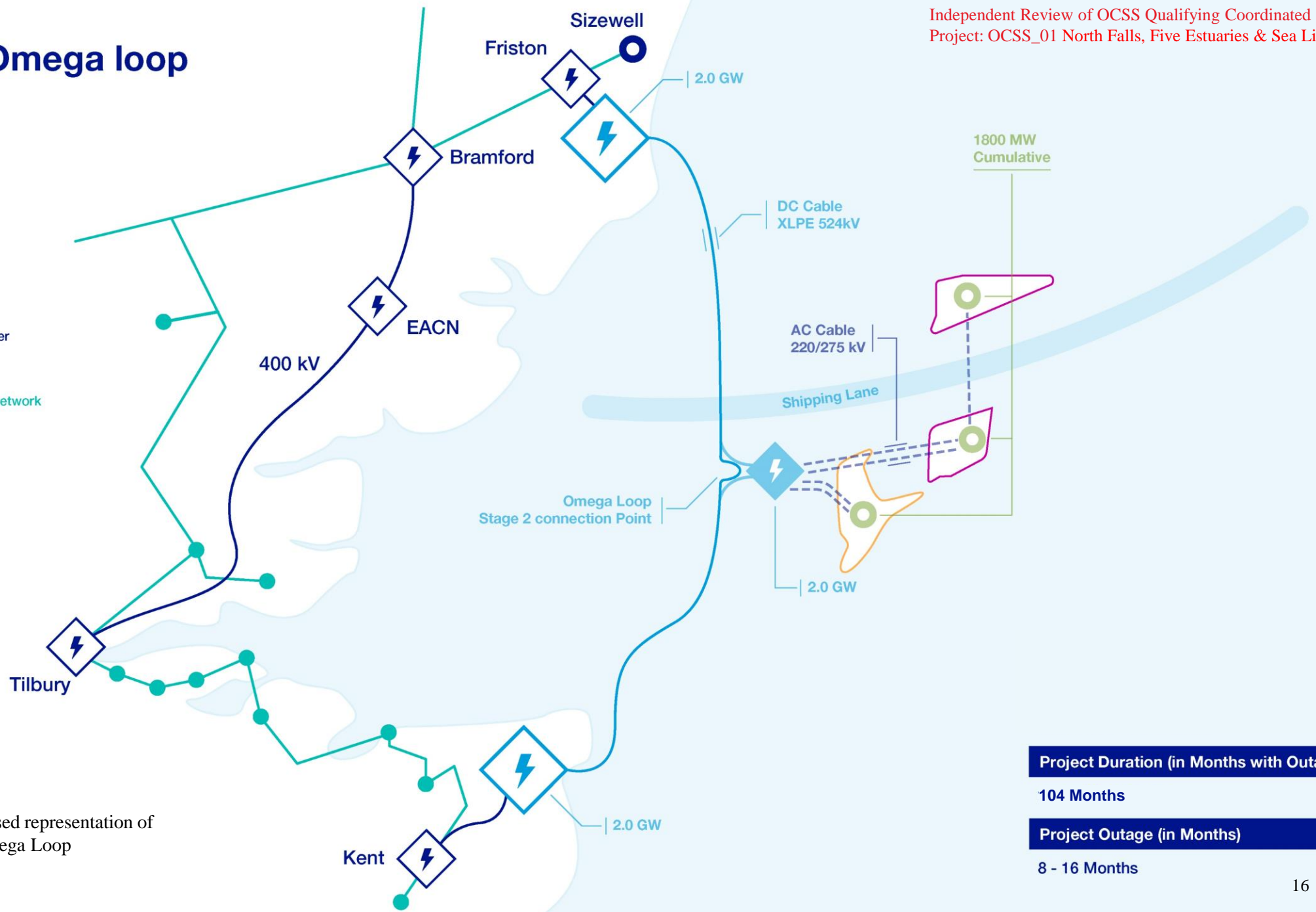
Option 1 - Omega loop

Key

- Onshore Substation - TO
- Onshore Converter Station
- HVDC Converter Platform
- Collector Platform - WF Developer
- AC Cable - WF Developer
- AC Cable - TO
- DC Cable - TO
- Existing Transmission Network

Wind Farms

- North Falls
- Five Estuaries



Project Duration (in Months with Outage)
104 Months
Project Outage (in Months)
8 - 16 Months

Figure 13. Full page stylised representation of Option 1 – Omega Loop

Option 2 - DC Switching Platform

- Key**
- Onshore Substation - TO
 - Onshore Converter Station
 - HVDC Converter Platform
 - DC switching platform
 - Collector Platform - WF Developer
 - AC Cable - WF Developer
 - AC Cable - TO
 - DC Cable - TO
 - Existing Transmission Network
- Wind Farms**
- North Falls
 - Five Estuaries

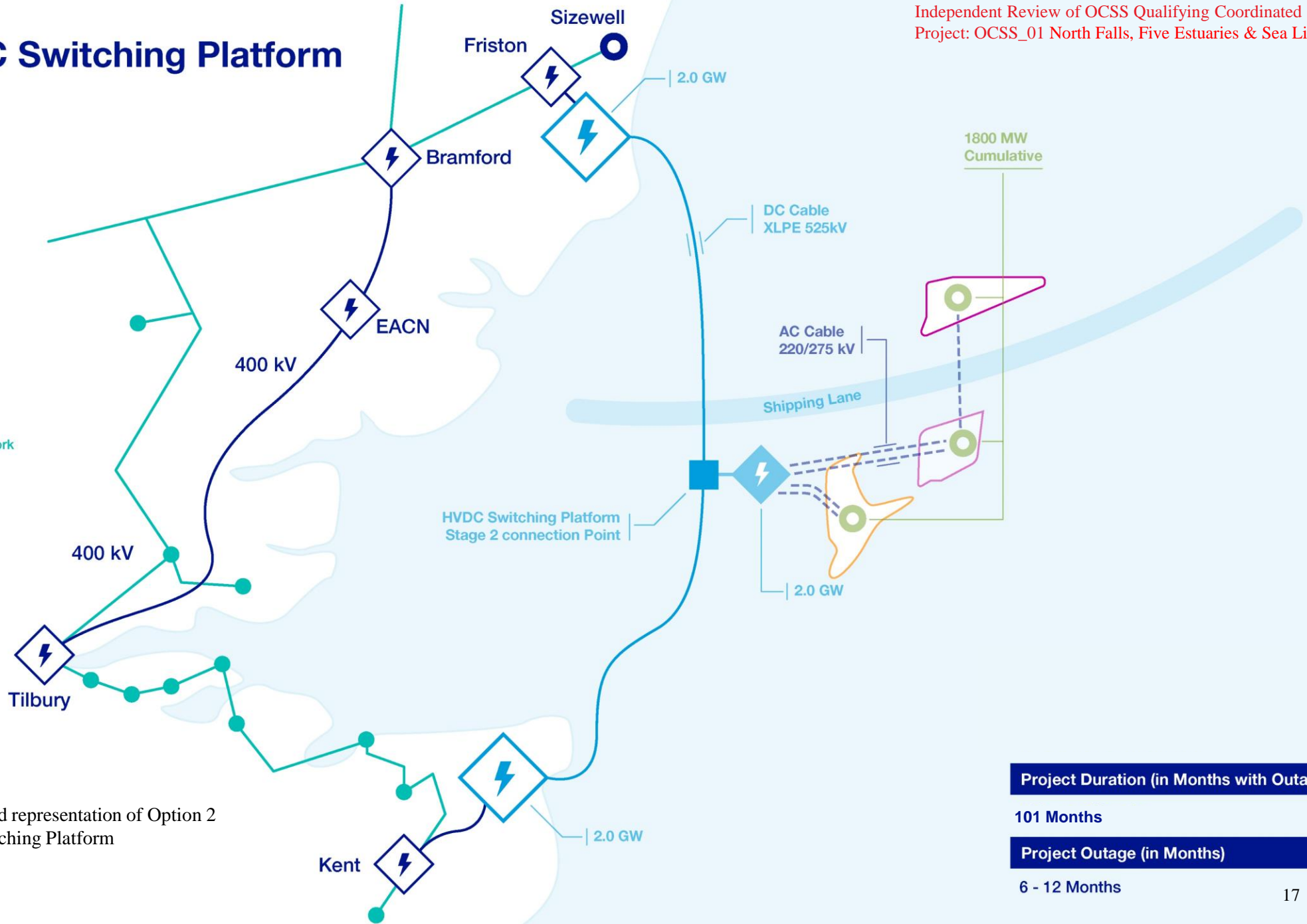


Figure 14. Full page stylised representation of Option 2 – HVDC Switching Platform

Project Duration (in Months with Outage)

101 Months

Project Outage (in Months)

6 - 12 Months

Building Blocks – Offshore Windfarm Collector Platform

All offshore windfarms which are located more than ~10 km offshore require an AC offshore substation which acts as a hub to collect the power from the wind turbines and increase the voltage for bulk transmission of the power. These offshore substations are a relatively mature technology which have been delivered in UK waters for the last ~15 years during which time, the total power and the voltages have increased, they have not fundamentally changed.

Depending on windfarm geography it could be a single large collector platform or a number of smaller platforms.

For this review it is envisaged that this component of the windfarms will not be heavily influenced between the baseline and Options 1 or 2.

Typical Offshore Collector Platform Electrical Equipment

- 220kV Cable Sealing End(s)
- 220kV Shunt Reactor(s)
- 220kV Switchgear
- 220/66kV 3 Phase Transformers
- 66kV Earthing Auxiliary Transformers
- 66kV GIS Sectionalised Bus System

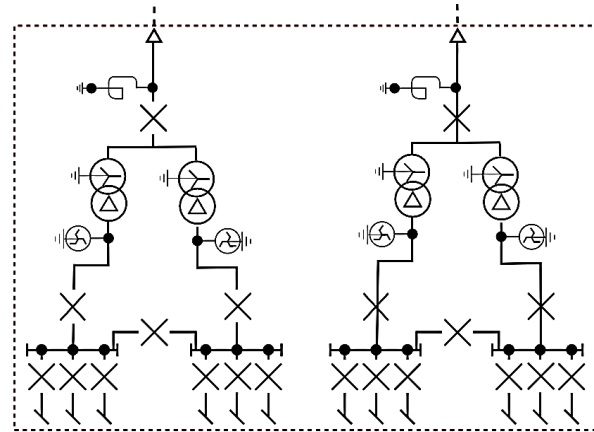


Figure 15 - Example Schematic: 'Single platform' collector with two export circuits

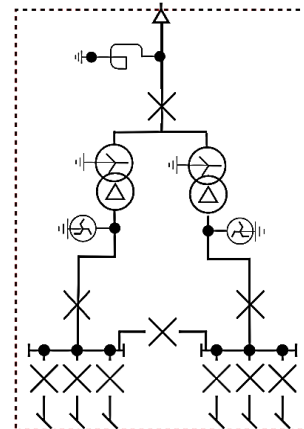


Figure 16 - Example Schematic: Collector platform with single export circuit.



Offshore Platform Substations

Building Blocks – Export Cables

For both offshore windfarms and HVDC links / bootstraps the bulk power transfer utilises subsea cables. High voltage power cables have been in use for many years but recent developments in the insulation materials as well as the rated voltages and size of conductor have allowed increased capacities on a single cable.

Cables are run between the seabed and the platform substations via protective ‘J-Tubes’.

These high voltage cables are expensive to manufacture and install and normally represent a substantial proportion of the total project cost for an offshore windfarm or interconnector.

Cables are predominantly made up: of the metallic conductors which transfer the power; an insulation material that allows the cable to be safely energised to the required voltage and outer protective layers. Different cables use various materials for the insulation layer. For 220kV AC cables the standard material would be Cross-linked polyethylene (XLPE). For 525kV DC cables the current standard material would be Mass Impregnated (MI) where a special paper impregnated with a high viscosity insulating compound is used. XLPE 525kV cables are currently under development.

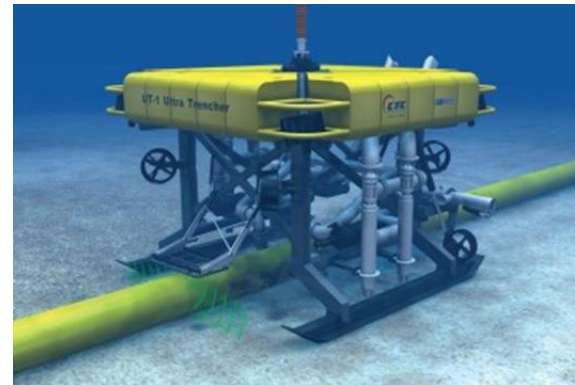
The cable systems are designed and installed with the highest priority given to reliability and availability. The protection design is of particular importance for the submarine cables given the long physical distances involved and the resulting continuous exposure to the risks of inadvertent third-party damage.

Cable repair procedures and repair operation contingency preparations are an important part of good cable industry standard practices, which need to be considered at the design phase.

Key Cable Data

- Sea Link HVDC will use a pair of 525kV single core DC cables
- North Falls / Five Estuaries will use 220kV (or possibly 275kV) 3 core subsea AC cables

Subsea ROV



Cable Joint on Vessel



3 Phase Cable Cross Section



Export Cable Laying Vessel

Building Blocks – Offshore Windfarm Onshore Substation

In addition to the offshore substation/s, each offshore windfarm will have an onshore substation. This will typically be located close to the TSO (Transmission System Operator) substation which provides their point of connection. This substation contains equipment to receive the export cables, transform the voltage and facilitate various aspects of grid code compliance such as harmonic filters for power quality as well as STATCOM's and shunt reactors for reactive power compensation and voltage control.

Where the windfarm is connected to shore via AC cables the technology in these substations is mature.

