Outer Hebrides Whole System Assessment
Phase 1: Optioneering Studies Report

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Scottish & Southern Electricity Networks

Outer Hebrides Whole System Project
Hebrides and Orkney Whole System RIIO-ED2 Re-opener
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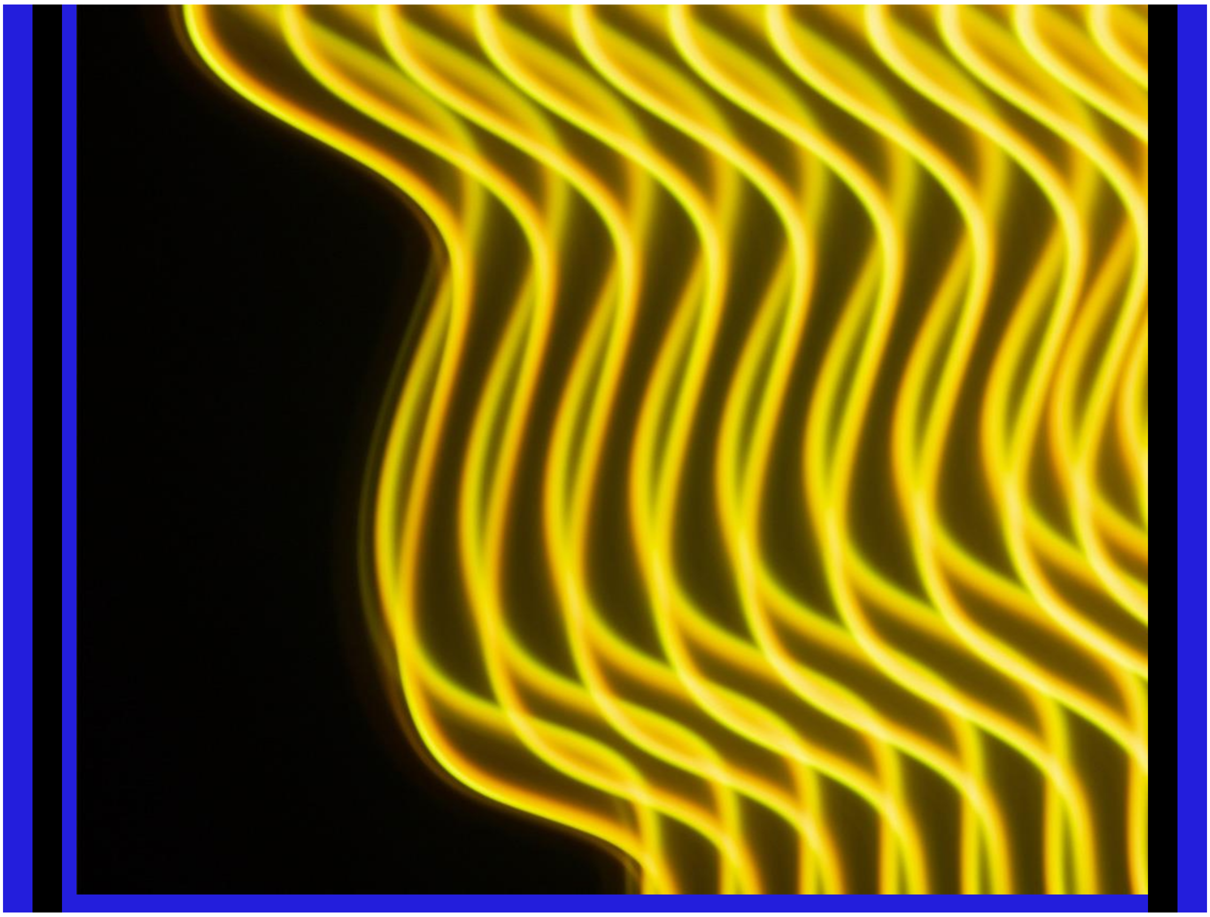

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Executive summary

Due to uncertainties in respect of the development of demand, renewable generation, and the status of the HVDC Western Isles transmission link at the time of submission of the RIIO-ED2 business plans a Hebrides & Orkney Whole Systems (HOWS) bespoke Uncertainty mechanism is in place until March 2025. The SSEN Island documentation provided to Ofgem during the ED2 submission process stated "Western Isles (Uist, Eriskay, Barra & Skye): We need to consider interactions with transmission proposals such as the proposed HVDC cable from Beauly to Lewis alongside meeting resilience and local capacity requirements; as well as decarbonising emissions from diesel generation units. Alternative network considerations need to be explored alongside a role for local flexibility services."

Jacobs has been engaged to assess the Outer Hebrides energy system using the Whole System approach to support investment proposals to enable SSEN to obtain Ofgem's approval when they make their re-opener application. The focus of this report is the Initial Optioneering and Power System Studies.

The Outer Hebridean islands are currently fed from Skye using two subsea cables, one feeds the Isles of Uist and is at the end of its life and the other which feeds the Isle of Lewis and Harris and has been recently replaced. There is no connection between the Isle of Lewis and Harris and the Isles of Uist. SSENs overarching strategy is "to decarbonise the Western Isles, meet security of supply standards, drive least worst regret investment to facilitate island net zero ambitions and deliver a coordinated approach that meets stakeholder, customer, and consumer needs".

This report which expands the optioneering undertaken in the initial EJPs developed for the RIIO-ED2 business plan to consider:

- Alternative connection options,
- The latest Distribution Future Energy Scenario (DFES) demand and generation data,
- The impact of the 1.8GW HVDC transmission line between Lewis and mainland Scotland (approved for pre-engineering works).
- SSEN strategy to reduce the use of Diesel Embedded Generation assets (DEG),
- Viable options based on a Whole System solution approach.

Options Overview

This report considers a number of options to improve the security of the existing connection arrangements to the Hebrides and ensure the system capacity is suitable for the predicted 2050 demand and generation profile. This includes the consideration of the future SSEN Transmission HVDC link landing near Stornoway and the possible addition of a 132 kV connection from Skye to the Isle of Lewis and Harris which will contribute to the security of supply to the islands.

Having two connections to the Isle of Lewis and Harris from the mainland with N-1 security will reduce the need for diesel embedded generation (DEG) under one circuit outage thus saving the cost of running the standby DEGs. Likewise, having two connections to the Isles of Uist (North and South) from the mainland, or establishing a connection between the Isle of Lewis and Harris and North Uist with one connection to the Isles of Uist from the mainland will reduce the need for DEG under outage conditions. It is noted that there are no current plans to upgrade the single circuit overhead line between Edinbane, Dunvegan and Ardmore. Hence if all the connections to the Hebrides from the mainland are from Skye via Ardmore and / or Dunvegan this portion of the connection will remain as a single point of failure.

A number of different supply configurations have been considered, considering the existing and proposed new 33 kV subsea cables from Skye to Harris, North Uist and South Uist, the future HVDC cable that will connect to the Isle of Lewis and Harris and a new 132 kV subsea cable between Skye and Harris.

The seasonal nature of the local renewable generation means that studies have been undertaken for both summer and winter demand and generation. This has resulted in the identification of options which meet acceptable voltages and circuit loading for both normal and N-1 security of supply.

Some local constraints have been identified resulting in recommendations to uprate the cable ratings & transformers and additional reactive power compensation requirements. Additionally, procurement of flexibility services is considered as an option to meet the future demand scenarios. The amount of flexibility that would need to be procured to prevent the need for reinforcement by 2050 is large, hence it is not proposed that flexibility is used as an enduring solution. However, it is possible that smaller amounts of flexibility could be used to defer the need for the reinforcement by a few years and it is suggested that this is considered in the next stage of the study with the CBA assessment.

Preferred Options

The fourteen options which are recommended to be taken forward to the Cost Benefit Analysis are summarised in Section 6 and tabulated in Table 1-1. In all cases the existing Ardmore – Loch Carnan subsea cable is decommissioned.

The overall security of supply to the islands will depend on the option selected, the dependency on the Skye network arrangements and the use of a 132 kV or HVDC link to the mainland. It is noted that the options using two separate sources of supply (Skye and the HVDC link) should provide inherent higher reliability to the Hebrides.

Local upgrades to the distribution systems on the islands have been identified as necessary. Table 4-2 details the local upgrades required for each option.

Table 1-1 Whole System feasible options

Feasible Options
Option-8 • Add two new Ardmore – Loch Carnan subsea cables. • Add new subsea cable/OHL from Admore to Harris.
Option-9 • Add two new Ardmore – Loch Carnan subsea cables. • Add new 132kV subsea/OHL from Admore to Harris.
Option-11 • Add new Ardmore – Loch Carnan subsea cable. • Add new subsea cable/OHL from Admore to Clachan. • Add new subsea cable/OHL from Admore to Harris.
Option-12 • Add new Ardmore – Loch Carnan subsea cable. • Add new subsea cable/OHL from Admore to Clachan. • Add new 132kV subsea/OHL from Admore to Harris.
Option-14 • Add Dunvegan – Loch Carnan OHL/subsea cable. • Add Ardmore – Clachan OHL/subsea cable. • Add new subsea cable/OHL from Admore to Harris.

Feasible Options
Option-15 • Add Dunvegan – Loch Carnan OHL/subsea cable. • Add Ardmore – Clachan OHL/subsea cable. • Add new 132kV subsea/OHL from Admore to Harris.
Option-18 • Add Dunvegan – Loch Carnan OHL/subsea cable. • Add Harris – Lochmaddy subsea cable plus new OHL from Lochmaddy to Clachan. • Add new subsea cable/OHL from Admore to Harris.
Option-19 • Add Dunvegan – Loch Carnan OHL/subsea cable. • Add Harris – Lochmaddy subsea cable plus new OHL from Lochmaddy to Clachan. • Add new subsea cable/OHL from Admore to Harris.
Option-20 • Add Dunvegan – Loch Carnan OHL/subsea cable. • Add Harris – Lochmaddy subsea cable plus new OHL from Lochmaddy to Clachan. • Add new 132kV subsea/OHL from Admore to Harris.
Option-23 • Add new Ardmore – Loch Carnan subsea cable. • Add Dunvegan – Loch Carnan OHL/subsea cable. • Add new subsea cable/OHL from Admore to Harris.
Option-24 • Add new Ardmore – Loch Carnan subsea cable. • Add Dunvegan – Loch Carnan OHL/subsea cable. • Add new 132kV subsea/OHL from Admore to Harris.
Option-26 • Add Ardmore – Loch Carnan subsea cable. • Add new subsea cable/OHL from Admore to Harris. • Add Harris – Lochmaddy subsea cable plus new OHL from Lochmaddy to Clachan.
Option-28 • Add Ardmore – Loch Carnan subsea cable. • Add Dunvegan – Loch Carnan OHL/subsea cable. • Add Harris – Lochmaddy subsea cable plus new OHL from Lochmaddy to Clachan. • Add new subsea cable/OHL from Admore to Harris
Option-29 • Add Ardmore – Loch Carnan subsea cable. • Add Dunvegan – Loch Carnan OHL/subsea cable. • Add Harris – Lochmaddy subsea cable plus new OHL from Lochmaddy to Clachan. • Add new 132 kV subsea cable/OHL from Admore to Harris

Contents

Appendices

Figures

Acronyms and abbreviations

BS	British Standard
CBA	Cost Benefit Analysis
DEG	Diesel Embedded Generation
DFES	Distribution Future Energy Scenario
EJP	Engineering Justification Paper
HOWS	Hebrides & Orkney Whole Systems
HV	High Voltage
HVDC	High Voltage Direct Current
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Standards Organization
kA	Kilo Ampere
Km	Kilometre
kV	Kilo Volt
kV	Kilovolt
Max	Maximum
Min	Minimum
MVA	Mega-volt-ampere
MVAr	Mega-volt-ampere-reactive
MW	Mega-Watt
NG	National Grid UK
NPV	Net Present Value
OHL	Overhead Line
SHEPD	Scottish Hydro Electric Power Distribution
SS	Sub-Station
SSE	Scottish and Southern Energy
SSEN	Scottish and Southern Electricity Networks
UK	United Kingdom

1. INTRODUCTION

1.1 Project background

Due to uncertainties in respect of the development of demand, renewable generation and the status of the HVDC Western Isles transmission link at the time of submission of RIIO-ED2 business plans a Hebrides & Orkney Whole Systems (HOWS) bespoke Uncertainty mechanism is in place until March 2025. The SSEN Island documentation provided to Ofgem during the ED2 submission process stated "Western Isles (Uist, Eriskay, Barra & Skye): We need to consider interactions with transmission proposals such as the proposed HVDC cable from Beauly to Lewis alongside meeting resilience and local capacity requirements; as well as decarbonising emissions from diesel generation units. Alternative network considerations need to be explored alongside a role for local flexibility services."