Windfarm Onshore Substation Typical Equipment

- 400kV Connection to TSO Substation
- 400/220kV Super Grid Autotransformers
- Tertiary Connected STATCOM Systems
- 220kV Split Bus System
- 220kV Shunt Reactors
- 220kV Harmonic Filters
- 220kV Cable Sealing Ends

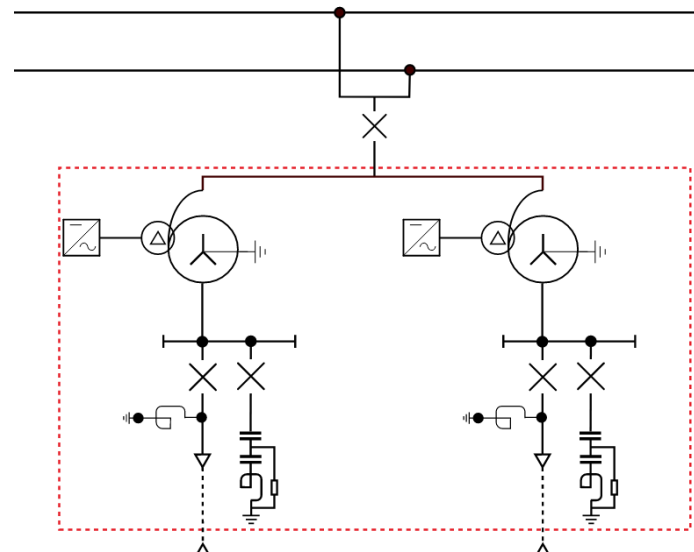


Figure 17 - Example schematic: Onshore Substation



Wind Farm Substation Ariel Views

Building Blocks – Onshore HVDC Converter Station

For the transmission of large amounts of power over long distances it can be beneficial to use direct rather than alternating current i.e. using HVDC. This can present significant savings in cable / overhead line costs but requires large and expensive specialist equipment at each end of the link to interface between the DC and AC systems.

HVDC technology has been used for many years, however in the past 20 years advances in power electronic technology have allowed new Voltage Source Converters (VSC) to be developed. VSC HVDC links are well established and with proven track record. Several 1.4 GW links have recently been commissioned and are in operation, there are also several 2 GW projects under development.

Whether a HVDC Link is used to connect two countries (an interconnector); connect two points within a country (boot strap) or used to connect a remote generation source such as an offshore windfarm the onshore converter station technology is largely identical.

When used to connect to a wind farm, some additional equipment - known as a "DC Chopper" – may be required. This item allows the energy produced by the windfarm to be safely dissipated in the event of a fault. This equipment would usually be housed within the same building as the HVDC converter station – meaning it would be difficult to 'retrofit' to a commissioned link. Typically, the converter building would need to be approximately 15-20% larger to accommodate the DC Chopper.

Onshore HVDC Converter Main Electrical Equipment

- 2 x 400kV Connection to TSO Substation
- One 2GW VSC HVDC converter station including:
 - 7 x single phase 400/330kV 350MVA (per phase) converter transformers (inc. one spare unit) operated as 2 x YNy 1050MVA transformers
 - 2 x Valve/DC Hall Buildings
 - 1x 400kV AC yard (AIS or GIS type)

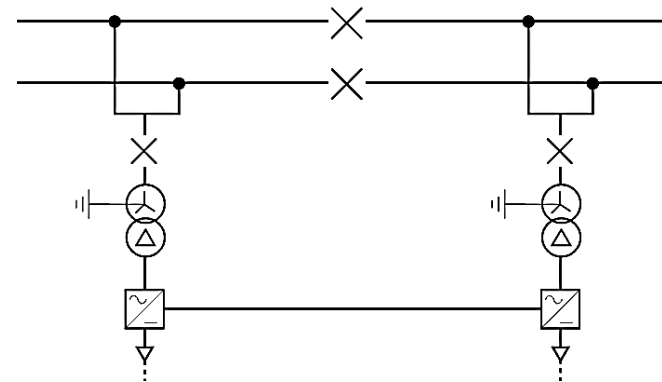


Figure 18 - Example Schematic Converter Substation – Point to Point

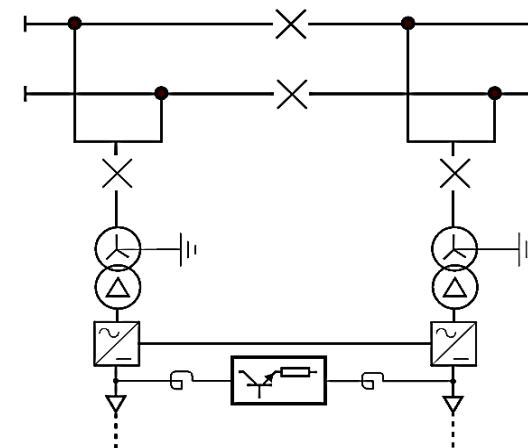


Figure 19 - Example Schematic: Converter Substation – With DC Chopper



Converter Station Ariel Views



Converter Valve Hall

Building Blocks – Offshore Platform HVDC Converter Station

Where a HVDC Link is used to connect an offshore wind farm it is necessary to build a HVDC converter station on an offshore platform similar to the windfarm collector platform.

Given the AC/DC conversion space requirements and finer environmental controls required for HVDC technology the HVDC offshore platforms are larger than their AC equivalents. This technology does not lend itself to being split across multiple platforms in the same manner as AC platforms.

There are several HVDC offshore converter platforms in service around the world with more projects under development with planned commissioning dates between 2024-2031. The largest of these projects currently in operation are Borwin3 and Dolwin3 in Germany at 900MW. Dogger Bank A in the UK is expected to become the world largest offshore platform in 2024 at 1200MW. More projects are under development via standard DC connections of 2000MW with planned commissioning dates between 2028-2031 such as IJmuiden Ver Beta in Netherlands and BalWin4 in Germany.

Offshore HVDC Converter Main Electrical Equipment

- HVDC Cable Sealing Ends
- HVDC valve halls
- 3 phase converter power transformers
- GIS AC Busbar system to interface with collector platforms

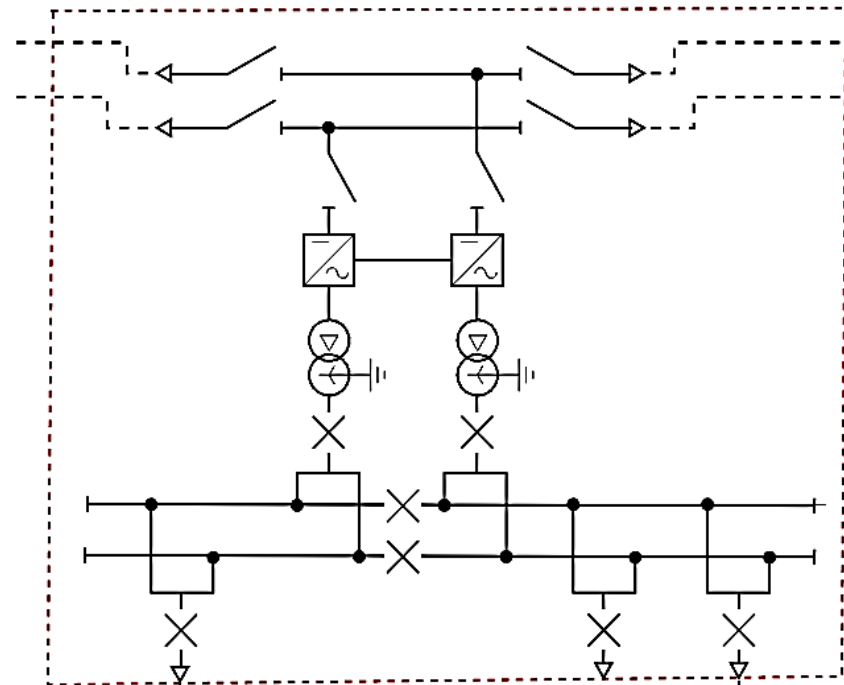


Figure 20 - Example Schematic: Converter Platform



Converter Station Platforms

Building Blocks – HVDC Switching Platform

One of the main disadvantages of DC systems is the lack of availability of a DC circuit breaker for full scale deployment – an item readily available on AC systems. Circuit breakers allow switching of branches of the system under all conditions: normal voltages, fully loaded conditions and even rapid disconnection of faulted branches which are carrying extremely high currents.

In DC systems the closest readily available component is a DC disconnecter. This plant item allows reconfiguration and switching of the DC network. However, this switching must be carried out with the system completely deenergised.

As part of Option 2 it will be considered to commission Sea Link with a substation platform containing several of these DC disconnecters. This equipment, implemented as DC modular gas-insulated switchgear on a platform, is comparatively small compared to a converter, so it is envisaged as a small offshore substation.

This platform could be used as a low-risk option to interface an additional HVDC cable into the Sea Link System when the converter platform is available.

Arup are not aware of any in-service or in commercial development dedicated DC switching platforms. However, the individual components including the DC modular gas-insulated switchgear and cable are deemed mature technologies.

Offshore HVDC Switch Platform Main Electrical Equipment

- HVDC Cable Sealing Ends
- HVDC Disconnectors

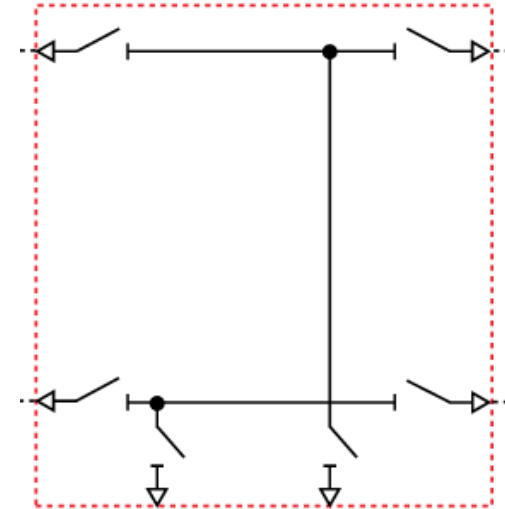


Figure 21 - Example Schematic: DC Switching Platform

Costs Analysis

Cost Analysis - Introduction

This section presents a comprehensive cost analysis for the proposed alternative schemes. To build up the costs in this assessment, a boundary was defined for the separate schemes to assign costs. The extents of Sea Link start from the substation works in Suffolk to the grid connection in Kent. Each wind farm starts at their respective collector platform/s and ends at the receiving onshore substations. Wind Turbines and inter-array cables are not included.

With a list of major assets grouped according to the assigned boundaries, Arup databases of costs were used to obtain a range of figures that could be attributed to these assets.

A PM and Engineering Cost is applied as a percentage of the equipment cost.

Finally, a percentage is applied commensurate with the detail available at this stage of the project to the each of the sub-totals to provide a cost range to capture the missing costs not included in this build-up such as risk, insurance and market trends; information not available at this stage which is likely to have a major impact on the project cost. The results of the assessment are detailed in a table that shows the listed equipment, sub-totals, totals and the final range.

The Cost Table summarises the major high-level costs for the baseline, Option 1 and Option 2 designs. The costs are estimated based on the key components and equipment identified in the building blocks as defined in this report:

- Costs directly influencing Sea Link are separated from those associated with the Wind Farm connections.
- The build-up of costs is an average obtained from schedules of costs from a range of sources most recent of which are from October 2023.
- The costs are given in a range based on an estimate using the unit costs in Arup's database for the key components/equipment, with adjustments as recommended by the Association for the Advancement of Cost Engineering (AACE), using a Class 5 level of estimation such as this (normally between -20% to -50% for lower end and 30% to 100% for upper end). This is to reflect the risk associated with supplier capability/capacity as well as market competition.
- These costs do not account for inflation.

Please note: To make a full cost comparison, it is necessary to include all the costs associated with each option, including not only the costs for building the Sea Link, Wind Farm connections but also the constraint cost for the Sea Link outages, as well as additional transmission reinforcements required to compensate for the capacity used by the Wind Farms with Option 1 & 2.

No cost distinction has been applied for the wind farms between an upper and lower bound. Here the prospective savings on the wind farm substations would be reduced. A design decision would need to be made about what size of converter platform to proceed with in the lower bound

scenario. While a lower capacity converter platform would offer cost savings these would not be as substantial as simply reducing the cost in proportion to the rating. This is because the equipment will still need to be 525kV bipole converter, which drives the space requirements. Potential savings could also be reduced in procuring a converter of a bespoke size when it is anticipated that the OEM's will be aiming to standardise their 525kV HVDC platforms at 2.0 GW. Selection of a smaller converter could also significantly complicate future development of those areas.

It is understood that the Electricity System Operator (ESO) is currently carrying out a separate study in the region of the East Anglia Network about the Sea link OCSS. The study is to consider the potential impact upon the existing transmission system if North Falls and Five Estuaries were to connect into Sea Link.

If the study identifies that additional reinforcements are required and to be completed prior to the wind farms connecting into Sea Link, any outages required to implement the connection would have a distinct cost profile compared to the counterfactual scenario. The specific design and timing of the chosen reinforcements would play a crucial role in this cost profile. Therefore, this report identifies the duration of outages associated with the connection options but not the cost of any outages as these are expected to be reflected in the high-level economic evaluation of options considered by ESO.

Cost Analysis - Table

Baseline		Option 1		Option 2	
Item	Cost	Item	Cost	Item	Cost
SEA LINK					
Friston Substation Extension		As per baseline		As per baseline	
Kent Substation		As per baseline		As per baseline	
Overhead Line Kent Substation to Grid		As per baseline		As per baseline	
2 No. onshore HVDC converter stations		Baseline with 2 No. DC Choppers		Baseline with 2 No. DC Choppers	
525 kV XLPE Cable offshore		525 kV XLPE Cable offshore		525 kV XLPE Cable offshore	
525 kV XLPE Cable onshore		As per baseline		As per baseline	
		-		Offshore DC Switching Platform	
		Offshore HVDC Converter Platform 3 terminal		Offshore HVDC Converter Platform 1 terminal	
PM and Engineering Costs					
Sub-totals LOW ESTIMATE	£		£		£
Sub-totals HIGH ESTIMATE	£		£		£
NORTH FALLS					
1 Nr. offshore collector platform		As per baseline		As per baseline	
220/275 kV Cable offshore		220/275 kV Cable offshore		220/275 kV Cable offshore	
220/275 kV Cable onshore		No onshore cable		No onshore cable	
1 No. Onshore substations including STATCOMS		No onshore wind farm substation		No onshore wind farm substation	
PM and Engineering Costs					
Sub-totals LOW ESTIMATE	£		£		£
Sub-totals HIGH ESTIMATE	£		£		£
FIVE ESTUARIES					
2 Nr. offshore collector platforms		As per baseline		As per baseline	
220/275 kV Cable offshore		220/275 kV Cable offshore		220/275 kV Cable offshore	
220/275 kV Cable onshore		No onshore cable		No onshore cable	
1 No. Onshore substations including STATCOMS		No onshore wind farm substation		No onshore wind farm substation	
PM and Engineering Costs					
Sub-totals LOW ESTIMATE	£		£		£
Sub-totals HIGH ESTIMATE	£		£		£
Total LOW ESTIMATE		Total LOW ESTIMATE		Total LOW ESTIMATE	
Total HIGH ESTIMATE		Total HIGH ESTIMATE		Total HIGH ESTIMATE	

Cost Analysis - Summary

The cost table above has presented the sub-totals and totals for Sea Link, North Falls and Five Estuaries under the baseline, Option 1 and Option 2 scenarios.

The table has listed out the major pieces of equipment accounted for in the cost build-up according to the cost boundary selected for each project. ‘As per baseline’ indicates that the same equipment is required in Option 1 or 2 as is required for the baseline scenario. “-” or “No *stated equipment*” indicates that the item is entirely removed from the build-up for that project in the context of the particular scenario.

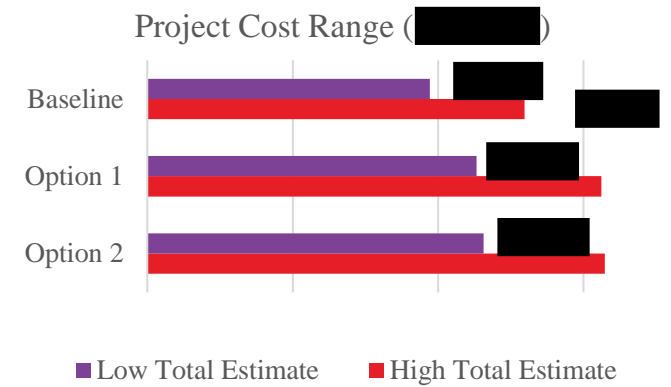
As shown in Figure 5 (repeated here from the Executive Summary) these totals are presented as a range LOW to HIGH, to capture numerous missing variables that would influence the cost accounting for the low maturity of the projects at this time and the missing information that would solidify these costs.

It is notable that the baseline generally presents as the lowest cost scenario.

Option 1 makes savings from the removed and reduced onshore and offshore cabling respectively and the removal

of two onshore substations. The total cost is higher than the baseline largely attributing to the cost of the offshore HVDC converter platform. It is worth noting the future market these platforms is considered highly volatile and overheated which presents a higher risk of availability and subsequent cost of the platforms for projects such as these.

Option 2 is the highest cost out of the three scenarios again with the cost of the offshore HVDC converter platform as well as a HVDC switching platform which exceeds any cost savings achieved from the reduced cable and onshore substations.



Programme

Programme - Introduction

This section of the report provides an overall high-level programme, focussing on the major estimated milestones, such as, Sea Link installation commissioning, outages and project completion. The programme comparison will highlight the impact of the Option 1 and 2 designs on the project durations.

The programmes display a similar detailed split of major equipment with focus on those items that influence the critical path to project completion.

The key activities are highlighted to make clear any advancements or delays caused by the alternative options. These details are intended to build a complete overview to show the impact of these alternative designs against the baseline scenario.

In addition to Sea Link, the development of the wind farms has been included in the overall programme for all the three options. The duration of the planning process is assumed to be the same for all three options. However, Option 1 and Option 2 may involve in separate public consultations and marine licence applications which will make their planning and consenting process durations longer than that of the baseline.

For Option 1 and 2 the initial commissioning period of Sea Link as a two ended link is deemed to be comparable with the baseline. For option 1 the subsea cable route is slightly longer accounting for the Omega loop, however the

manufacturing and installation of the extra length of the cable is not believed to have significant impact on the programme. For option 2 there are extra activities to design and build the DC switching platform, but most of these activities can be carried out in parallel with the Sea Link activities; although some additional time will be required to cater for connecting the HVDC cables to the switching platform (J-Tube Pull-in etc.), conducting these activities in parallel will not add extra time to the overall programme.

These programmes have been developed using a range of allowances for legislative proceedings as well as durations for the installation timelines, informed by previous projects.

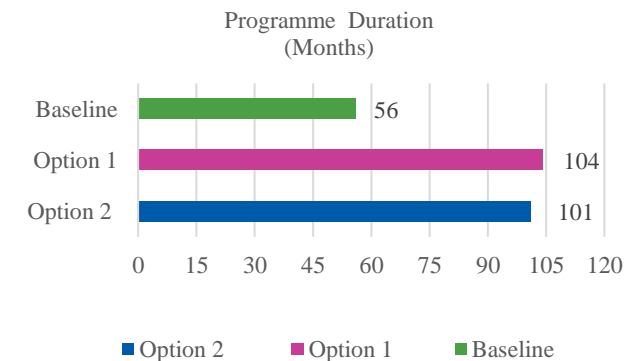
The outage details are showing the 100% contingency duration for each option.

As shown in the Option 1 and 2 programmes, towards the end of the outage for commissioning the 3-ended HVDC system, the activities for connecting the wind farms to Sea Link will commence to ensure the construction periods are aligned. The further commissioning window is followed at a suitable time in the next available summer season to complete the whole commissioning programme.

As shown in the Figure adjacent (repeated here from the Executive Summary) both Option 1 and 2 would be fully built and commissioned at similar times, around quarter 3

and 4 of 2034. This is primarily driven by the delivery of the Offshore HVDC Converter Platform of which availability, as informed by market engagement, is extremely limited and has a very long lead time.

Please note that the duration of the construction and commissioning activities for the wind turbines and the inter-array cables following the commissioning of the 3-ended HVDC system are high-level estimates, subject to further change to align with offshore works at suitable seasonal windows.



Programme – Assumptions and ModApp Impact

Several key assumptions were made to align with the expectation of having Sea Link operational by the end of 2030. This section lists those assumptions to facilitate a clearer understanding of the programmes.

The key assumptions made for the programmes are:

1. It will be required to undertake a ModApp for the windfarm connections for the OCSS alternative options. This activity can take place in parallel with the ongoing Sea Link planning process. As a key critical path, the programmes for the alternative options are assumed to be able to start the FEED for the converter platform in Q4 2024. If all required regulatory changes and stakeholder acceptance are not in place before this date, the activity would need to be commenced ‘at risk’ to maintain the outlined programmes, which would need to be underwritten by the authority.
2. The duration of the planning process is difficult to predict due to its complexity, it is assumed to be the same for all three options for this study. Note, Option 1 and Option 2 may involve in separate public consultations and marine licence applications etc., which may make their planning process durations longer than that of the baseline.
3. It is assumed that any protected designated areas near the offshore construction site, won’t affect the alternative proposed solutions, as per the Baseline.
4. A significant proportion of the marine survey information from the baseline projects will be re-used to apply for the required marine licences for Option 1 e.g. The additional DC cabling required for the Omega Loop can sit in the Baseline Wind Farm AC cable corridor where it is proposed to cross the DC cable.
5. Similarly for Option 2 it is assumed that the DC Switching Platform would sit on the baseline cable corridor and the DC cable between the switching platform and converter platform could utilise the baseline AC export cable corridor.
6. The minimum time to deliver a 2GW offshore converter platform is 8 years. The 8 years is from Front End Engineering Design (FEED) to installation of the platform offshore.
7. For Option 1 and 2 the initial phase of design and build work for Sea Link will be carried out with key components required for a 3 ended HVDC system installed and tested prior to the 2 ended HVDC link in operation e.g. DC Choppers included in the onshore converter stations.

8. Converter platform and collector platforms may be installed along with the associated inter-platform export cabling prior to the Sea Link outage commencing.

If there are any deviations from any one of these assumptions the programmes will likely be affected.

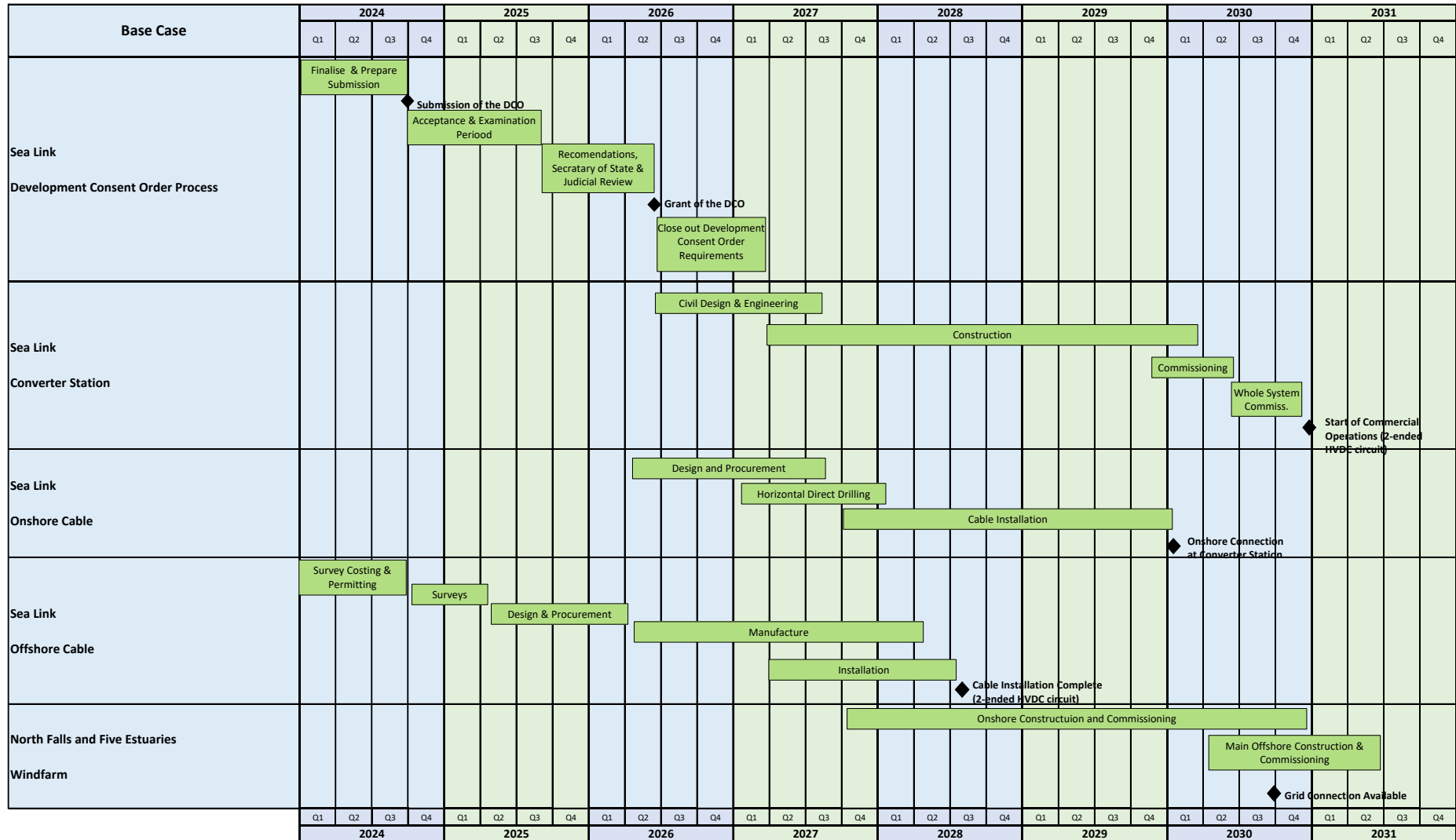
ModApp Impact

Two further programmes have been developed, shown under Option 1 and 2 ModApp Impact on slides 36 and 37, to illustrate the low-risk scenario where design work will be held back until a ModApp (modification application) has been accepted.

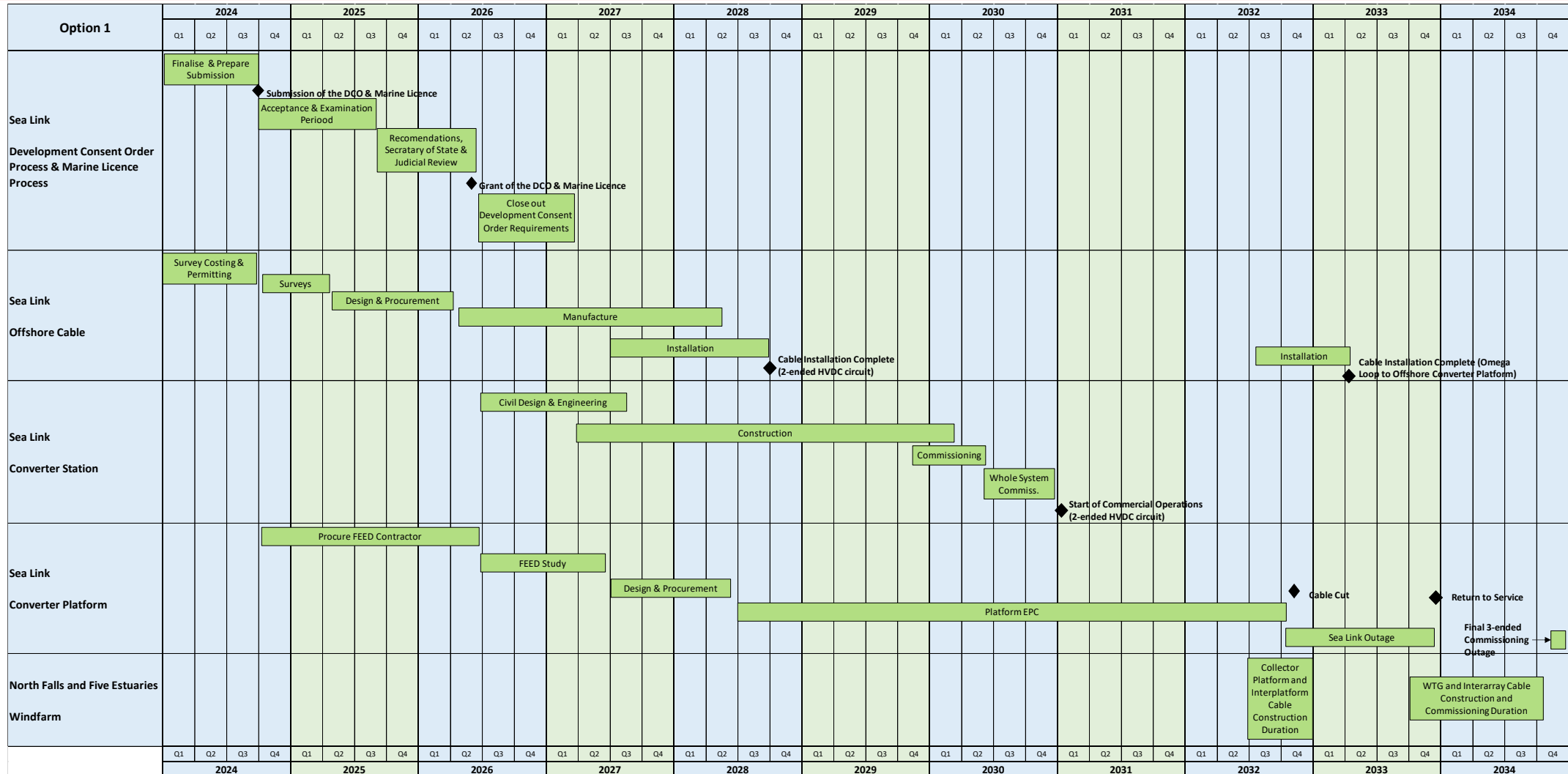
Based on the above, an additional two years is required. The ModApp would start upon the completion of the OCSS Phase 2 submission and must conclude before design work can progress on Sea Link. Proceeding this period any extra required surveys will then be undertaken e.g. the switching and converter platforms and added cabling.