The Outer Hebridean Islands under consideration are Vatersay, Barra, Eriskay, South Uist, Benbecula, North Uist, Harris and Lewis.

At present there is a Skye to South Uist, 46km, 33 kV subsea cable which is over 30 years old, and which connects over 4,400 customers and 7.5 MW of generation. The existing cable has the worst Health Index score (HI of 5), indicating it is at the end of its life and accounts for 70% of the total monetised risk of all the SSEN subsea cables. There is also a recently replaced 33 kV subsea cable from Skye to the Isle of Lewis and Harris, and a 1.8 GW HVDC cable (subsea and onshore) from Stornoway to Dundonnell on the mainland, which is scheduled for after 2030.

There is currently no electrical connection between the Isle of Lewis and Harris and the North Uist.

SSEN developed Engineering Justification Papers (EJPs) for the RIIO-ED2 business plan which considered 7 options. The installation of two subsea cables between Skye and North Uist and between Skye and South Uist was identified as the preferred planned intervention option as illustrated in Figure 1-1.

Figure 1-1 Proposed two new circuits to Uist in ED2 submission[1]

[1] Diagram from SSEN Outer Hebrides Whole System Assessment Terms of Reference

1.2 Study aims

Jacobs has been engaged to assess the Outer Hebrides energy system using the Whole System approach to support investment proposals to enable SSEN to obtain Ofgem's approval when they make their re-opener application.

SSENs overarching strategy is "*to decarbonise the Western Isles, meet security of supply standards, drive least worst regret investment to facilitate island net zero ambitions and deliver a coordinated approach that meets stakeholder, customer, and consumer needs*".

1.3 Project scope

The project scope is divided into three stages:

Stage1: Initial Optioneering and Power System Studies – the focus of this report.

Stage 2: Cost Benefit Analysis - a risk assessment of all the options and a Cost Benefit Analysis (CBA) to determine which option has the highest Net Present Value (NPV) and is the Least Worse Regret Option.

Stage 3: Reopener Submission Support - provision of support to SSEN with completion of the Hebrides & Orkney Whole System (HOWS) resubmission.

1.4 Initial Optioneering and Power System Studies overview

This is the Stage 1 report which expands the optioneering undertaken in the initial EJPs to consider:

- Alternative connection options,
- The latest Distribution Future Energy Scenario (DFES) demand and generation data,
- The impact of the 1.8GW HVDC transmission line between Lewis and mainland Scotland (approved for pre-engineering works),
- SSEN strategy to reduce the use of Diesel Embedded Generation assets (DEG),
- Other viable options based on a Whole System solution approach.

The technical assessment considers cable and equipment loadings, system voltages, reactive power compensation and security of supply as well as short circuit ratings. Full details of the study basis and assumptions are given in section 3.

Updated DFES data 2025 – 2050 for demand and generation was provided, the studies have been undertaken for Customer Transformation (CT) 2050 data using both summer minimum and winter maximum scenarios. Peak renewable generation data was considered in the analysis as appropriate. No Diesel Embedded Generation (DEG) was included. A set of options to facilitate long term demand and generation growth have been identified.

1.5 Report Structure

This report comprises of the following sections:

Section 2: Overview of the existing arrangements

Section 3: Option development

Section 4: Optioneering studies and results

Section 5. Short Circuit Analysis

Section 6. Option assessment

Section 7. References

Appendix A, PSS/E overview diagram

Appendix B, PSS/E option results

Appendix C, Sub-sea cable data sheets

2. OVERVIEW OF THE EXISTING ARRANGEMENTS

2.1 Introduction

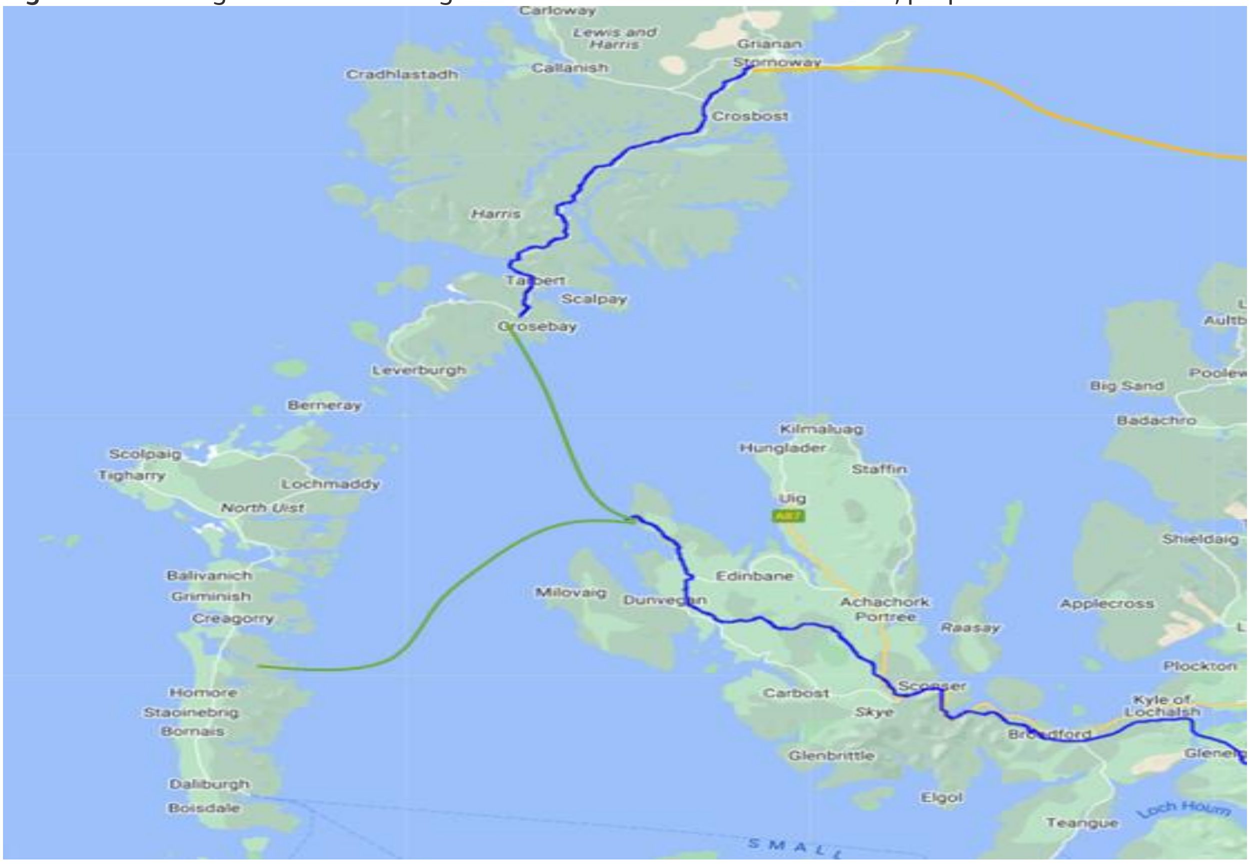
The Outer Hebrides or Western Isles is a chain of islands located off the West Coast of Scotland. Under consideration in this assessment are Vatersay, Barra, Eriskay, South Uist, Benbecula, North Uist, Harris and Lewis Islands.

As illustrated in Figure 2-1 there is a single existing Skye (Ardmore Grid) to South Uist, 46km, 33 kV subsea cable which is over 30 years old, and which connects over 4,400 customers and 7.5 MW of generation. The existing cable has the worst Health Index score (HI of 5), indicating it is at the end of its life and accounts for 70% of the total monetised risk of all the SSEN subsea cables.

There is also a recently replaced 33 kV subsea cable from Skye (Ardmore Grid) to Harris and Isle of Lewis. Planned transmission reinforcements are:

- A 1.8 GW, 81 km, HVDC subsea cable and 80 km onshore cable from Stornoway to Dundonnell (mainland).
- Upgrade of the 132 kV network on the Isle of Lewis and Harris, between Stornoway and Harris, using an H pole design, whilst the capacity will be increased this will still be single circuit.

Figure 2-1 Existing circuits connecting Outer Hebrides with the Mainland inc, proposed HVDC link to Lewis. [2]



² Diagram from SSEN Outer Hebrides Whole System Assessment Terms of Reference

2.2 Technical observations

Previous EJPs considered the need to reinforce the network due to load and DEG growth. At present if there is a failure of one of the subsea cables between Ardmore (Skye) and Loch Carnan (South Uist) or Harris substations there will be an outage to the supply on the affected islands until standby diesels are used.

There is currently no electrical connection between North Uist and the Isle of Lewis and Harris.

The existing 95 mm^2 subsea cable from Ardmore to Loch Carnan will currently be overloaded when the demand on North Uist and South Uist is at maximum and there is no generation operating on the islands.

2.3 Commercial observations

Despite regular inspection non-planned faults will occur on subsea cables which incurs costs associated with alternative provision of electricity to the consumers and the cost of repair.

The cost of repairing a subsea cable can be significant as specialist vessels are needed to lay a non-standard cable and poor weather can prevent or hamper the repair. This means the outage time can be prolonged and the standby DEG used to provide an alternative supply to the Islands can run for over six months.[3]

The RIIO-ED2 business case submission[4] identifies the installation of two new subsea cables between Skye and Uist (Cost [redacted] but includes Pentland Firth West to Orkney). There are also additional ancillary costs related to the additional management required for subsea cables compared to conventional onshore cables.

Having two connections to the Isle of Lewis and Harris from the mainland with N-1 security will reduce the need for diesel embedded generation (DEG) under one circuit outage thus saving the cost of running the standby DEGs. Likewise, having two connections to the Isles of Uist (North and South) from the mainland, or establishing a connection between the Isles of Lewis and Harris and North Uist with a connection to the Isles of Uist from the mainland will reduce the need for DEG under outage conditions.

It is noted that there are no current plans to upgrade the single circuit overhead line between Edinbane, Dunvegan and Ardmore. Hence if all the connections to the Hebrides from the mainland are from Skye via Ardmore and / or Dunvegan this portion of the connection will remain as a single point of failure.