This approach adds two years to the completion date of Option 1 and 2. The duration of the ModApp is subject to change which would further alter the final completion date.

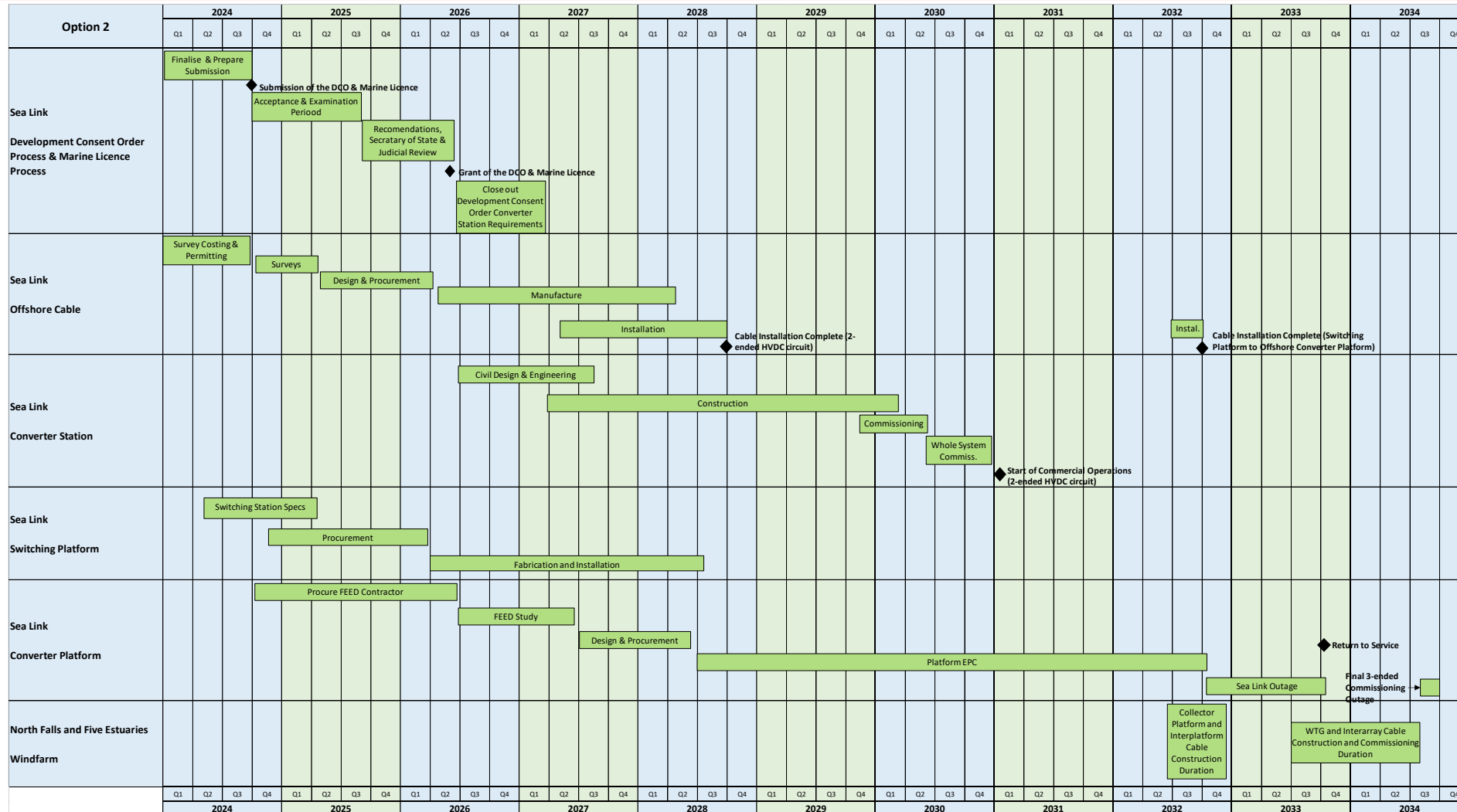
Programme - Baseline



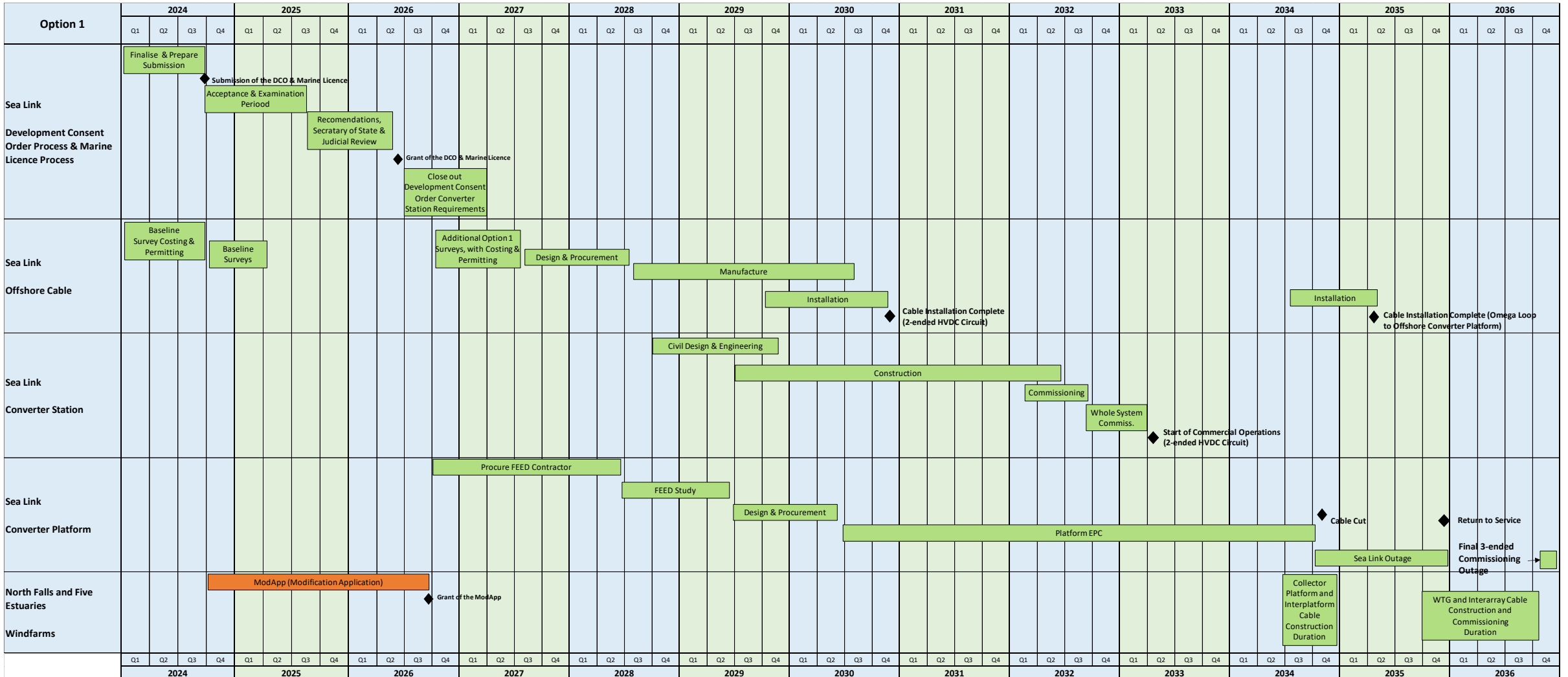
Programme - Option 1



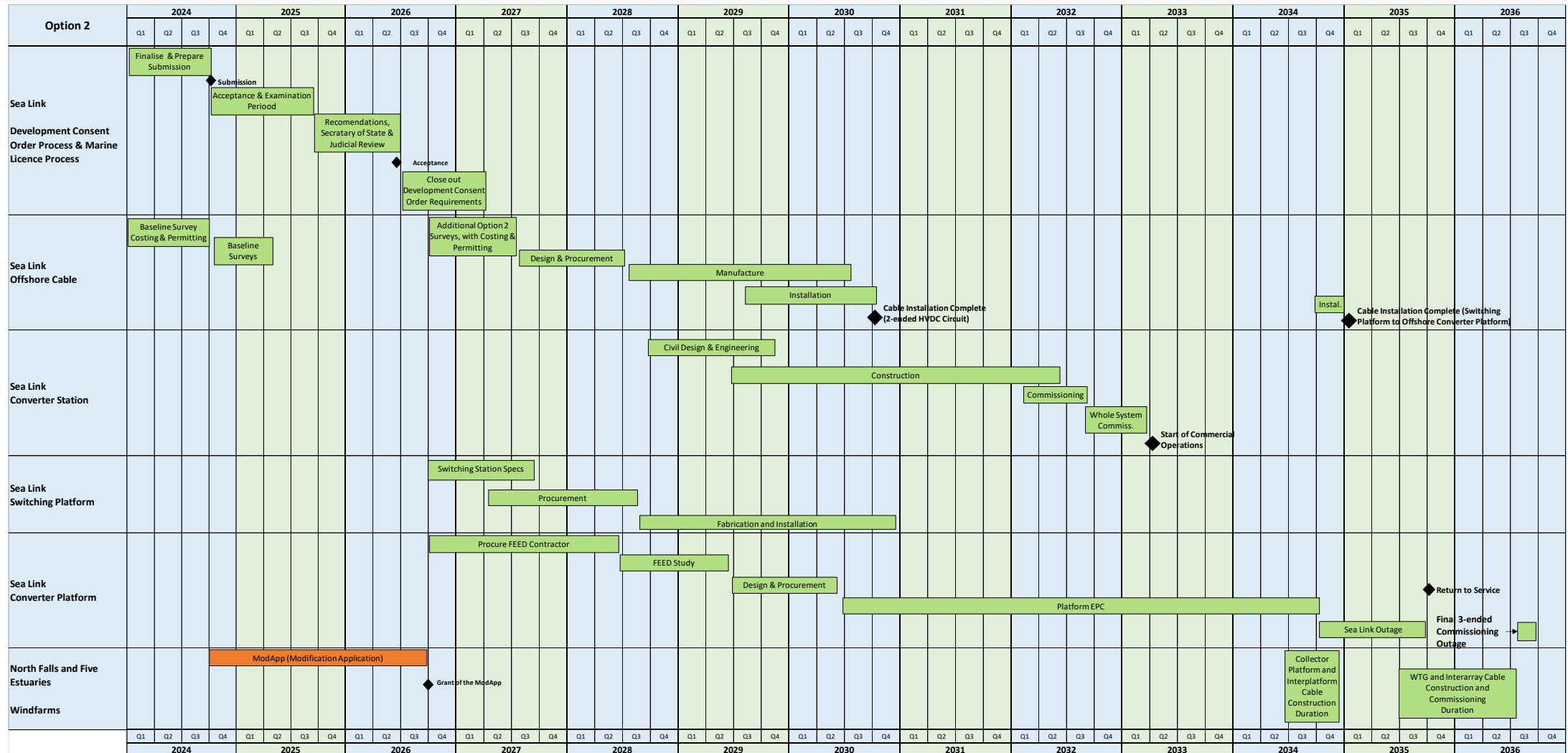
Programme - Option 2



Programme - Option 1 ModApp Impact



Programme - Option 2 ModApp Impact



Construction, Commissioning and Outages

Construction, Commissioning and Outages

- Introduction

Overall Considerations

This section outlines the complexities involved in the envisaged testing and commissioning process to reconfigure Sea Link as a “Multi- Purpose Interconnector” (MPI) as well as the related wind farm commissioning process

To best mitigate the complexities involved in this commissioning, strategic planning and sequencing should be integrated from the project's inception. This approach will allow the duration of Sea Link outage to be minimised. Effective implementation of this strategy requires that considerations for this phase start as early as the procurement stage of Sea Link, in order that key considerations can be incorporated into the design, testing and initial 2 ended construction.

Options 1 and 2 have almost identical considerations for the initial design through to the final testing. The main significant differences between the options are around the steps to connect the HVDC cables to the converter platform. The ‘hot commissioning’ which will take place once the equipment has been energised, including testing the equipment at full load, which will be common between both options 1 and 2.

While it is feasible to execute a significant portion of the wind farms' cold commissioning before Sea Link's outage period, it is unrealistic to expect the wind farms to be completely installed and operational before the main Sea Link Outage – during which time Sea Link will be completely de-energised and the DC cables will be connected to the offshore converter platform.

The standard approach for the wind farm commissioning is that the offshore substations are energised from the onshore network prior to the build out of the offshore turbines. Deviation from this standard approach, with energisation of the offshore network from the wind turbines would necessitate more complex “Grid Forming” WTG technology and would be of limited benefit as power would still not be able to be exported.

Construction, Commissioning and Outages

- Initial Phase Considerations

Procurement

It is recommended that during the procurement process for Sea Link that the HVDC OEMs should be asked to provide the option of delivery of Sea Link as a 2 ended interconnector at the earliest date with the subsequent delivery of the converter platform and conversion to a 3 ended HVDC - multipurpose interconnector (MPI). The OEM's will be in the best position to advise the optimal split of which work should be carried out during the upfront design / initial commissioning. Given the focus on reducing the total outage time required for Sea Link to be reconfigured as an MPI it is likely they key areas that will be identified by the OEM's are the upfront installation of a DC Chopper and the design of the control and protection systems for the link incorporating the potential 3rd converter from the outset.

Design & Testing

There are some aspects of the onshore converters that would be required for operation as an MPI that would not necessarily be require in a two ended interconnector. Therefore, if the HVDC system is designed with final configuration in mind it will make the transition to the MPI configuration more straightforward. For example, an MPI connecting renewable generators would normally necessitate a 'DC Chopper' to be included at the onshore converter stations. This equipment would normally be located in the

same building as the main converter power electronic equipment. Therefore, as a minimum space would need to be allowed for this equipment from the outset. However, if minimisation of outage time is a priority it would be strongly recommended to fully install and commission this equipment during the initial phase.

The control and protection systems for an MPI are more complicated than a two ended interconnector. The MPI system should be compatible with running any two ends in service with the third end out of service. Therefore, if the converter platform control and protection systems could be developed in the initial project phase - this would potentially allow for Factory Acceptance Tests (FAT) to be carried out considering all three ends in all allowable configurations (including two ended Suffolk to Kent operation).

Although it is expected that XLPE insulated 525kV HVDC cables will be available for this project, Mass Impregnated (MI) insulation is a more mature technology for 525kV cables. Given that as part of option 1 it is know that we would need to cut and recover the cable from the sea bed, using the more mature the MI technology could be advantageous. Additionally, the construction of the converter platform will need to be carried out closer to the HVDC cable under option 1. If the cable were accidently damaged the repair / jointing technology for the MI cable will be more mature.

As the adoption of XLPE for use in 525kV cables becomes standard, the availability of MI insulated cables may decline rapidly as suppliers phase out production lines – a trend that has already been observed for lower voltage HVDC cables.

Initial Construction

During the initial construction – in addition to the design aspects mentioned above there are some additional considerations for HVDC cable installation. For option 1 the HVDC cable loop will have to shallow buried in order for the cable to be recovered in the main outage. Therefore, a cable risk assessment evaluation would need to be made and appropriate measures undertaken for the length of the cables to be recovered.

Additionally, consideration would need to be given to the cable bundling: Often in HVDC subsea cables the positive and negative cables are bound together using polypropylene tapes in an orbital binding machine on the deck of the laying vessel prior to over boarding. This binding would have implications for the cable recovery and cutting. It should be considered whether the binding for the omega loop section specifically could be foregone while the section was laid.

Construction, Commissioning and Outages

- Pre-Sea Link Outage

Much of the construction, installation and cold commissioning of the converter offshore platform and wind farm collector platforms can be carried out prior to any outage being taken on the two ended Sea Link interconnector.

The assumed approach here would be that the well-established standard practices used for offshore substation construction and commissioning would be followed. As much of the cold commissioning as possible would be carried out on shore prior to the shipping of the platform topsides.

Following the lifting of the topsides onto their jackets temporary diesel power would be used to power the platforms to allow cold commissioning to continue.

For Option 1 the converter platform will be need to be constructed in closer proximity to the Sea Link HVDC cable, placing the cable at increased risk of damage. These risk can be mitigated (but not eliminated) through the chosen loop size as well as the chosen position of the platform relative to the loop.

It is assumed that this approach would be followed and that therefore all new platforms will be available for first energisation prior to the commencement the Sea Link outage. (In Option 2 the DC Switching Platform would have been energised during the original Sea Link Commissioning)

Standard practice is that the WTGs and associated array cable installation programme will not be completed prior to this phase. Normally a small proportion of WTG's - if any - will be installed prior the energisation of the offshore substation. This is because the installation and commissioning of the WTG's will follow a sequential program. Due to the large numbers of turbines this program will run for several months. It would potentially have a negative impact on the WTG's operational life to be installed and unable to generate / export power during this period.

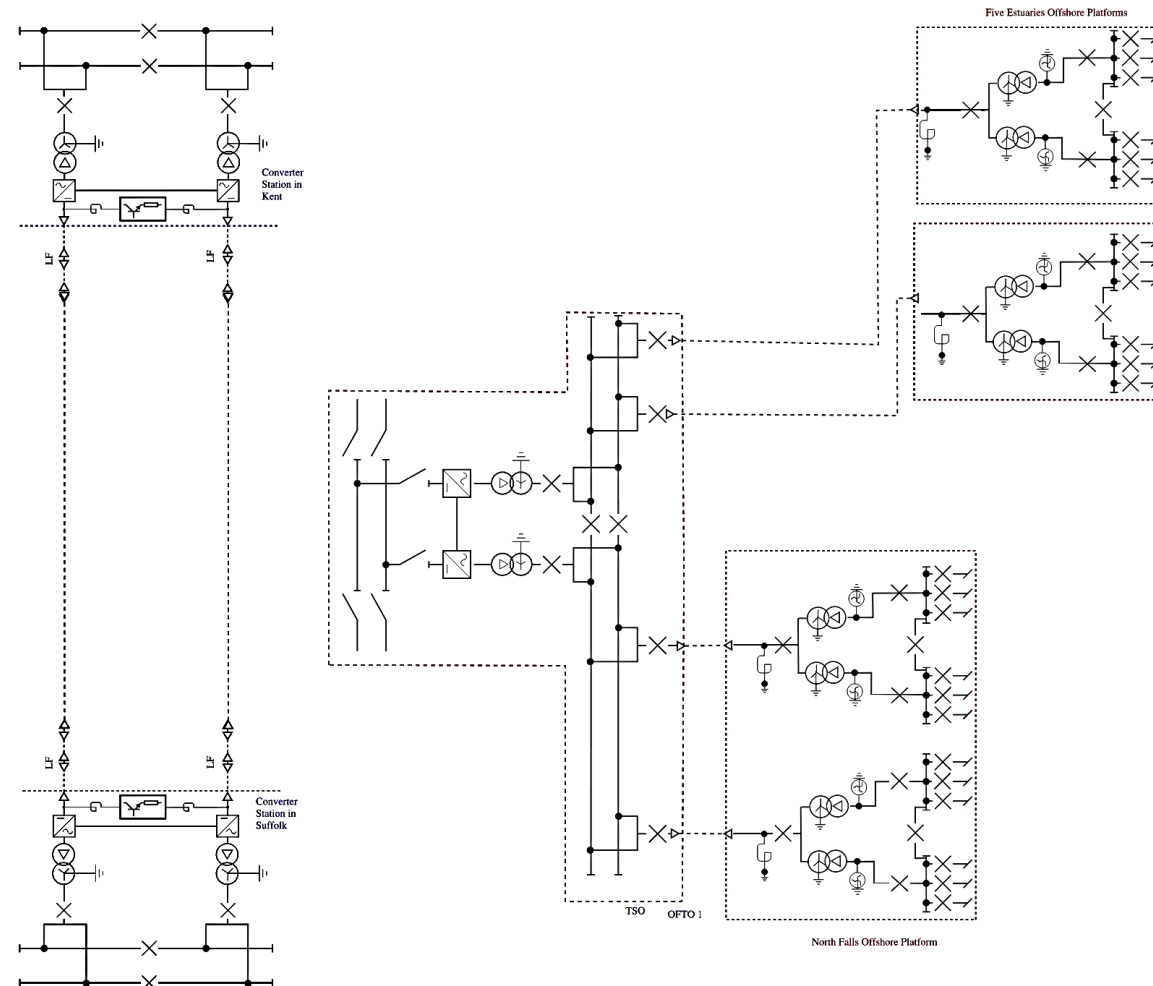


Figure 22- In Service Sea Link ; Constructed Platforms and Inter Platform Export Cabling Under Cold Commissioning

Construction, Commissioning and Outages

- Construction: Option 1 Delayed Cut-in to Tee-off (1/2)

For option 1 the following steps are considered for retrieving the in-service cable and connecting it to the converter platform.

Subsea Survey

The existing condition of the cables forming the Omega loop will be assessed by a marine survey. This will involve multibeam echo sounder and sub bottom profiling sonar scanning in order to confirm the position and burial depth of the cables and provide a confirmation of no obstacles on the route. The survey will provide a report to confirm the equipment and methodology is optimally appropriate for the subsequent de-burial and re-direction activity.

Cable De-burial

The marine spread required to perform the cable de-burial, cutting and re-direction to the platform will be a DP cable lay vessel equipped with a work class ROV, Mass Flow Excavation equipment, diving equipment spread and diving team and deck mounted cable traction engines and a powered carousel. The MFE equipment will be trailed at site to confirm its positional accuracy and height above seabed measurement. The equipment will then be used to de-bury the cables over a distance required to enable the completion of the cable routing diversion and pulling work into the platform. The cables once de-buried will be visually surveyed by the ROV and confirmed to be accessible and free of obstruction. The position of the cable cutting will be established and the ROV will confirm sufficient working area and access is available for the stainless-steel stocking application to the cables by divers. Divers will then be mobilized and will apply the four stainless steel stockings, one either side of the two cutting positions.

Cable Cutting

The first HVDC cable will be cut by the diamond wire tool using the ROV. The first end of the first cable will then be lifted to the vessel deck via the stainless-steel stocking lifting point. The cable will

be stripped back for 5m, and a dampness check performed to establish no moisture ingress beyond this point. If moisture is found then another 5m will be stripped back and the test repeated. Once no moisture has been found the cable end will be sealed and a permanent pulling eye attached. The cable end will then be deployed to the seabed with an anchor and marker buoy back into the MFE trench. The second end of the first cable will then be lifted to the vessel deck via the stainless-steel stocking lifting point. The cable will be stripped back for 5m, and a dampness performed to establish no moisture ingress beyond this point. If moisture is found then another 5m will be stripped back and the test repeated. Once no moisture has been found the cable end will be sealed and a permanent pulling eye attached. The cable end will then be deployed to the seabed with an anchor and marker buoy back into the MFE trench. The above procedure will then be applied to the second HVDC. The final result of this procedure will be the placement and marking of four cut cable ends into the MFE trench.

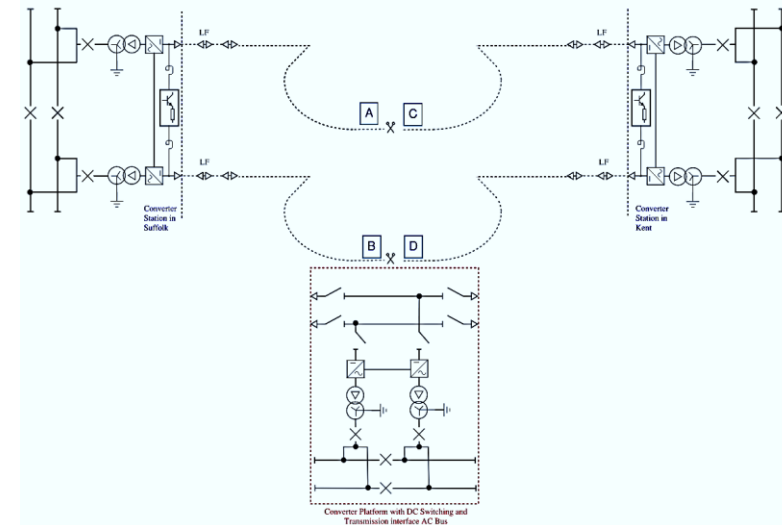


Figure 23 Omega Loop Cutting

Construction, Commissioning and Outages

- Construction: Option 1 Delayed Cut-in to Tee-off (2/2)

Cable Re-positioning

Prior to the cable de-burial and cutting work the cable pulling team will be mobilized to the platform and preparations made for pulling the cables to the termination position. The ROV will then again survey the cable route to ensure that sufficient cable has been de-buried for the recovery and re-direction into the platform J tube. The cable lay vessel will recover the first cable end to deck and secure it into the carousel. The vessel will then follow the existing cable route recovering the cable as it goes. Once sufficient cable length has been recovered the vessel will transit to the J tube position along the new design cable route, surface laying the cable as it proceeds. Upon reaching the J-tube position the cable length will be assessed to see if further cutting is required. The CPS will be applied to the cable end once the correct length is established.

J-Tube Installation

The messenger wire for pulling the cable will be recovered from the J Tube by the ROV and attached to the cable pulling eye on the cable lay vessel. The cable end and CPS will be pulled into the platform J tube using a support quadrant system. The cable will be secured with a temporary hang off clamp, ready for the termination work to be undertaken. The above procedure will be repeated for the 2nd, 3rd and 4th cable ends in sequence. The final result of this procedure will be the placement of the four cut cables along the new cable routes into their securement into the platform.

Cable Termination and Testing work

Once the four cable ends are secured within the platform termination chamber the termination work for the 525kv HVDC and the fibre optic cables can be performed by the trained jointers. Final testing of the cables will be performed in line with the established technical requirements as per the international standards.

Cable Re-Burial work

In parallel with the termination activity and prior to the testing work, the four re-positioned cables will be reburied into the seabed to an established burial protection depth by the MFE tool deployed from the cable lay vessel.

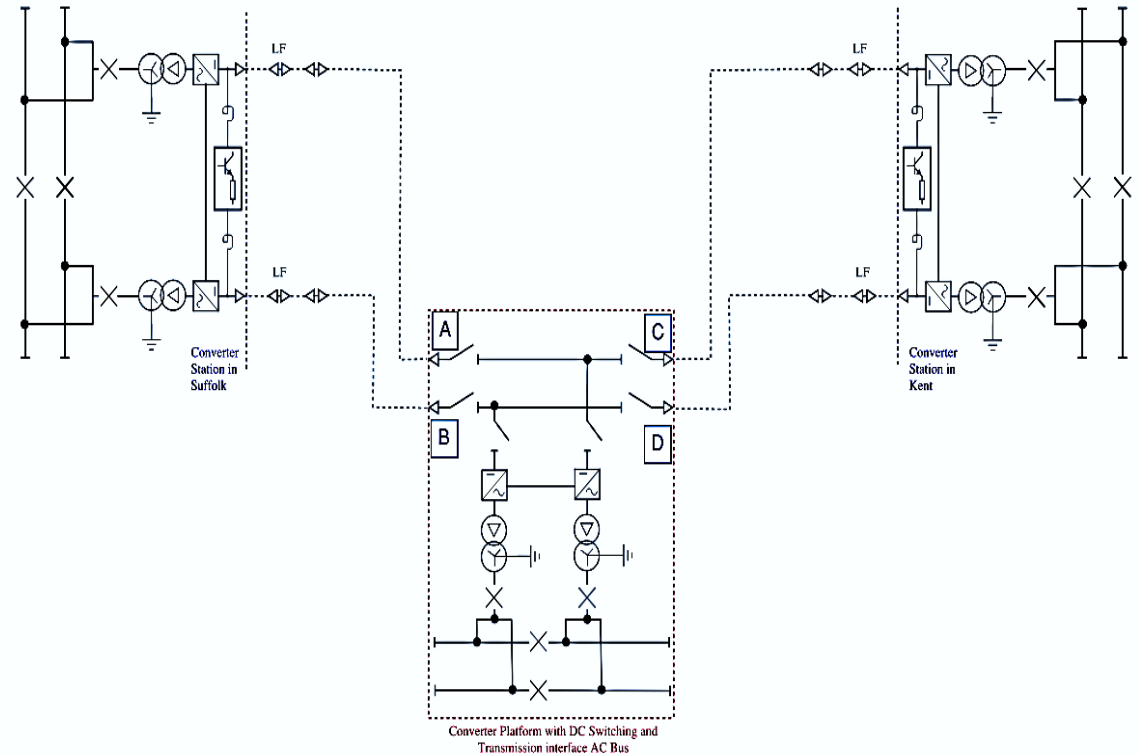


Figure 24 - Cable Ends Re-terminated at Platform

Construction, Commissioning and Outages

- Construction: Option 2 – Cabling from Converter Platform to Switching Platform

For option 2 the cabling aspects are obviously more straight-forward, with the DC Switching Platform having been commissioned during the initial project phase. This provides an easier location to interface with the original cable. It would be recommended that the HVDC cables were laid from the converter platform toward the DC Switching Platform which would mean that taking the main Sea Link Outage could be delayed until the point where the DC cables were interfaced to the rest of the system on the HVDC switching platform.