2.4 Regulatory observations

Due to uncertainties in respect of the development of demand, renewable generation, and the status of the HVDC Western Isles transmission link at the time of submission of RIIO-ED2 business plans, a Hebrides & Orkney Whole Systems (HOWS) bespoke Uncertainty mechanism is in place until March 2025. The Uncertainty mechanism allows time for some of the factors that affect the supply to the Hebrides, such as the HVDC link from Lewis to mainland Scotland and the advancements in the procurement of flexibility, to become more certain. The SSEN Island documentation provided to Ofgem during the ED2 submission process stated "Western Isles (Uist, Eriskay, Barra & Skye): We need to consider interactions with transmission proposals such as the proposed HVDC cable from Beauly to Lewis alongside meeting resilience and local capacity requirements; as well as decarbonising emissions from diesel generation units. Alternative network considerations need to be explored alongside a role for local flexibility services." This allows this work to be

[3] SSEN Distribution, Scottish Islands Strategy, RIIO_ED2 Business Plan Annex 8.1

[4] SSEN Distribution, Scottish Islands Strategy, RIIO_ED2 Business Plan Annex 8.1

undertaken to determine the best whole system option for the Hebrides to be determined as there is greater information about local generation connection, the HVDC link from Lewis to mainland Scotland and the advancements in the procurement of flexibility.

SHEPD (The SSEN Scottish distribution licence area) operate the DEG units on the island under special licence conditions, the Medium Combustion Plant Directive and for Battery Point, a Pollution Prevention Control licence. Reduction in the use of DEG as a backup solution will assist with decarbonising the Hebrides.

2.5 Economic observations

There are already a number of wind generators connected to the networks in the Hebrides and it is noted that there is significant wind resource available as demonstrated by the 200 MW Stornoway windfarm which was successful in the 2022 Contract for Difference auction, and which will be connecting to the transmission network. Improved connection to the mainland will provide additional capacity (headroom) on the distribution network and is expected to enable additional generation to connect to the distribution network, assisting local community economic development.

3. OPTION DEVELOPMENT

3.1 Overview discussion

We have considered a number of options to improve the security of the existing connection arrangements to the Hebrides and ensure the system capacity is suitable for the predicted 2050 demand and generation profile. This has considered the future HVDC link, which will contribute to the security of supply to the islands. Specific considerations of the power system model are detailed in Section 3.2, and an overview of the options is given in Section 3.3.

3.2 Power system model

3.2.1 PSS/E model

Base models for the Loch Carnan and Stornoway distribution systems were provided by SSEN. In order to perform a whole system assessment, we have merged the models and the resulting model has been verified by SSEN. For option identification we have considered the summer minimum demand and the winter maximum demand in 2050 as agreed with SSEN [1].

SSEN provided the Dunvegan grid parameters, which were used in the analysis.

Where new cables, overhead line and transformers are required the models are taken from the existing PSS/E data, SSEN standards, typical manufacturers catalogues or past project experience . In option 17, a 60MVA, 132/33 kV transformer is assumed at the Harris substation.

3.2.2 Demand forecast

The demand forecast was taken from the Customer Transformation 2050 DFES. The Clachan load forecast was considered as per the revised Clachan load forecast by SSEN [6]. A summary of the 2023 load and generation is given in Table 3-1. The total DFES consumer transformation load demand forecast at Loch Carnan and Stornoway grids for the summer and winter scenarios are shown Figure 3-1 and Figure 3-2. The load power factors at each demand bus in future years are maintained as per existing load power factors.

Table 3-1 Load generation summary for summer minimum and winter_maximum scenarios

Load_Generation Summary for Summer_Min and Winter_Max in MW				
Islands	Existing Summer Min		Existing_Winter_Max	
	Load	Generation	Load	Generation
Loch Carnan	1.73	11.43	10.25	0
Stornoway	5.65	42.05	25.84	42.05

Figure 3-1 Load demand forecast for the 2050 summer scenario

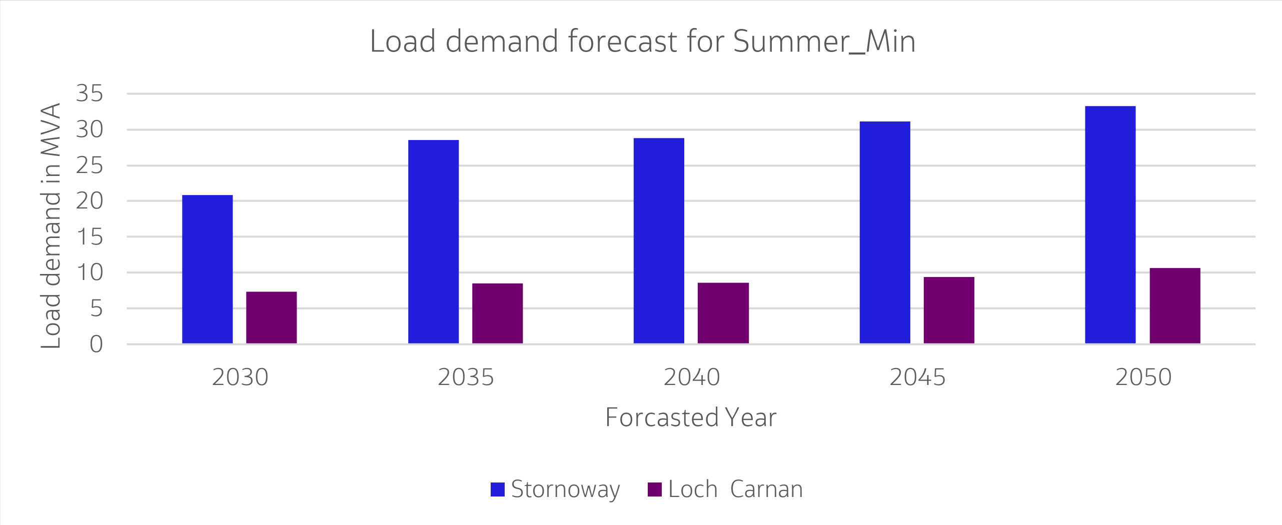
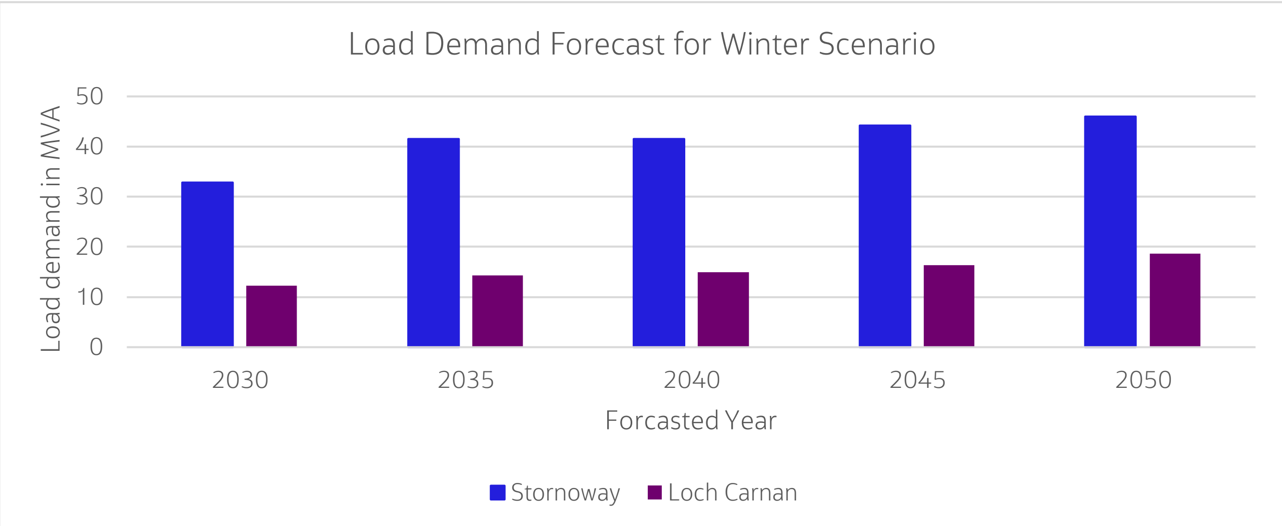


Figure 3-2 Load demand forecast for the 2050 winter scenario



3.2.3 Generation forecast

The Customer Transformation DFES provided peak DER forecasts to 2050 which was used in the model. The maximum generation over 48 intervals was considered. The total DFES Consumer Transformation generation forecast at Loch Carnan and Stornoway grids for both summer and winter scenarios are shown in the Figure 3-3 and Figure 3-4 and the maximum and minimum reactive power limit for inverter-based generation was considered as +/- 0.33xPmax [4].

Figure 3-3 Generation demand forecast for 2050 summer scenario

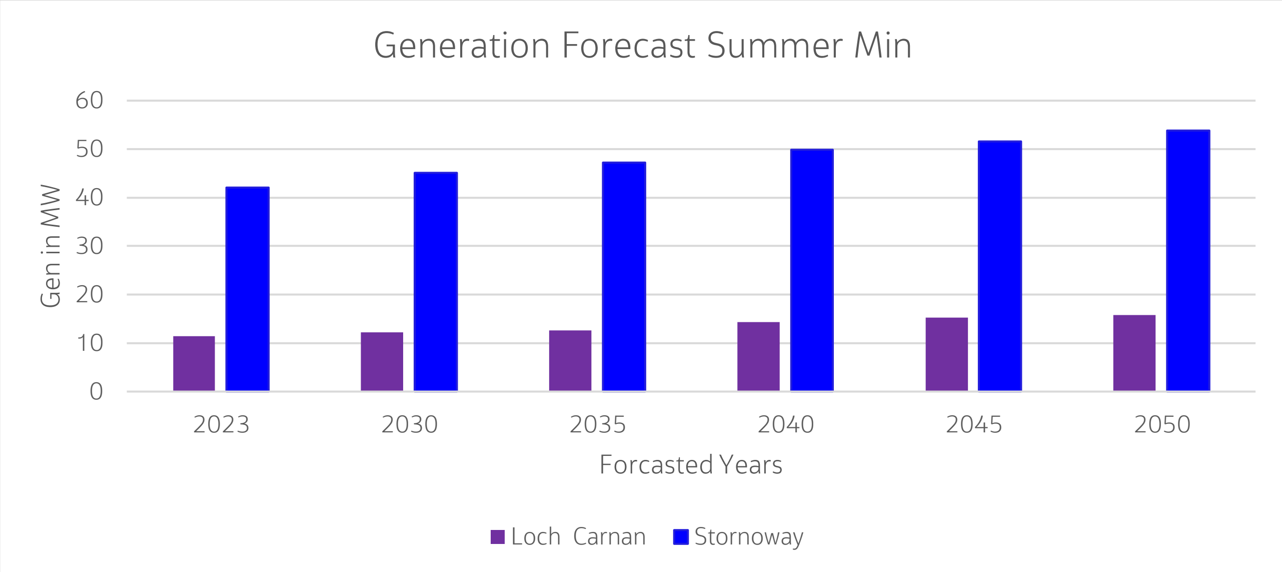
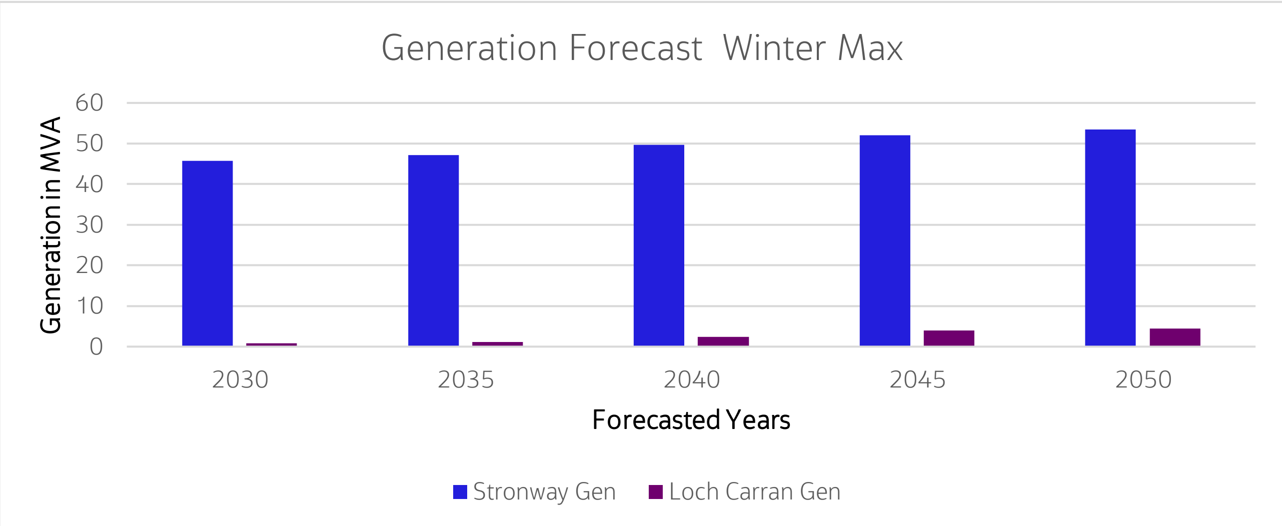