There would be additional requirements to design the cable route for the converter platform to switching platform, and interface with J-Tubes at both platforms rather than just the converter platform.

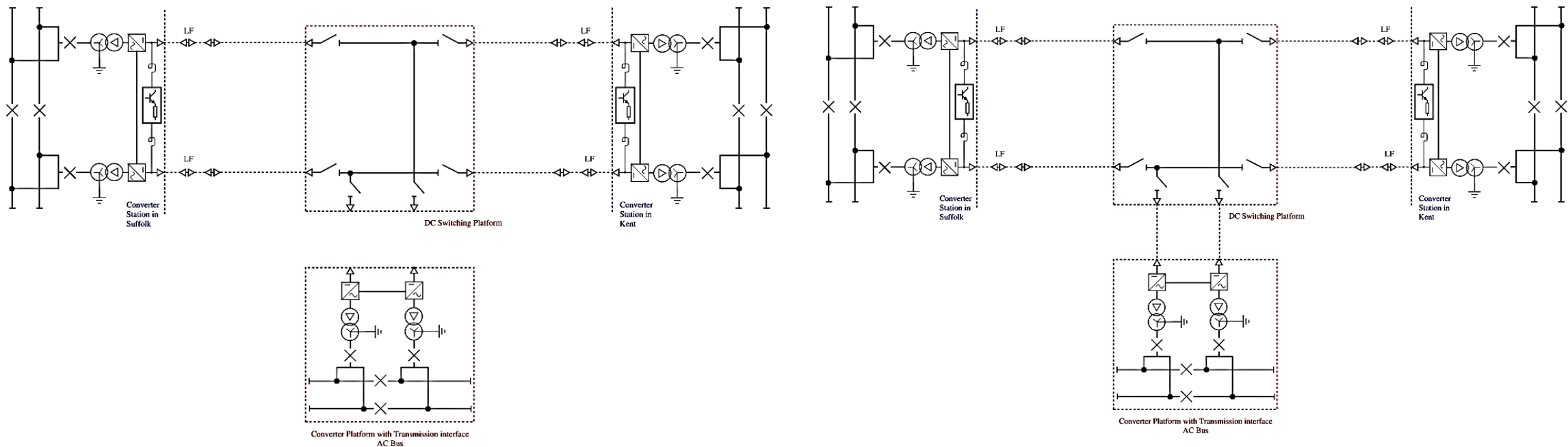


Figure 25 - Pre-Cabling

Figure 26 - Post Cabling

Construction, Commissioning and Outages

- Commissioning (1/3)

Activities During Outage and restoration

Following the activities to connect the DC cable(s) to the offshore converter platform, the process followed for the next stage of commissioning would be similar to those followed for any other offshore substation. Along with the HVDC electrical cable this phase would have brought the fibre optic cables to the platform and the first step would be to establish and verify the comms between the offshore converter platform and each of the onshore converter stations. With comms established, offline testing of the three ended MPI would be carried out.

Once these tests are completed the onshore converter stations will be fully reenergised and the standard approach will be taken to sequentially energise all new / unproven equipment including first soak tests of each item. This approach would be used to fully energise the converter platform all the way to the AC 'Transmission Interface Bus' and would also include commissioning the LVAC auxiliary power systems on the platform. At this stage the platform systems would no longer be required to be powered by temporary diesel generator supplies.

Following this energisation of the offshore platform it will not be possible to fully commission the offshore converter as full power will not be available to prove power flow from offshore to both onshore ends. However, following the re-testing of the Kent-Suffolk and Suffolk-Kent power capability the original two end capability of Sea Link will effectively be restored.

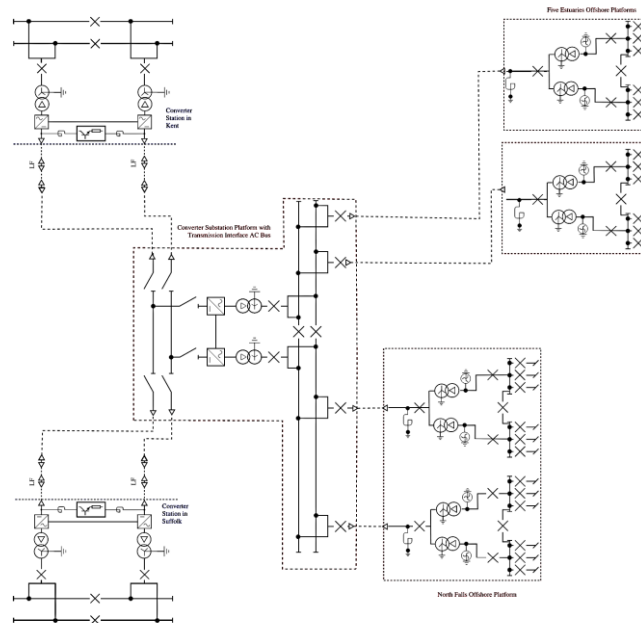


Figure 27 Converter Platform Connected to Sea Link DC System Under Full Outage

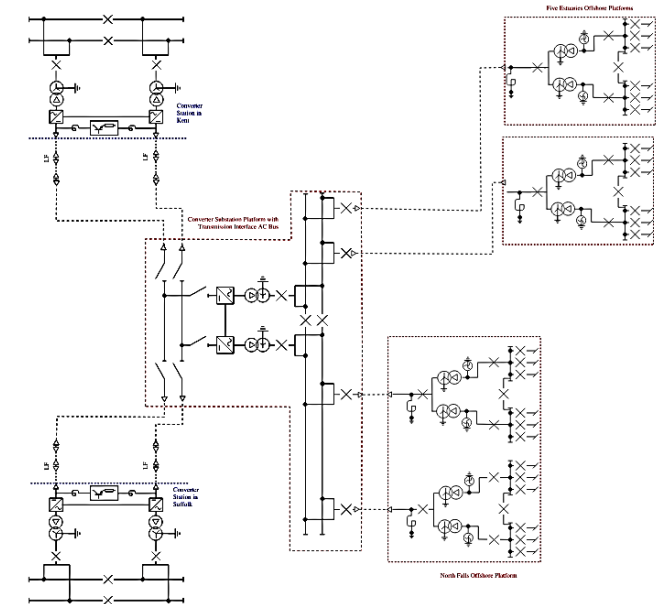


Figure 28 - MPI Sequentially energised to Transmission interface bus

Construction, Commissioning and Outages

- Commissioning (2/3)

Wind Farm Commissioning

Following the availability of a stable AC voltage at offshore Transmission Interface Bus the approach to energising the collector platforms and subsequently the WTG's and associated collection array cables is envisaged to follow standard practice for offshore windfarms. Similar to the converter platform, each collector platform would follow a process of first energisation of the new unproved equipment with associated soak testing. This would include the commissioning of the platform LVAC supplies at which point the platforms would no longer be reliant on temporary diesel supplies and will draw power from the converter platform.

It is envisaged that this point will see the start of the sequential build out and commissioning of the WTG's. For the same connection date, this activity will run in parallel for each wind farm, for the largest wind farm it is anticipated that this stage of the programme will run for around 9 months.

Considering the above, the envisaged program has a more complicated and lengthy list of offshore specific tasks than a typical offshore windfarm program. As these offshore tasks could last for greater than 12 months it represents challenges to scheduling works in preferred seasons. This could result in additional overall time if decisions are made to postpone aspects to align with seasonal windows rather than directly sequencing tasks.

With all turbines available for each wind farm, they will need to complete their grid compliance testing.

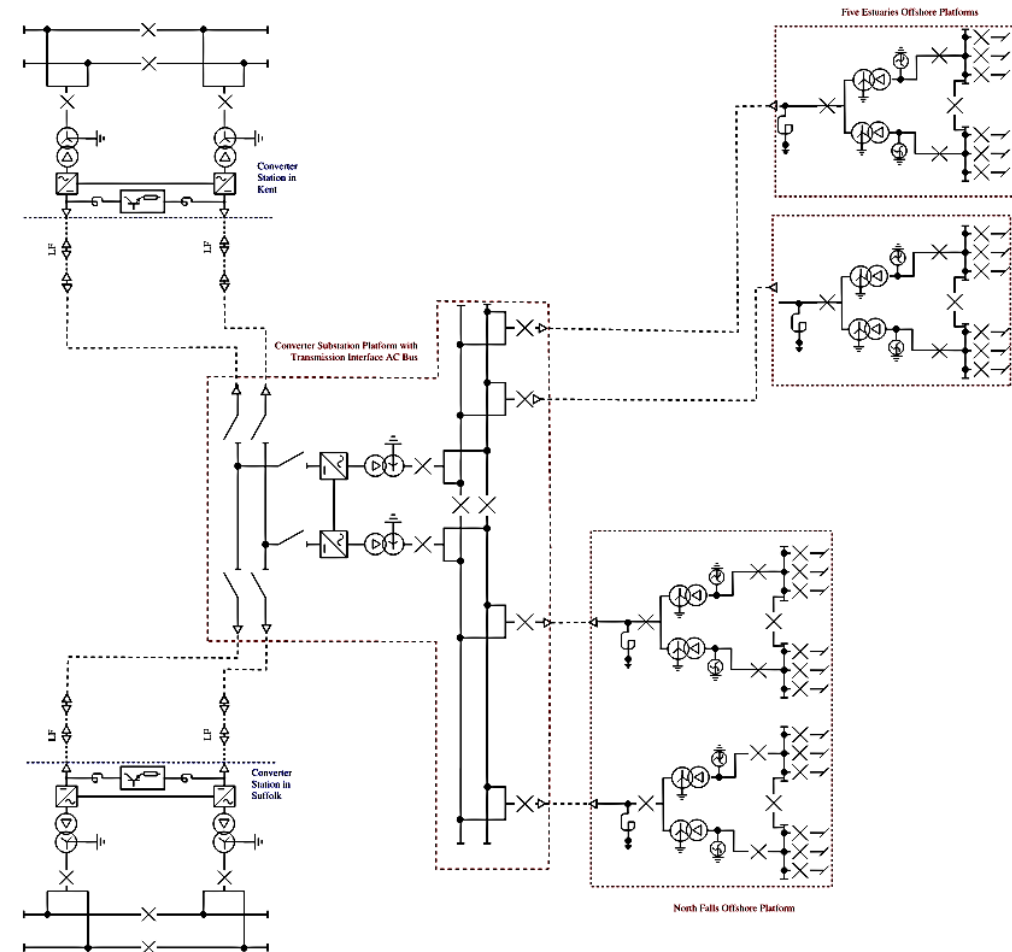


Figure 29 - Wind Farm Platforms Sequentially Energised and Soak Tested – Ready for WTG Installation Programme

Construction, Commissioning and Outages

- Commissioning (3/3)

Sea Link Operation During Wind Farm Commissioning Window

As each WTG is commissioned, standard practice is that these turbines become active generators and begin exporting power to the system. As mentioned above, following the energisation of the converter platform and retesting of the two ended functionality of Sea Link will effectively be restored.

In practice it is envisioned that during this period that either the Suffolk or Kent converter station will be run in a constant power mode. The converter will inject or absorb power from the local NGET network as dispatched. The platform converter will be configured to provide a constant AC voltage to the offshore network; this will result in the converter supplying any required power to this network during no wind conditions as well as injecting any power generated by commissioned turbines when wind conditions allow.

The second onshore converter station will in effect act to balance the active power on the link system. For example the Kent converter station may be configured to inject 1GW into the local NGET network. On a day with high wind when 50% of the WTG's are commissioned, 900MW of renewable energy could potentially be injected into the link by the converter platform. In this scenario the Suffolk converter would act to 'balance' the link flows by drawing 100MW plus some power to account for link losses from the local NGET network. Each additional turbine commissioned will effectively limit the amount of power that can be drawn from the Suffolk area during high wind conditions.

Final MPI Commissioning

Following the completion of the WTG installation / commissioning programme, the availability of full power at the offshore converter platform would allow final commission of the three ended HVDC System. In this period full ramp tests would be carried out between all ends, therefore in this period the functionality to dispatch power

between Suffolk and Kent would be lost for the duration of these tests.

Following the end of these tests the 3 ended MPI and the wind farms will have been fully load tested. At this stage the link capacity will be nearly fully utilised to export the wind farm power under high wind conditions.

Construction, Commissioning and Outages

- Outage Duration

Outage Duration

Based on the above construction and commissioning considerations it has been estimated that the required main outage on Sea Link – i.e. the time during which the link would need to be de-energised until it would be returned to service and dispatchable to transmit power between Suffolk and Kent - would range from 33 weeks (~8 months) (contains no risk contingency) up to 66 weeks (~16 months) for Option 1, and 27 weeks (~6 months) to 54 weeks (~12 months) for Option 2. This time period caters for offshore construction works to connect the converter platform to the HVDC system as for the testing and commissioning activities required to turn the two ended HVDC link into the three ended system.

The duration range given above allows for a risk contingency of 100% for the Sea Link offshore activities – in line with common offshore commissioning practice. This contingency is larger than would usually be applied for

onshore activities. This difference is driven by the significantly increased impact that adverse weather can have on offshore activities as well the more complicated logistics risks.