Figure 3-4 Generation demand forecast for 2050 winter scenario



There are some large generators which will be connected to the transmission network on the Isle of Lewis and Harris. From the perspective of this study, they can be considered to supply the distribution network in the same way as the planned HVDC link between Stornoway to Dundonnell on the mainland as detailed in Section 3.2.7.1.

3.2.4 Flexibility provision

When considering demand and generation increases SSEN are considering the use of the procurement of flexibility services to prevent or defer reinforcement. The load and generation growth on the Hebrides is such that flexibility services are unlikely to be able to prevent the need for reinforcement. We have quantified the amount of flexibility that would be needed for each option instead of reinforcement.

3.2.5 Design limits

Design limits considered in the studies, in line with SSEN standards, were:

- **Voltage variations**
  - Normal Running Arrangements:
    0.940 – 1.012pu for networks with 33kV/LV connections
    0.940 – 1.03pu for 33kV networks
  - N-1 Conditions:
    0.9 – 1.012pu for networks with 33kV/LV connections
    0.9 – 1.03pu for 33kV networks
- 100% of the equipment's rating

Transformer nominal taps are considered for the analysis.

3.2.6 Fault Contribution

PSS/E models included a representation of the fault infeed at the 132 kV Ardmore substation (Skye).

SSEN provided the machine impedance values for different generation types which were used in the short circuit studies, as shown in Table 3-2.

Table 3-2 Machine Impedance values for various generation types

Type	PV	Storage	Wind
R Source (pu)	0.05	0.05	0.005
X Source (pu)	1	1	0.24
RTran (pu)	0.05	0.05	0.002
XTran (pu)	0.5	0.5	0.06
Positive R (pu)	0.05	0.05	0.005
Subtransient X (pu)	1	1	0.24
Transient X (pu)	1	1	0.24
Synchronous X (pu)	1	1	0.24
Negative R (pu)	0.05	0.05	0.005
Negative X (pu)	1	1	0.24
Zero R (pu)	0.05	0.05	0.005
Zero X (pu)	1	1	0.24
Grounding Z units	P.U. (Per Unit)	P.U. (Per Unit)	P.U. (Per Unit)
Grounding R	0	0	0
Grounding X	0	0	0
Wind machine Control Mode	Not a wind machine	Not a wind machine	Not a wind machine
Wind Machine Power factor	1	1	1

3.2.7 Other Considerations

3.2.7.1 HVDC link from Isle of Lewis to mainland Scotland

To represent the future HVDC link we have assumed:

- A 35 MW, ±11.9 MVAr power infeed at 33kV Harris substation and
- A 10kA symmetrical short circuit contribution with an X/R of 15 at Harris 33 kV substation.

3.2.7.2 Planned reinforcement on Skye

Around 2027 it is expected that the transmission network on Skye will be reinforced with a double circuit to a new GSP Edinbane, Southeast of Dunvegan. From Edinbane there will be a new single circuit wood pole Trident OHL to Dunvegan and Ardmore. It should be noted therefore that an outage between Edinbane and Dunvegan would cause loss of the connection from Skye to any subsea cable between Skye and the Western Isles. The indicative location of Edinbane substation is noted in

Figure 3-5. However, the supply to the Hebrides will be maintained from the HVDC link feeding Harris substation.

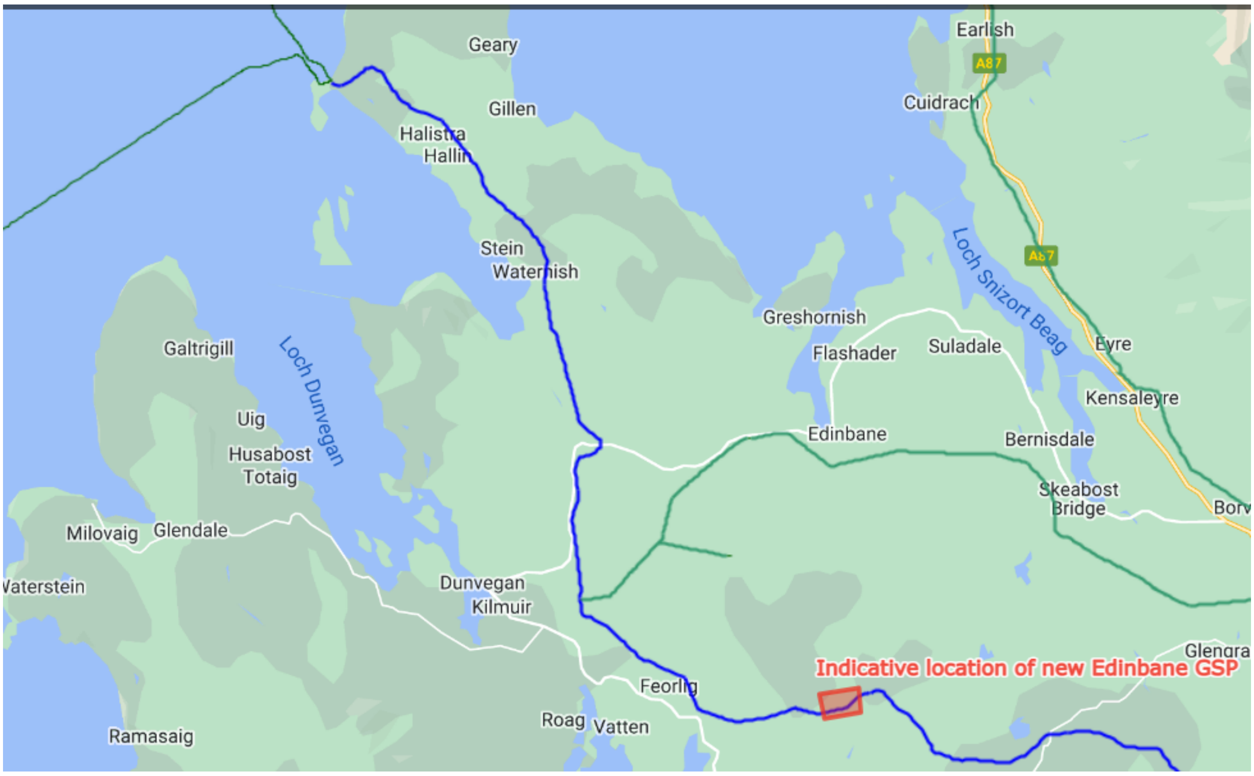


Figure 3-5 Indicative location of Edinbane substation[5]

[5] Figure provided by SSEN

3.2.7.3 Subsea cable options

The SHEPD subsea cable team have undertaken offshore desktop studies which have identified possible landing sites for subsea cables on Skye, Uist and Harris as detailed in Table 3-3.

Table 3-3 Subsea cable landing points

Location	Comment
Skye	Ardmore – 2 or 3 suitable landing points, multiple cables, minimal onshore to Ardmore Grid
	Dunvegan – 3 landing locations identified around Loch Pooltiel to the West, all have challenges with charted anchorages. Likely that there is only one suitable onshore route from Dunvegan to Loch Pooltiel, circa 17km from landing point to Dunvegan substation
South Uist	Loch Carnan - likely only one cable can land in Glomar Bay. It may be possible to obtain a second landing if the existing cable shore end is removed
North Uist	Lochmaddy – one suitable cable route for landing of one cable, circa 16km onshore to connect to Clachan substation
Harris	2 possible landing locations around Rodel and St Clements, marine and onshore challenges including the need for the new cables to cross each other, if both locations are used Require significant onshore OHL construction to Harris Grid which may only allow a single circuit

3.3 Options for supply / evacuation to / from the Hebrides

3.3.1 Overview of Options

The 17 options (plus 15 sub options, totalling 32 options) considered are summarised Table 3-4. Overview diagrams of each option are provided in the following sections.

Table 3-4 Summary of cable & OHL connection options

Option	New/Existing Cable/OHL	Cable/OHL from	Cable/OHL to	Length km	
				Onshore (OHL)	Offshore cable
Option-1	Existing Subsea cable 95mm^2	Ardmore	Loch Carnan	-	47
Option-2	New Subsea cable 95mm^2	Ardmore	Loch Carnan	-	47
Option-3	Summer Min New Subsea cable185mm^2 Winter Max New Subsea cable185mm^2	Ardmore	Loch Carnan	-	47
Option-4	Existing Subsea cable 95mm^2	Ardmore	Loch Carnan	-	47
	New Subsea cable 95mm^2	Ardmore	Loch Carnan	-	47
Option-5	Existing Subsea cable 95mm^2	Ardmore	Loch Carnan	-	47
	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 185mm^2	Ardmore	Loch Carnan	-	47
Option-6	Existing 95mm^2	Ardmore	Loch Carnan	-	47
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 185mm^2, 129mm^2 OHL	Ardmore	Lochmaddy		33
		Lochmaddy	Clachan	16	
Option-7	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
Option -8	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
	Existing Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3

Option	New/Existing Cable/OHL	Cable/OHL from	Cable/OHL to	Length km	
				Onshore (OHL)	Offshore cable
	New Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3
Option-9	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
	New Subsea cable 185 mm^2(132 kV)	Admore	Harris End		33
	New 175mm^2 OHL Line(132 kV)	Harris End	Harris substation	5.6	
Option-10	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Ardmore	Lochmaddy		33
		Lochmaddy	Clachan	16	
Option-11	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Ardmore	Lochmaddy		33
		Lochmaddy	Clachan	16	
	Existing Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3
	New Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3
Option-12	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
		Ardmore	Lochmaddy		33

Option	New/Existing Cable/OHL	Cable/OHL from	Cable/OHL to	Length km	
				Onshore (OHL)	Offshore cable
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Lochmaddy	Clachan	16	
	New Subsea cable 185 mm^2(132 kV)	Admore	Harris End		33
	New 175mm^2 OHL Line(132 kV)	Harris End	Harris substation	5.6	
Option-13	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Dunvegan	Loch Carnan	16.5	
					38.5
	Summer Min New Subsea cable 185mm^2, 129mm2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Ardmore	Lochmaddy		33
		Lochmaddy	Clachan	16	
Option-14	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Dunvegan	Loch Carnan	16.5	
					38.5
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Ardmore	Lochmaddy		33
		Lochmaddy	Clachan	16	
	Existing Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3
	New Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3
Option-15	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Dunvegan	Loch Carnan	16.5	
					38.5

Option	New/Existing Cable/OHL	Cable/OHL from	Cable/OHL to	Length km	
				Onshore (OHL)	Offshore cable
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Ardmore	Lochmaddy		33
		Lochmaddy	Clachan	16	
	New Subsea cable 185 mm^2(132 kV)	Admore	Harris End		33
	New 175mm^2 OHL Line(132 kV)	Harris End	Harris substation	5.6	
Option-16	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Ardmore	Lochmaddy		33
		Lochmaddy	Clachan	16	
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Ardmore	Lochmaddy		33
		Lochmaddy	Clachan	16	
Option-11	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Dunvegan	Loch Carnan	16.5	
					38.5
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Harris	Lochmaddy	-	25
				16	
		Lochmaddy	Clachan	16	
Option-18	Winter Max New Subsea cable 300mm^2, 150mm OHL	Dunvegan	Loch Carnan	16.5 (15km-overground (OHTL),1.5km-underground)	38.5
Option-19	Winter Max New Subsea cable 300mm^2, 150mm OHL	Dunvegan	Loch Carnan	16.5(16.5km-	38.5

Option	New/Existing Cable/OHL	Cable/OHL from	Cable/OHL to	Length km	
				Onshore (OHL)	Offshore cable
				Undergroun d)	
	Winter Max New Subsea cable 300mm^2, 150mm OHL	Harris	Lochmaddy	-	25
				16	
		Lochmaddy	Clachan	16	
	Existing Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3
	New Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3
Option-20	Winter Max New Subsea cable 300mm^2, 150mm OHL	Dunvegan	Loch Carnan	16.5	38.5
	Winter Max New Subsea cable 300mm^2, 150mm OHL	Harris	Lochmaddy	-	25
				16	
		Lochmaddy	Clachan	16	
	New Subsea cable 185 mm^2(132 kV)	Admore	Harris End		33
	New 175mm^2 OHL Line(132 kV)	Harris End	Harris substation	5.6	
Option-21	Existing Subsea cable 95mm^2	Ardmore	Loch Carnan	-	47
	Summer Min New Subsea cable 185mm^2, 129mm2 OHL Winter Max New Subsea cable 185mm^2, 129mm2 OHL	Dunvegan	Loch Carnan	16.5	38.5

Option	New/Existing Cable/OHL	Cable/OHL from	Cable/OHL to	Length km	
				Onshore (OHL)	Offshore cable
Option-22	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	

Option	New/Existing Cable/OHL	Cable/OHL from	Cable/OHL to	Length km	
				Onshore (OHL)	Offshore cable
	Summer Min New Subsea cable 185mm2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Dunvegan	Loch Carnan	16.5	
Option-23	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
	Summer Min New Subsea cable 185mm2, 129mm^2 OHL Winter Max New Subsea cable 300mm^{2,} 150mm OHL	Dunvegan	Loch Carnan	16.5	
					38.5
	Existing Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3
	New Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3
Option-24	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Dunvegan	Loch Carnan	16.5	
					38.5
	New Subsea cable 185 mm^2(132 kV)	Admore	Harris End		33
	New 175mm^2 OHL Line(132 kV)	Harris End	Harris substation	5.6	
Option-25	Existing Subsea cable 95mm^2	Ardmore	Loch Carnan	-	47

Option	New/Existing Cable/OHL	Cable/OHL from	Cable/OHL to	Length km	
				Onshore (OHL)	Offshore cable
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 185mm^2, 129mm^2 OHL	Harris	Lochmaddy	- 16	25
		Lochmaddy	Clachan	16	
Option-26	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Harris	Lochmaddy	- 6	25
		Lochmaddy	Clachan	16	
Option-27	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Dunvegan	Loch Carnan	16.5	 38.5
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Harris	Lochmaddy	- 16	25
		Lochmaddy	Clachan	16	
Option-28	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL	Dunvegan	Loch Carnan	16.5	
					38.5

Option	New/Existing Cable/OHL	Cable/OHL from	Cable/OHL to	Length km	
				Onshore (OHL)	Offshore cable
	Winter Max New Subsea cable 300mm^2, 150mm OHL				
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Harris	Lochmaddy	-	25
				16	
		Lochmaddy	Clachan	16	
	Existing Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3
	Existing Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3
Option-29	Summer Min New Subsea cable 185mm^2 Winter Max New Subsea cable 300mm^2	Ardmore	Loch Carnan	-	47
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^2, 150mm OHL	Dunvegan	Loch Carnan	16.5	
					38.5
	Summer Min New Subsea cable 185mm^2, 129mm^2 OHL Winter Max New Subsea cable 300mm^{2,} 150mm OHL	Harris	Lochmaddy	-	25
				16	
		Lochmaddy	Clachan	16	
	New Subsea cable 185 mm^2(132 kV)	Admore	Harris End		33
	New 175mm^2 OHL Line(132 kV)	Harris End	Harris substation	5.6	
Option-30	Existing Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3
Option-31	Existing Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3
	New Subsea cable 500mm^2	Ardmore	Harris	5.6	32.3
Option-32	New Subsea cable 185 mm^2(132 kV)	Admore	Harris End		33

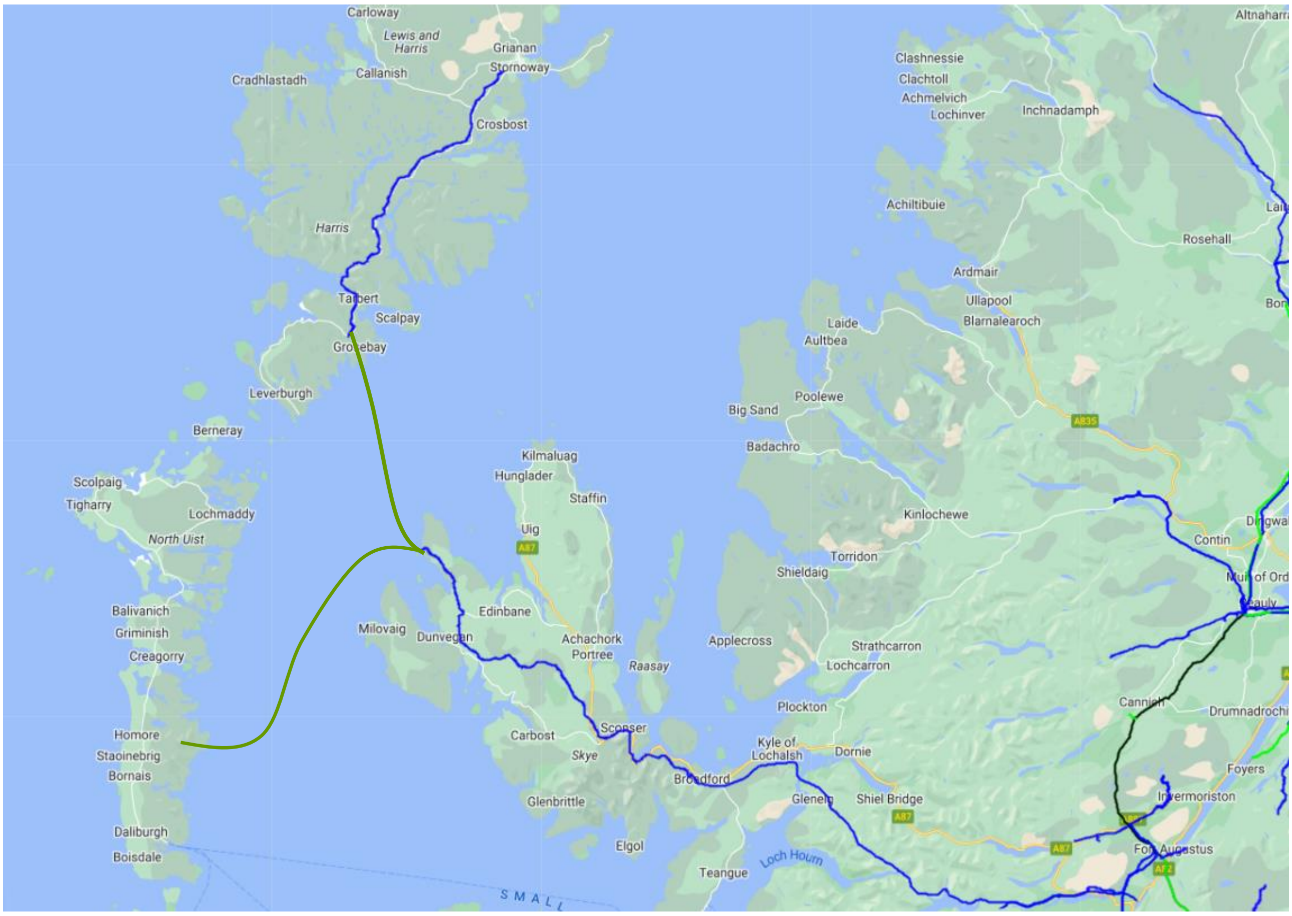
Option	New/Existing Cable/OHL	Cable/OHL from	Cable/OHL to	Length km	
				Onshore (OHL)	Offshore cable
	New 175mm^2 OHL Line(132 kV)	Harris End	Harris substation	5.6	

3.3.2 Option 1: Retain existing Ardmore – Loch Carnan subsea cable

Option 1, illustrated in Figure 3-6, is the retention of the existing 47 km, 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) to either repair or replace it on failure.