The durations have been estimated assuming the previously highlighted steps are taken during the initial design and construction phases (e.g. inclusion of DC Chopper) and that all offshore construction activities associated with the new platforms have been carried out, as well as all possible cold commissioning under temporary diesel power prior to the de-energisation of Sea Link. These include all the activities for HVDC cable cutting and rerouting, offshore cable connections to the offshore platforms for both Options as well as related generation termination and testing etc.

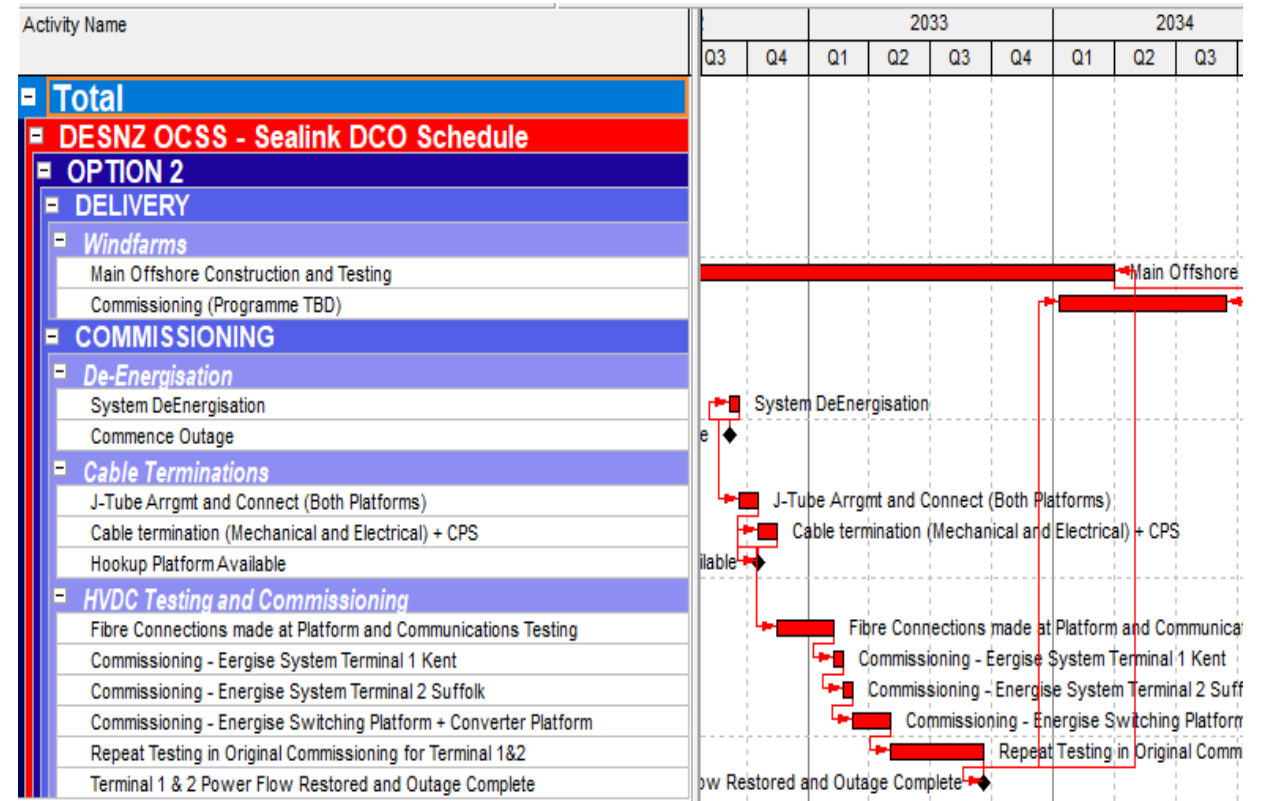
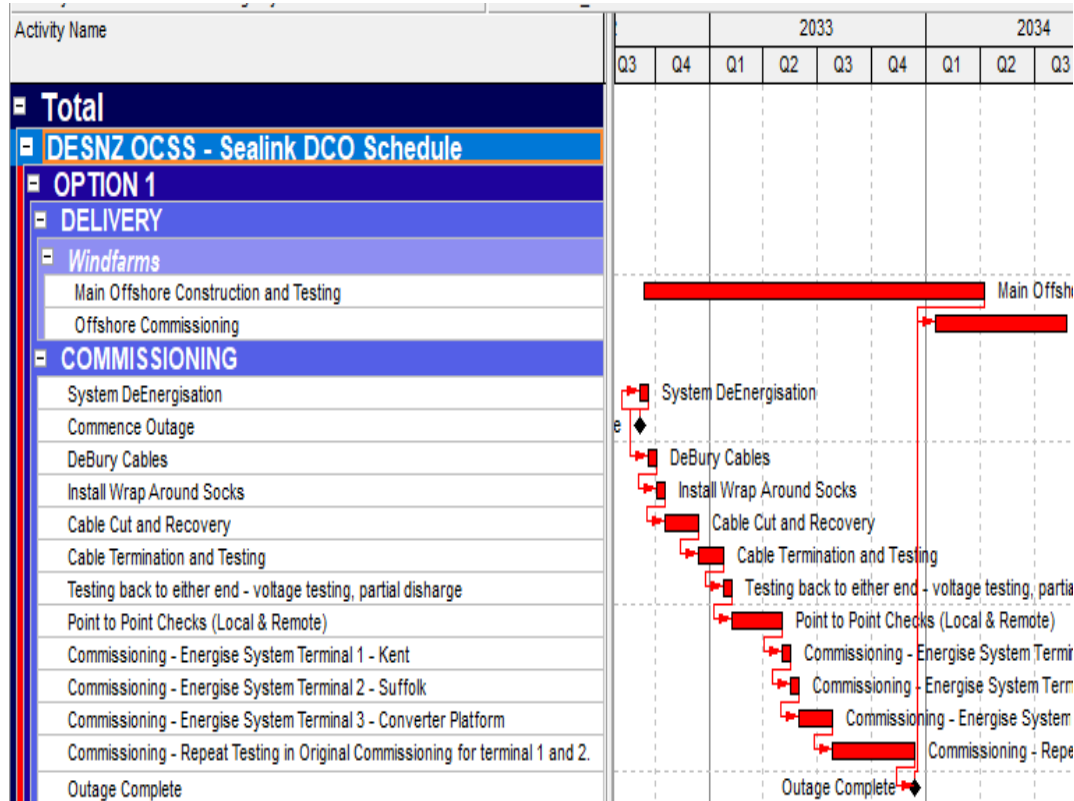
Indicative programmes for these activities (with contingency) are shown on the next slide. More precise details and activities for the commissioning and testing phase would need to be further developed – especially when

the OEM’s preferred approach for optimising the process of transitioning from a 2 ended link to an MPI were known.

As described above – following the completion of wind farm commissioning programme an extra final outage would be required on the Sea Link MPI in order to carry out the final full power tests between the offshore converter platform and each onshore station.

Construction, Commissioning and Outages

- Outage Programme



Durations assigned to commissioning activities includes a risk contingency of 100%. This is based on the current industry risk factor for offshore activities and accounts for weather, market and logistics risks.

Risks

Risk Introduction

As the proposed alternatives (Options 1 and 2) to the baseline are built upon some innovative solutions, i.e., the XLPE cables, the 2.0 GW converter platform, the cable cutting operation and the HVDC switching platform, additional emphasis is required on the risk, to evaluate and mitigate any issues that might arise from the integration of these novel solutions in some already highly complex projects.

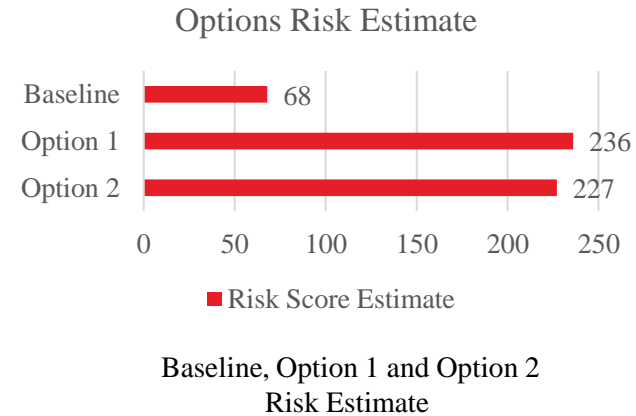
In this section the overall risks for both the baseline and the alternative Options 1 and 2 are explored, with the aim of comparing aggregated risk scores between the options. Only key risks have been considered at this moment.

Risks associated with technical, commercial and programme risks have been identified and qualitatively assessed for all the options using a combination of internal (e.g. WBS, expertise of team representatives) and external (historical/ current risk registers from comparable projects) data. This combination provides for project-specific intelligence as well as diluting subjective bias.

Risks have been assessed qualitatively only, using a 5x5 scoring system; the two variables being probability and impact. The scores for each risk are aggregated for each option. As shown on this page (repeated here from Figure 7 in the Executive Summary).

For the purpose of illustration, the tables in the following slides provide some of the major

including interface risks associated with the proposed alternative scenarios. As mentioned previously, the table is not exhaustive.



Risks - Construction Interface Risks

Contracting approach for offshore transmission

Offshore transmission assets, for offshore wind farms for example, are often procured through a hybrid-contract strategy, utilising a number of key contracts as shown in the table to the right.

In the UK, a hybrid-contract approach is a common procurement strategy and has been used and proven with success in the offshore industry. It balances the interface risk between the project and the contractors and thus achieves a good compromise between cost and risk.

Interface agreements are sometimes required between contractors where there is a more extensive interface and interaction. This can help to manage construction risks and liability. Construction interface risks are explored in further detail on the next pages for the Sea Link options.

Contract	Contract description	
Offshore substation	Design, engineering, manufacture and installation of the offshore substation platform and foundation.	Offshore station structure and foundation fabrication and installation are sometimes separated from the electrical system design and installation, which is usually contracted to an OEM. This is due to the complex and specialised nature of the offshore structural and electrical engineering.
	Design, engineering, manufacture and installation of the HVAC or HVDC equipment/ system	
Offshore export cable	Offshore cable and cable joint design, engineering, manufacturing and installation.	Sometimes delivered by a joint venture or installation is sub-contracted.
Onshore export cable	Onshore cable and cable joint design, engineering, manufacturing and installation.	Design and manufacture, and installation are sometimes separated into two different contracts or sub-contracted.
Onshore substation	Design, engineering, manufacture and installation of the onshore substation foundation and structure.	The onshore substation civils can sometimes be separated from the electrical system design and installation.
	Design, engineering, manufacture and installation of the onshore HVAC or HVDC equipment/ system.	

Risk – Option 1 Construction Interface Risks

	Interface	Construction interfaces	Risk Type	Risk Description	Mitigation
1	HVDC Platform - Sea Link HVDC Cables	The HVDC platform will be built in proximity to the existing Sea Link HVDC cable omega loop. The omega loop will be cut and pulled into cable terminations on the platform.	Technical	During construction of the offshore HVDC platform, there is increased potential for damage of the HVDC cable (omega loop) due to movement of large vessels for example (anchor drag).	This can be mitigated with safety zones and marine construction GIP.
			Commercial	Offshore HVDC platform construction and the HVDC cable cutting and pulling operations are likely to be different contractors.	A hybrid contract arrangement is typical for offshore transmission.
2	HVDC Platform – HVAC Export Cables from OWF Collector Platforms	The HVAC export cables from the OWF collector platforms will be terminated on the HVDC platform.	Technical/ Commercial	During termination of the HVAC cables on the HVDC platform, there is an interface risk between the offshore HVDC contractors and the HVAC cable installation contractors.	A hybrid contract arrangement is typical for offshore transmission.
			Commercial	Interface risk between the TSO (offshore HVDC platform) and the OWF developer (HVAC export cables).	Interface agreement that clearly defines allocation of risk, liability and responsibilities.
3	HVDC Platform – Offshore wind farm	The HVDC platform may be co-located in the marine licence area of the NF OWF and is likely to be constructed in the same timescales as the OWF	Technical	During construction of the HVDC platform and OWF, there is increased potential for damage of the subsea cables and platform, and also of the wind turbines e.g. due to movement of large vessels, and other marine interactions.	This can be mitigated with safety zones and marine construction GIP.
			Commercial	Interface risk between the TSO (offshore HVDC platform owner) and the OWF developer.	Interface agreement that clearly defines allocation of risk, liability and responsibilities.

Risk – Option 2 Construction Interface Risks

	Interface	Construction interfaces	Risk Type	Risk Description	Mitigation
1	DC switching platform – Sea Link HVDC cables	The Sea Link HVDC cable will be routed through the offshore DC switching station.	Technical	The DC switching station and the Sea Link HDVC cable will be installed concurrently and commissioned as part of the same system, reducing interface risks. This assumes that the TSO develops and owns the DC switching station.	This can be mitigated with safety zones and marine construction GIP.
			Commercial	Offshore DC platform construction and the HVDC cable cutting and pulling operations are likely to be different contractors.	A hybrid contract arrangement is typical for offshore transmission.
2	DC switching platform – HVDC Export Cables from HVDC Offshore platform	The HVDC cables connecting the offshore HVDC platform and the DC switching station will be installed after the DC switching station has been installed.	Technical	During termination of the HVDC cables on the DC switching platform, there is an interface risk between the offshore DC switching station contractors/owners and the HVDC cable installation contractors.	This can be mitigated with safety zones and marine construction GIP.
3	HVDC Platform – HVAC Export Cables from OWF Collector Platforms	The HVAC export cables from the OWF collector platforms will be terminated on the HVDC platform.	Technical/ Commercial	During termination of the HVAC cables on the HVDC platform, there is an interface risk between the offshore HVDC contractors and the HVAC cable installation contractors.	A hybrid contract arrangement is typical for offshore transmission.
			Commercial	Interface risk between the TSO (offshore HVDC platform) and the OWF developer (HVAC export cables).	Interface agreement that clearly defines allocation of risk, liability and responsibilities.
4	HVDC Platform – Offshore wind farm	The HVDC platform may be co-located in the marine licence area of the NF OWF and is likely to be constructed in the same timescales as the OWF	Technical	During construction of the HVDC platform and OWF, there is increased potential for damage of the subsea cables and platform, and also of the wind turbines e.g. due to movement of large vessels, and other marine interactions.	This can be mitigated with safety zones and marine construction GIP.
			Commercial	Interface risk between the TSO (offshore HVDC platform owner) and the OWF developer.	Interface agreement that clearly defines allocation of risk, liability and responsibilities.