The green solid lines are the existing 33 kV subsea cable (rated capacity-14MVA) from Ardmore to Loch Carnan (South Uist) and the recently replaced 33 kV cable between Ardmore and Harris

Figure 3-6 Overview of connections from Skye to the Hebrides (Option 1)



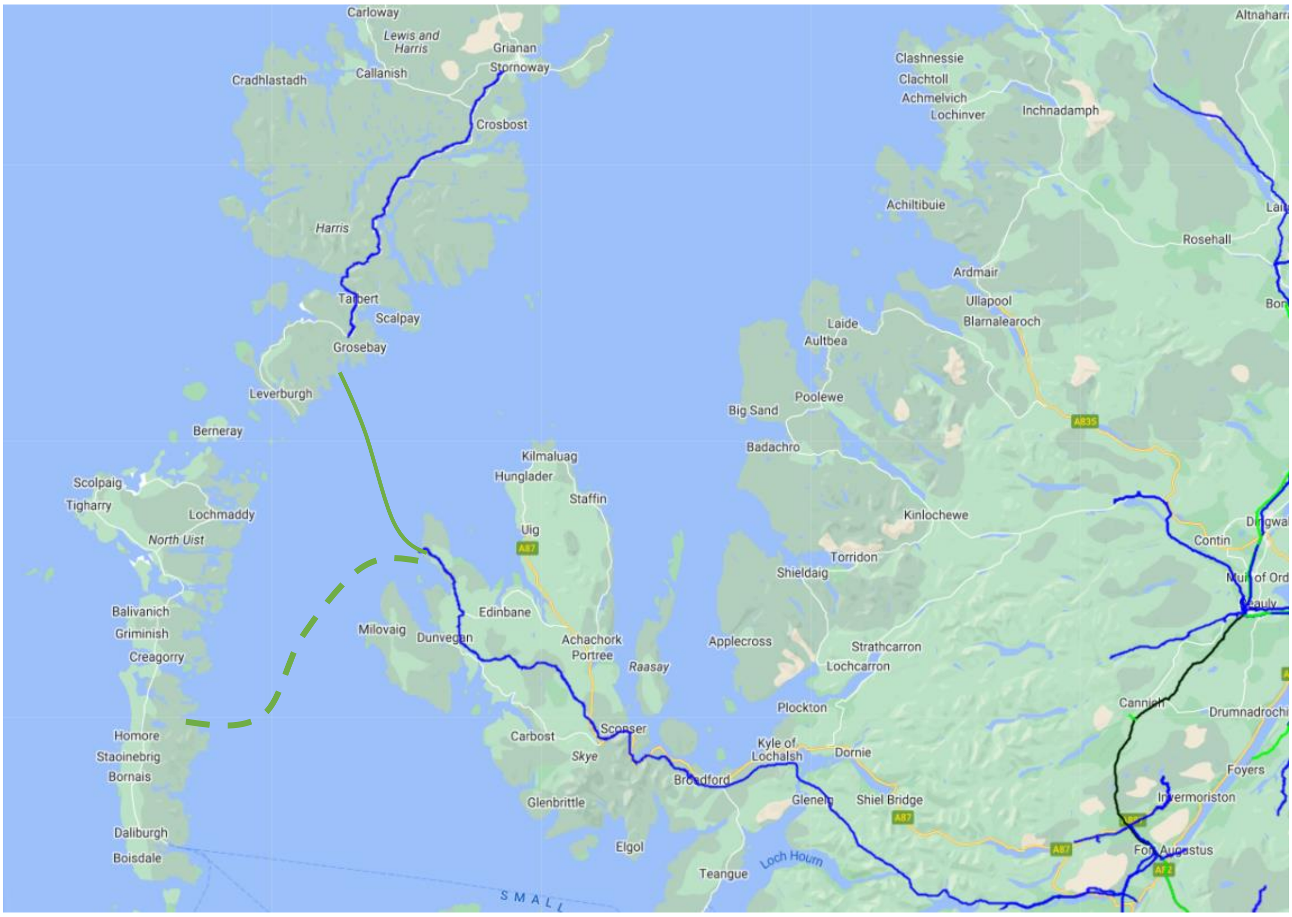
3.3.3 Option 2: Replace existing Ardmore – Loch Carnan subsea cable with same size cable

Option 2, illustrated in Figure 3-7, is the decommission of the existing 47km, 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A new 95mm^2 (capacity: -16MVA) subsea cable using a similar route between Ardmore and Loch Carnan (South Uist)

The new circuit is 33 kV and shown with a dashed green line. The green solid line is the existing Ardmore to Harris cable.

Figure 3-7 Overview of connections from Skye to the Hebrides (Option 2)



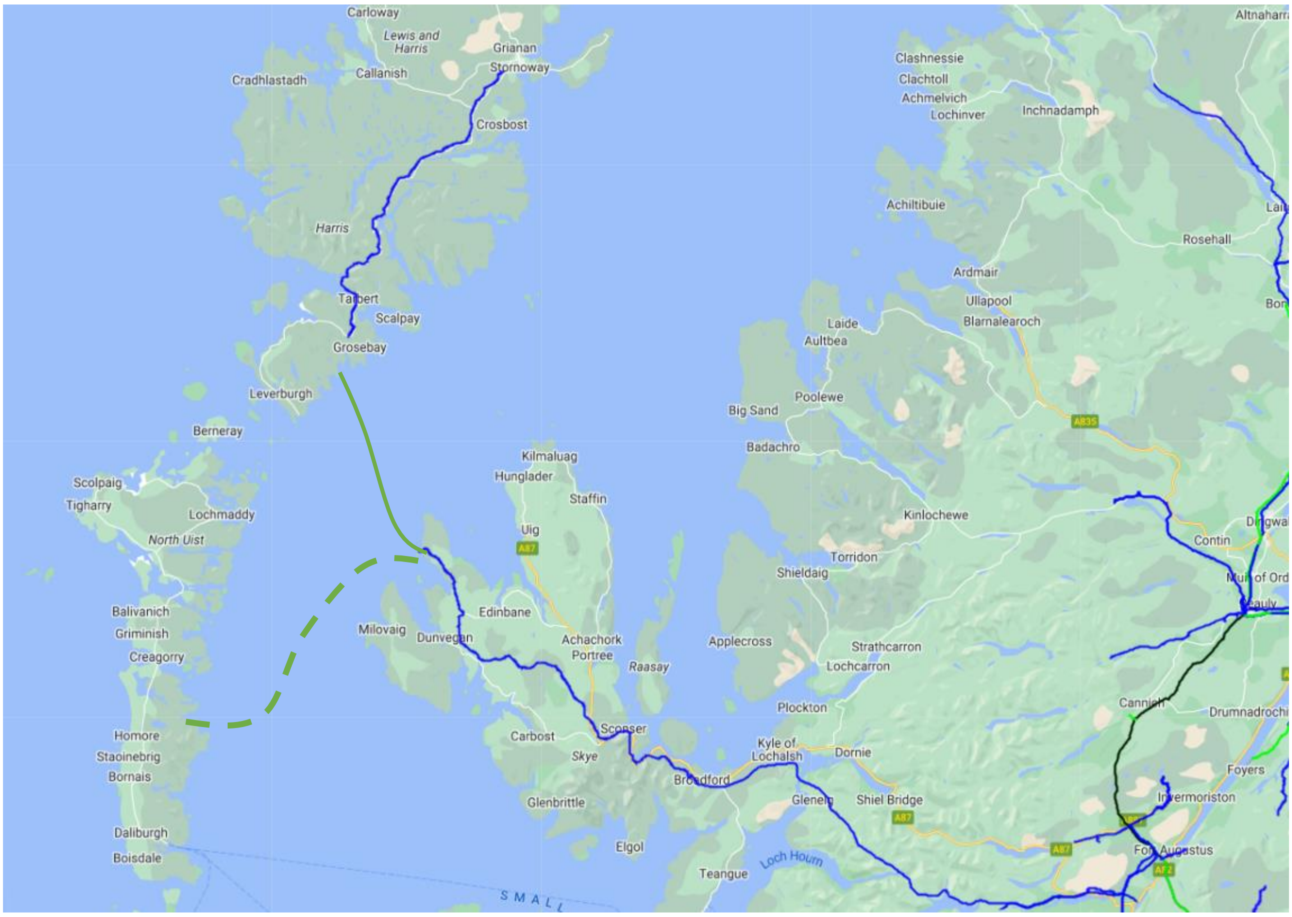
3.3.4 Option 3: Replace existing Ardmore – Loch Carnan subsea cable with larger cable

Option 3, illustrated in Figure 3-8, is the decommission of the existing 47km, 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A larger 185mm^2 (capacity:-21.94MVA as per SSEN) subsea cable using a similar route between Ardmore and Loch Carnan (South Uist)

The new circuit is 33 kV and shown with a dashed green line. The green solid line is the existing Ardmore – Harris cable.

Figure 3-8 Overview of connections from Skye to the Hebrides (Option 3)



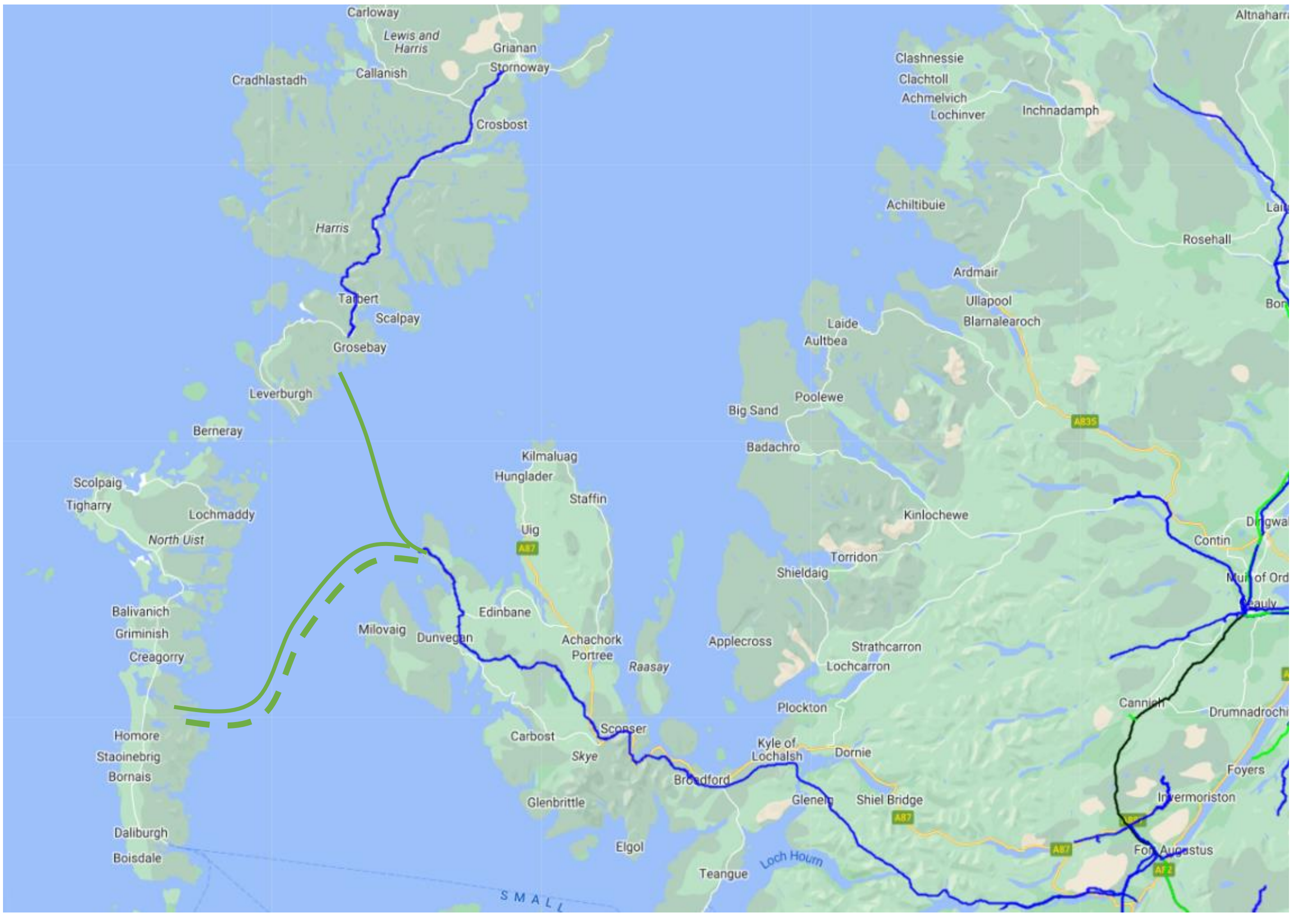
3.3.5 Option 4: Maintain existing Ardmore – Loch Carnan subsea cable and add a new cable of the same size

Option 4, illustrated in Figure 3-9 is the retention of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) and the addition of:

- A 47km, 95mm^2 subsea cable on a similar route between Ardmore and Loch Carnan (South Uist)

The new circuit is 33 kV and is shown with a dashed green line. The green solid lines are the existing Armore – Loch Carnan and Ardmore to Harris cables.

Figure 3-9 Overview of connections from Skye to the Hebrides (Option 4)



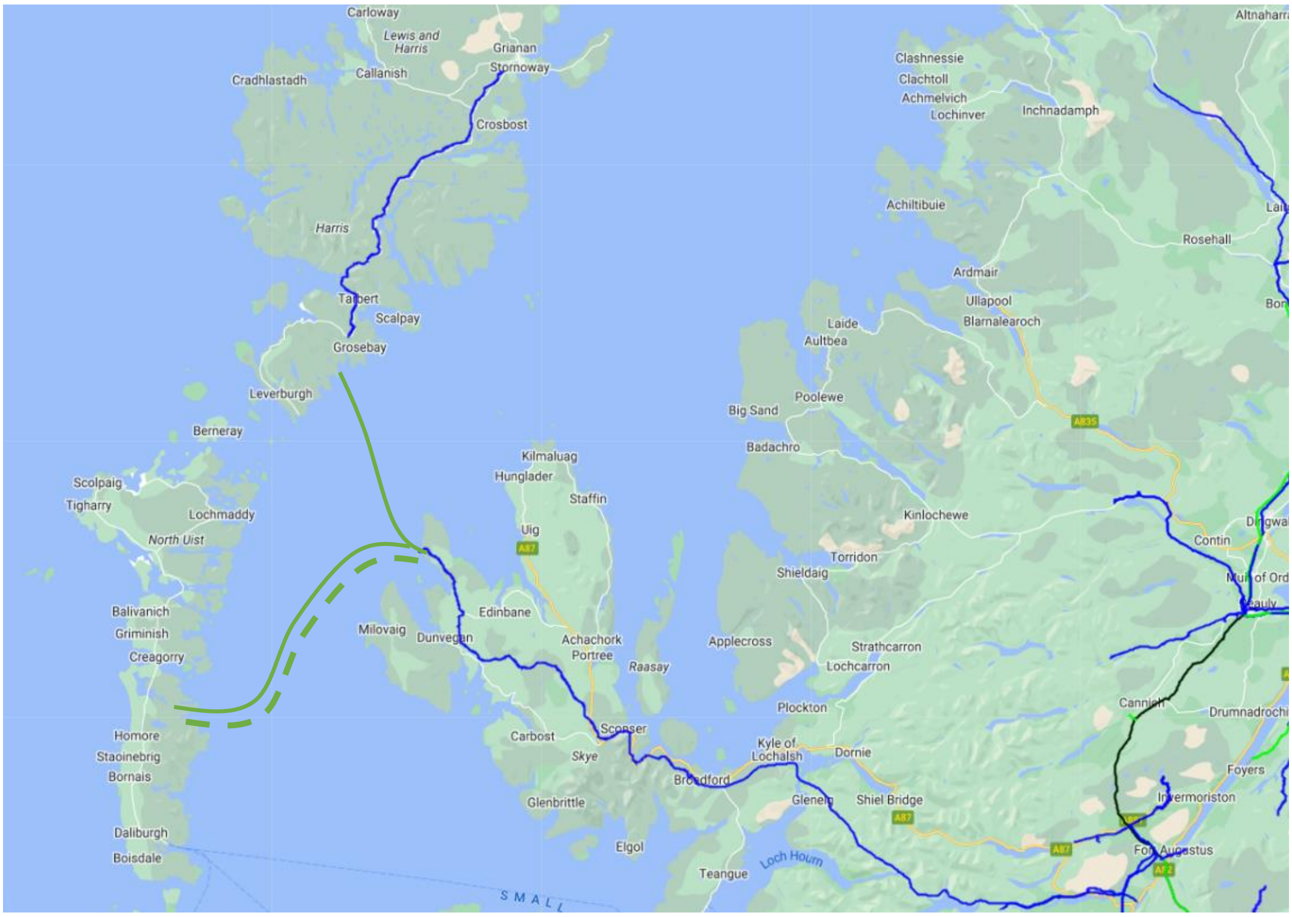
3.3.6 Option 5: Maintain existing Ardmore – Loch Carnan subsea cable and add a new larger size cable

Option 5, illustrated in Figure 3-10 is the retention of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) and the addition of:

- A 47km,185mm^2 subsea cable on the same route between Ardmore and Loch Carnan (South Uist)

The new circuit is 33 kV and is shown with a dashed green line. The green solid lines are the existing Ardmore to Loch Carnan and Ardmore – Harris cables.

Figure 3-10 Overview of connections from Skye to the Hebrides (Option 5)



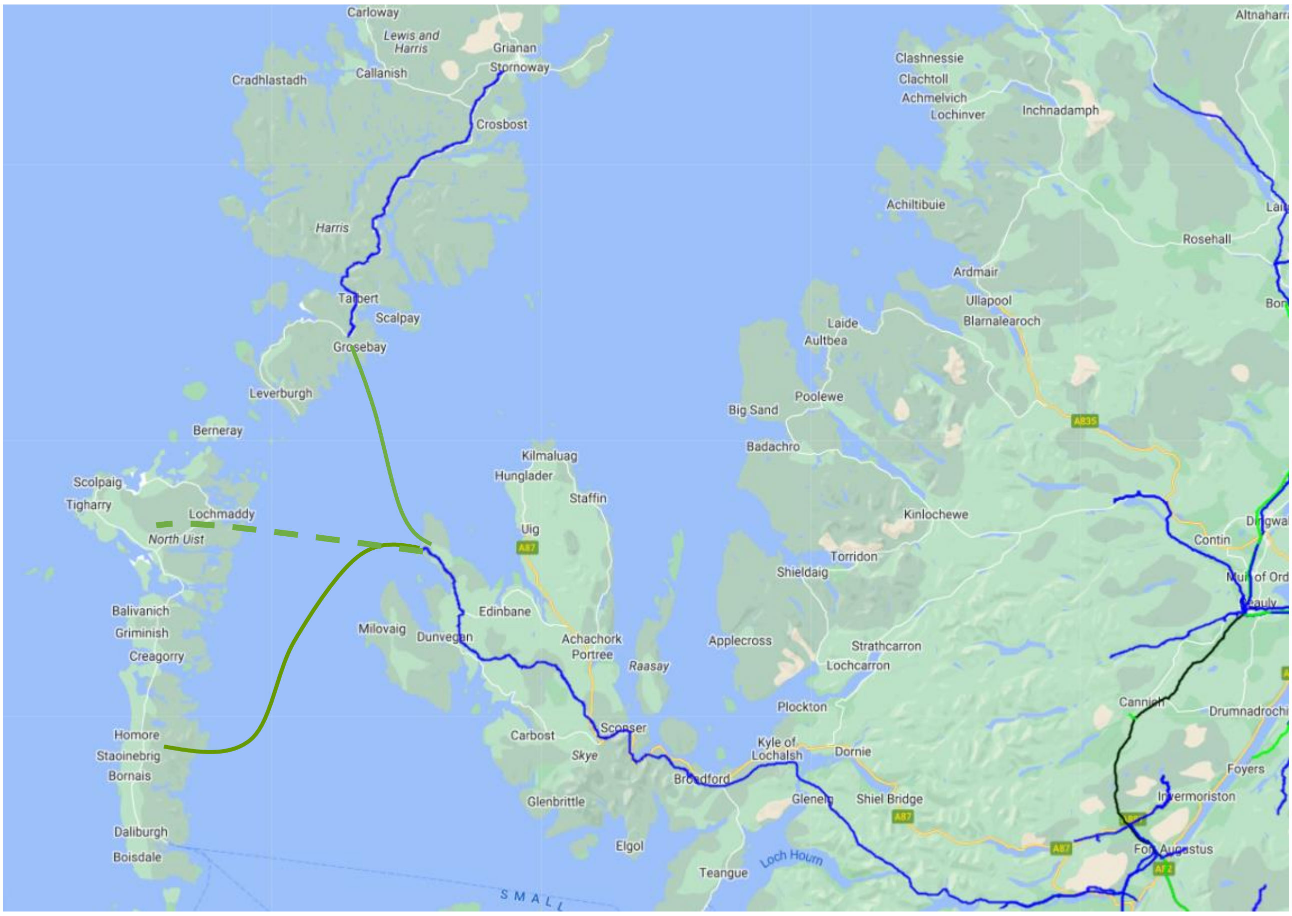
3.3.7 Option 6: Maintain existing Ardmore – Loch Carnan subsea cable and add a new larger size subsea cable from Ardmore – Lochmaddy with new OHL from Lochmaddy to Clachan

Option 6, illustrated in Figure 3-11**Figure 3-11**, is the retention of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) and the addition of:

- A 33km,185mm^2 subsea cable between Ardmore and Lochmaddy and a 16km overhead line between Lochmaddy and Clachan (North Uist)

The new circuit is 33 kV and is shown with a dashed green line. The green solid lines are the existing Ardmore – Loch Carnan and Ardmore – Harris cables.

Figure 3-11 Overview of connections from Skye to the Hebrides (Option 6)



3.3.8 Option 7: Replace Ardmore – Loch Carnan subsea cable with two larger cables

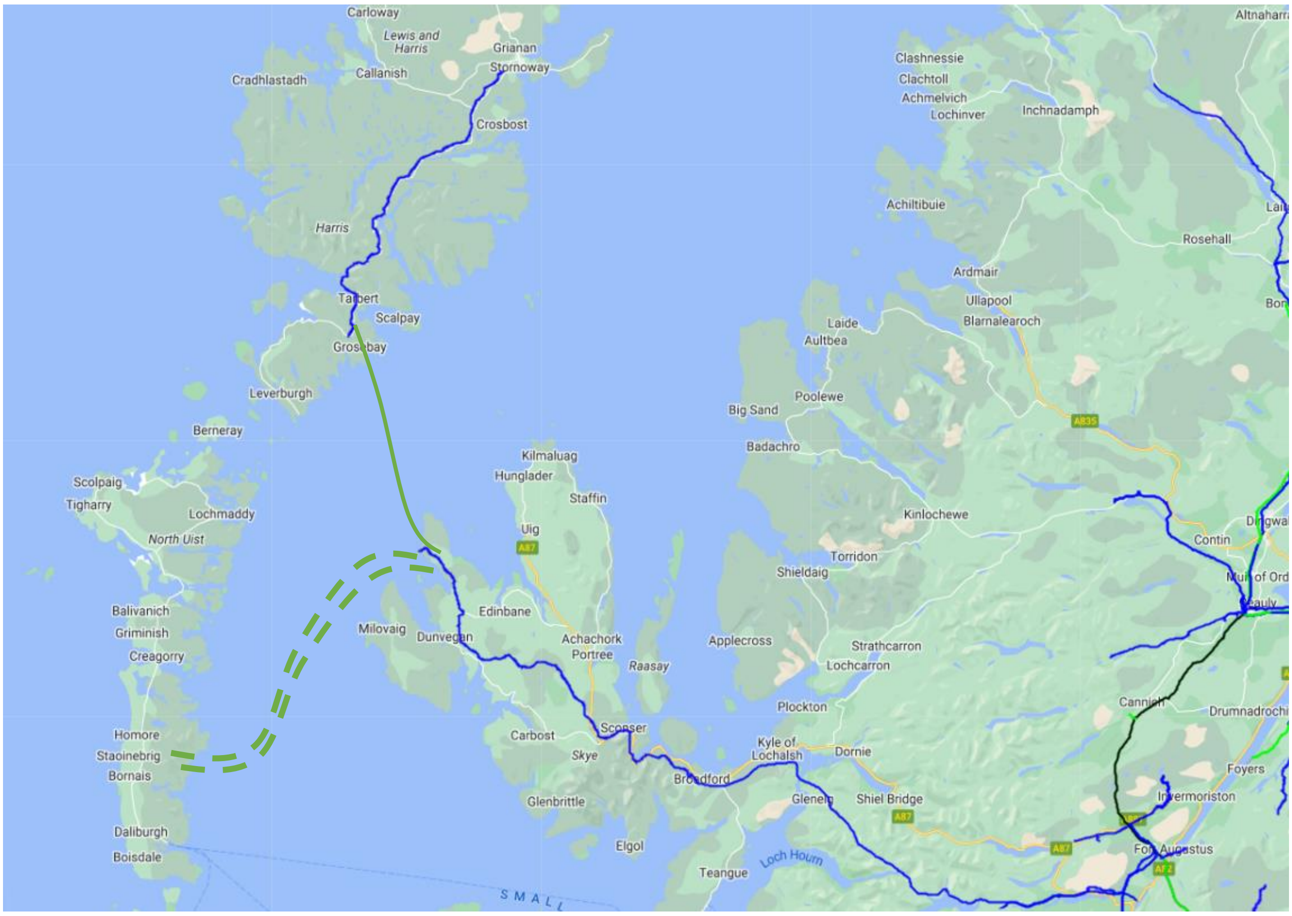
Option 7, illustrated in Figure 3-12, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- Two 47km, 300mm^2 subsea cables between Ardmore and Loch Carnan (South Uist)