Other Major Risks

Warranties

Where an asset is modified during the warranty period, this risks voiding the warranty.

For example, a cable manufacturer may not be prepared to continue to warrant a cable where it has been deliberately modified e.g. cut.

This is because if there was a future warranty claim on the cable, the modification could obscure any root cause analysis. In the case of a fault or defect, it could be more challenging to allocate root cause and thus, allocate responsibility for the cost of repair. Indeed, the modification itself could potentially have caused the fault/defect or exacerbated an underlying issue. The manufacturer may seek to protect themselves from this risk by voiding the warranty.

Cable Length

For all scenarios, the length of the offshore HVDC cable is a commercially material risk. If there was a manufacturing fault and the cable needed to be replaced, this may not be covered if the warranty was void. The developer may seek to place some liability with the contractor responsible for the cable cutting however the contractor is unlikely to accept substantial liability, and not beyond the scope of their works.

Insurance

Insurance and insurance premiums may also be affected if an asset is modified during service. For example, an insurer may not be prepared to continue to insure a cable where it

has been deliberately modified if this could affect its physical properties and/or characteristics and increase the future likelihood of a defect or fault.

It may be possible to get the insurer more comfortable with the risk once cable rejoining has taken place and the cable has undergone a number of full thermodynamic load cycles with no unusual trends or patterns.

De-burial

In Option 1, the cable omega loop may be shallow buried initially to facilitate de-burial at a later time for connection to the offshore HVDC platform. This could increase the risk of anchor strike if there is some vessel activity in proximity and if the cable is not buried to the depth as recommended in the Cable Burial Risk Assessment (CBRA), a standard assessment carried out to assess typically external damage risks along an offshore cable route and referred to by insurers. Permanent guard vessels could be located by the omega loop, this could be costly over an extensive duration. Burying a cable to the target depth may be preferable, with jetting used to extract it later.

Multi-party coordination

Minimizing the risk of vessel collisions and cable damage due to anchor drag or loss of dynamic-positioning systems during offshore construction is crucial for ensuring safety and preventing major accidents. Industry good practice includes:

- Compliance with offshore construction regulation and industry standards.
- Guidelines for Offshore Marine Operations (GOMO) such as DNV-ST-N001 and those published by the International Marine Contractors Association: These guidelines should be considered as a minimum standard for all vessels attending offshore installations.
- Risk avoidance, control and management strategy and processes e.g. establishment of exclusion and safety zones during construction.
- Regular monitoring to ensure compliance and that risk controls remain effective.
- Planning, coordination and regular communication between contractors and other stakeholders e.g. fishing industry, Marine licencing bodies.
- Installation Design Considerations: Offshore structures should be structurally sound and account for reasonably foreseeable collision forces.

Planning and Consenting

The marine licence applications, ModApp to the Grid windfarm connections as well as the DCO process for the alternative options would significantly affect the delivery programmes if work cannot proceed 'at risk'.

Sea Link and the offshore wind connections Consenting Considerations

Sea Link Project

- Overview of the Current Project Status

The Sea Link Project received direction from the Secretary of State in May 2022 that development consent for the project can be sought under the Planning Act 2008. National Grid will seek to obtain a Development Consent Order (DCO), with the aim of submitting a DCO application to the Planning Inspectorate in Autumn 2024.

The Project is currently in the pre-application stage of the DCO process, and two rounds of consultation have taken place. The non-statutory consultation took place between October and December 2022 to introduce the project to the public and stakeholders, explain why National Grid need to build the reinforcement, set out the options that have been considered and how National Grid made the decision on the proposed cable corridors, convertor station sites and the marine route and cable landfall locations. Statutory consultation took place between October and December 2023.

The [Strategic Options Report](#) was published in October 2023 as part of the statutory consultation. The SOR includes the needs case for the project, which can be summarised as the need for system reinforcement to resolve distinct issues of capacity provision in the East Anglia and South East regions.

Prior to this, a [Corridor and Preliminary Routing and Siting Study](#) was published in Oct 2022, which identified four

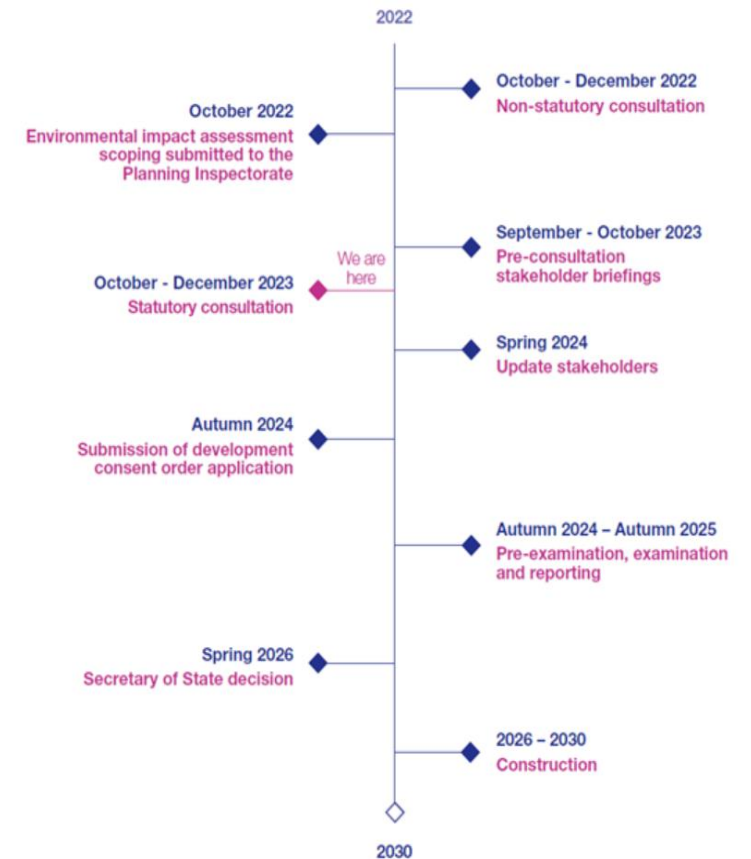
strategic options to address the need.:

- SL1 – Sizewell Area to Sellindge subsea - approx. 180km
- SL2 – Sizewell Area to Richborough subsea - approx. 120km (for the purposes of this review, the baseline option)
- SL3 – Sizewell Area to Canterbury subsea - approx. 120km
- LL 1 – Sizewell Area to Canterbury onshore - approx. 220km

The Sea Link project is currently within the Assessment and Land Rights stage of National Grid’s Approach to Consenting Process, as shown below.

In the recent [Network Options Assessment \(NOA\) 2021/22 Refresh \(July 2022\)](#) the ESO has identified SCD1/Sea Link and other reinforcements in the NOA as ‘Holistic Network Design (HND) essential’ to deliver the Pathway to 2030 Holistic Network Design - connecting offshore wind needed to meet the Government’s 50 GW by 2030 target. Further, the ESO advises the reinforcement needs to be accelerated to meet this target.

The assumed submission date of Autumn 2024 anticipates a decision from SoS by Spring 2026, with construction slated for 2026-2030 for 2030 delivery.



North Falls & Five Estuaries Offshore Wind Farms

- Implications of Option 1 and Option 2 on the consenting process

The options proposed by this review introduce additional development and changes to the proposed development as promoted by the Sea Link Project. These changes are summarised below alongside the existing Project and consenting considerations.

Change to the current Projects	Consenting considerations	Resolution
<p>Option 1</p> <ul style="list-style-type: none"> Additional cable – ‘the Omega Loop’ Proposed additional offshore platforms – HVDC Converter Platform <p>Option 2</p> <ul style="list-style-type: none"> Proposed additional offshore platforms – HVDC Converter Platform, DC switching platform 	<p>Both windfarm project have signed a good neighbour agreement that enables closer liaison, information sharing and joint planning.</p> <p>For the counterfactual projects, this is evidenced by the common onshore cable route and the co-located substations. It also allows for greater communication of working ideas, with proposals for platform locations based on feedback received by the projects. This allows for the inclusion of certain aspects within the North Falls DCO to minimise the overall impacts, such as allowing for HVDC converter stations within the DCO.</p>	<p>Both the offshore wind farms have a projected in-service date of 2030, the same as Sea Link. Due to the imminent anticipated DCO application submission dates of the two offshore wind projects, it is recognised the current approach of the wind farms is to continue with the proposals within the remit of that consulted upon, to enable a 2024 submission, the overall construction programme and 2030 delivery, with aspects of the QCP that do not impact the consent included, e.g. the allowance for a HVDC converter station within the North Falls array area that would serve both windfarms .</p>

Sea Link Project (1/2)

- Implications of option 1 and option 2 on the consenting process

Change to the Sea Link Project	Consenting considerations	Resolution
<p>Option 1</p> <ul style="list-style-type: none"> • Additional cable – ‘the Omega Loop’ • Proposed additional offshore platforms – HVDC Converter Platform <p>Option 2</p> <ul style="list-style-type: none"> • Proposed additional offshore platforms – HVDC Converter Platform, DC switching platform 	<p>The Project includes an offshore scheme boundary and limits of deviation, within which the proposed development will be required to take place. (See Figure 1.1.4 of the PEIR, Oct 2023). The offshore scheme includes the marine HVDC cable route: this is the cable route from the TJB at the landfall in Suffolk to the TJB at the landfall in Kent. The marine HVDC cable route is up to 130km in length.</p> <p>The marine alignments, connecting the landfall areas of search in Suffolk and Kent, are reported in the Corridor and Preliminary Routing and Siting Study. This is based on several criteria including design principles, shipping areas and environmental considerations.</p> <p>The offshore environmental impact assessment and habitats regulation assessment, as required by the EIA and HRA regulations, is based on several Offshore Scheme design characteristics as set out in Table 1.4.10 of the PEIR, October 2023.</p>	<p>The proposed offshore scheme is founded on an optioneering methodology as documented in the SOR and CPRSS. A backcheck should be undertaken to identify if the decisions taken to date to arrive at the Sea Link Project (as is proposed by the DCO application) remain strong in light of the proposed Omega Loop and therefore if it presents any challenge to the needs case and option report conclusions that support the Sea Link Project.</p> <p>The development and operation of the Omega Loop would require a Marine Licence. The Marine Licence required for the offshore elements of the Sea Link Project are to be sought as part of the application for a DCO because a DCO may include provision for deemed marine licence consent under <u>Part 4 of the Marine and Coastal Access Act 2009</u>. However, the Marine Management Organisation is responsible for enforcing, post-consent monitoring, varying, suspending, and revoking any <u>deemed marine licence(s)</u> as part of the DCO.</p> <p>The Omega Loop would require a change to the scheme boundary and limits of deviation for the offshore scheme to those presented in the current Sea Link Project (as per the statutory consultation in the General Arrangement Plans, Offshore Scheme Sheet 2, October 2023.) Furthermore, it may have different environmental impacts and a review of the EIA and HRA of the offshore scheme would be required to identify if the changes (that Option 1 would require) could be accommodated within the existing assessment scope or if further survey and/or assessment work would be required.</p>

Sea Link Project (2/2)

- Implications of option 1 and option 2 on the consenting process

Change to the Sea Link Project	Consenting considerations	Resolution
<p>Option 1</p> <ul style="list-style-type: none"> Additional cable – ‘the Omega Loop’ Proposed additional offshore platforms – HVDC Converter Platform <p>Option 2</p> <ul style="list-style-type: none"> Proposed additional offshore platforms – HVDC Converter Platform, DC switching platform 		<p>It is considered that there are four potential options, to seek consent for the development proposed by Option 1:</p> <ol style="list-style-type: none"> Amend the existing Sea Link Project so that Option 1 is included within the proposed DCO application: The current target submission date for the Sea Link DCO application is Autumn 2024, which is required to meet the 2030 delivery date. There would be insufficient time to incorporate this Option (and the changes it would require to the existing Project) into the Sea Link DCO application, based on the current programme. This is because it would require additional assessment, reporting, engagement and consultation work. For example; an additional targeted supplementary consultation would be required; an update to the Project Development Overview Report would be required; updates to the Project drawings (limits of deviation, red line boundary etc); and a review of the EIA/HRA and revisions to the Environmental Statement. Amend the existing Sea Link Project so that Option 1 is included in the proposed DCO application during the examination of the DCO: this would require an application for proposed change to the DCO application, to the Planning Inspectorate, early in the examination timetable and for the necessary amended application documentation to be submitted, should the application for a change be accepted. There would be limited time to make these changes and it would require significant additional pressure in the examination process. Amendment to the deemed Marine Licence, following the making of the DCO, by a variation application to the Marine Management Organisation: this would require a review of the extent of change, proposed by this option, and engagement with the MMO to advise if this could be dealt with by way of a variation application. A new Marine Licence Application: this would require the preparation of a new application to seek a new Marine Licence for the additional infrastructure proposed.

Consenting Considerations

- Concluding Comments

North Falls completed its statutory consultation phase in July 2023 with the intention of submitting its DCO application in 2024.

The DCO application for the Five Estuaries Offshore Wind Farm Project is anticipated to be submitted in March 2024. Both the offshore wind farm projects are more advanced than Sea Link.

For National Grid, the planned approach is continuation of the existing programme with the final design freeze for the DCO application design set for May 2024 not inclusive of Options 1 or 2.

Sea Link and the offshore wind projects have not planned for the incorporation of the proposed option/s in the current proposed DCO applications and the associated programmes for consent and delivery. However, it is understood that North Falls has allowed for an offshore

HVDC platform in their DCO.

It is considered that there is insufficient time, in the current DCO application programmes (Sea Link and the Windfarms) to incorporate the changes that Options 1 and 2 would bring. The programmes for submission and for examination could be reviewed in detail in respect of what would be required to accommodate the changes. This would determine with more certainty the level of risk this would pose on the 2030 delivery date.

This initial review of consenting consideration concludes that a standalone marine license complementing the DCO is likely to be the most risk adverse in regard to meeting the 2030 delivery date. However, this would be subject to legal review and the views of PINS and DESNZ. The separate marine license approach would require National Grid to seek the marine elements of the NSIP to be consented via marine license under Part 4 of the Marine

and Coastal Access Act, 2009.

In this instance, the MMO will engage with PINS throughout the DCO process to ensure that the NSIP is considered in its entirety and does not conflict with any license issued under Part 4 of the 2009 Act. Specialist legal advice should be sought in order to establish the risk of this approach and any impact on the DCO.

ARUP