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-12 Overview of connections from Skye to the Hebrides (Option 7)



3.3.9 Option 8: Replace Ardmore – Loch Carnan subsea cable with two larger cables plus new subsea/OHL from Admore to Harris

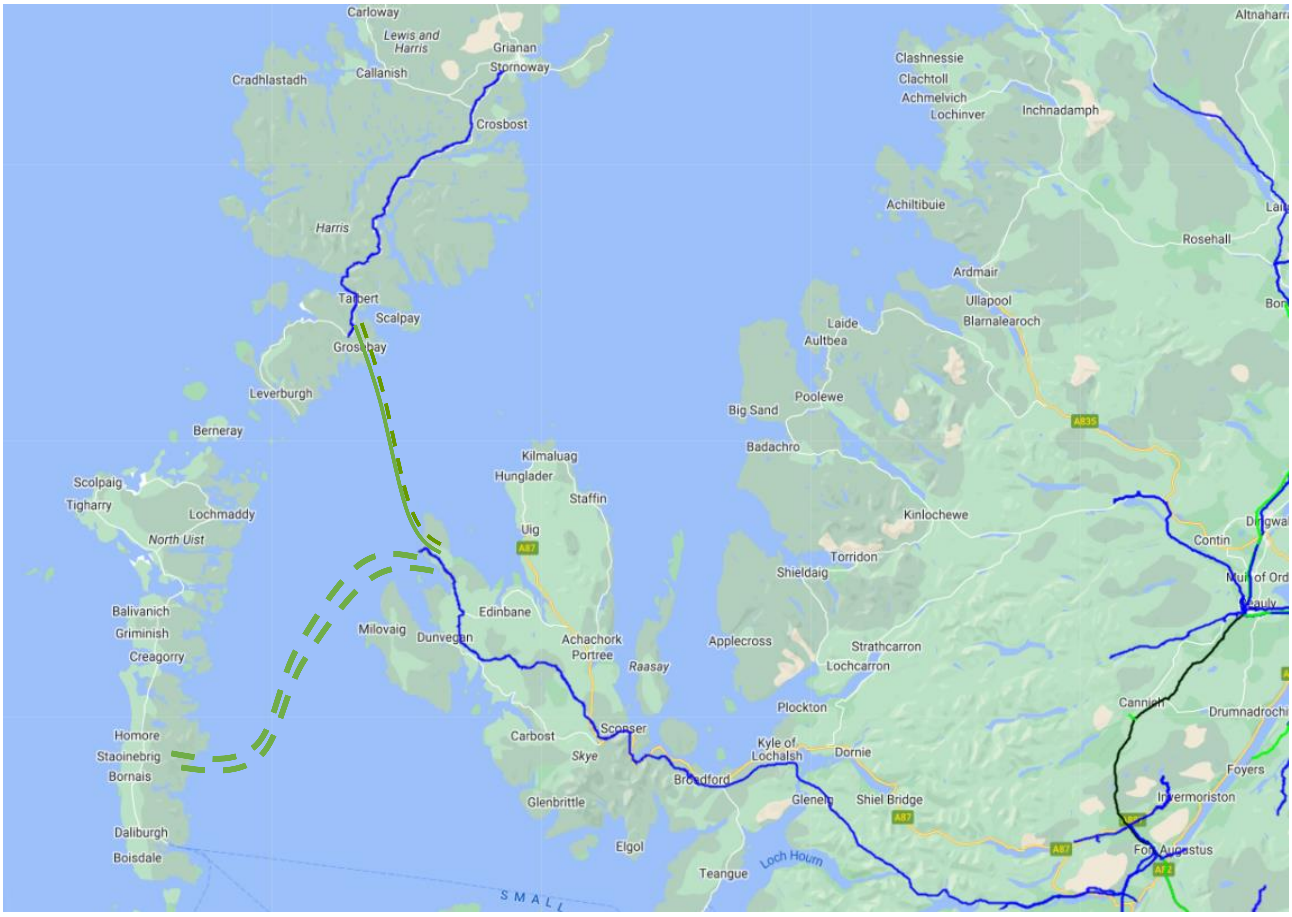
Option 8, illustrated in Figure 3-13, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- Two 47km, 300mm^2 subsea cables between Ardmore and Loch Carnan (South Uist)
- Retention of the existing 32.3km, 500 mm^2 subsea cable between Ardmore and Harris and the addition of a second 500 mm^2 subsea cable between Ardmore and Harris

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-13 Overview of connections from Skye to the Hebrides (Option 8)



3.3.10 Option 9: Replace Ardmore – Loch Carnan subsea cable with two larger cables plus new 132kV subsea/OHL from Admore to Harris

Option 9, illustrated in Figure 3-14, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- Two 47km, 300mm^2 subsea cables between Ardmore and Loch Carnan (South Uist)
- Retention of the existing 500 mm^2, 33 kV subsea cable between Ardmore and Harris and the addition of a 132 kV feeder comprising 33 km and 5.6 km of subsea cable and OHL between Ardmore and Harris

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-14 Overview of connections from Skye to the Hebrides (Option 9)

3.3.11 Option 10: Replace Ardmore – Loch Carnan subsea cable with larger cable and add a new larger subsea cable from Ardmore to Lochmaddy with new OHL from Lochmaddy – Clachan

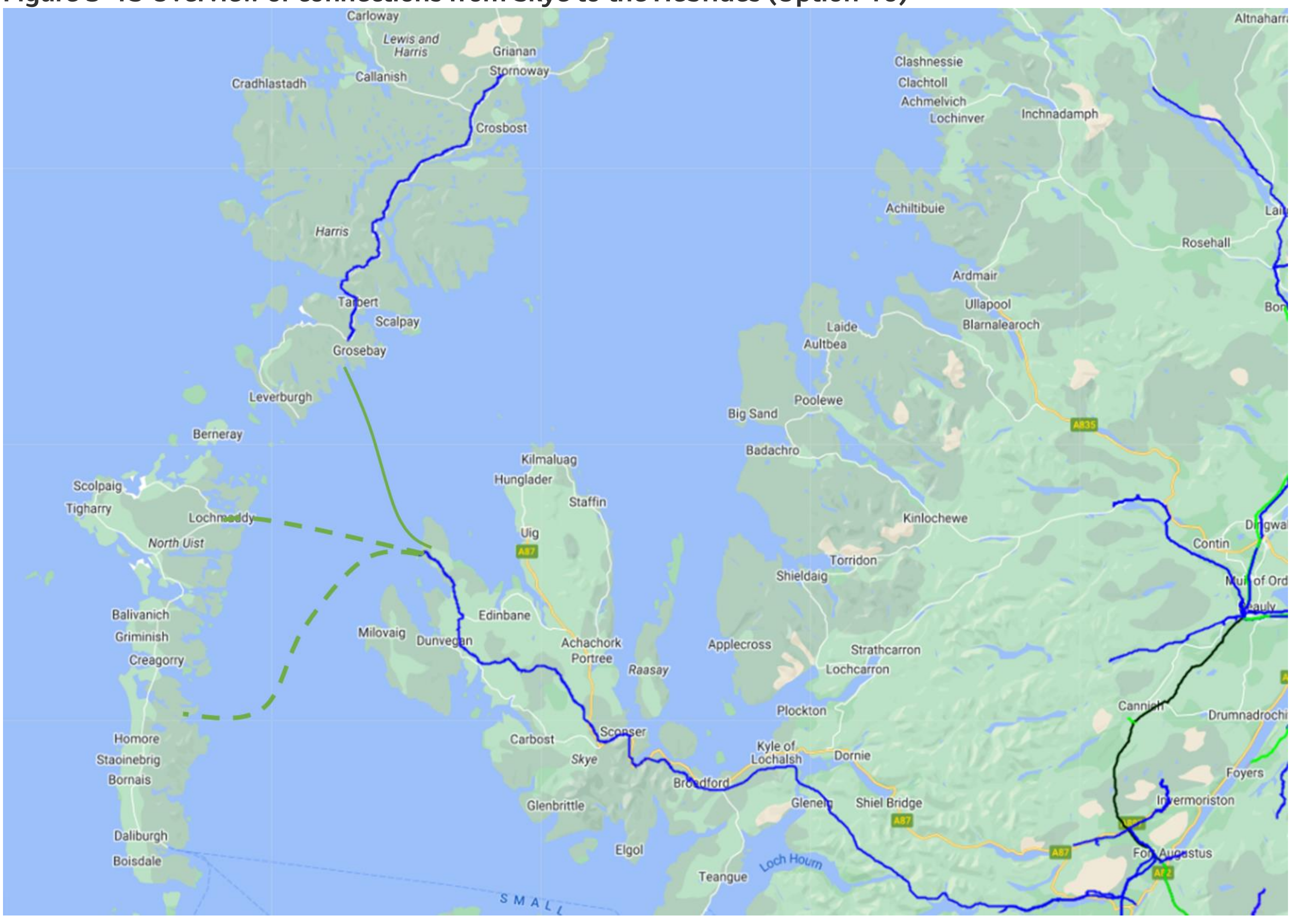
Option 10, illustrated in Figure 3-15, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 47km,300mm^2 subsea cable between Ardmore and Loch Carnan (South Uist)
- A 33km, 300mm^2 subsea cable between Ardmore and Lochmaddy and a 16km overhead line between Lochmaddy and Clachan (North Uist)

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-15 Overview of connections from Skye to the Hebrides (Option 10)



3.3.12 Option 11: Replace Ardmore – Loch Carnan subsea cable with larger cable and add a new larger subsea cable from Ardmore to Lochmaddy with new OHL from Lochmaddy – Clachan plus new subsea/OHL from Admore to Harris

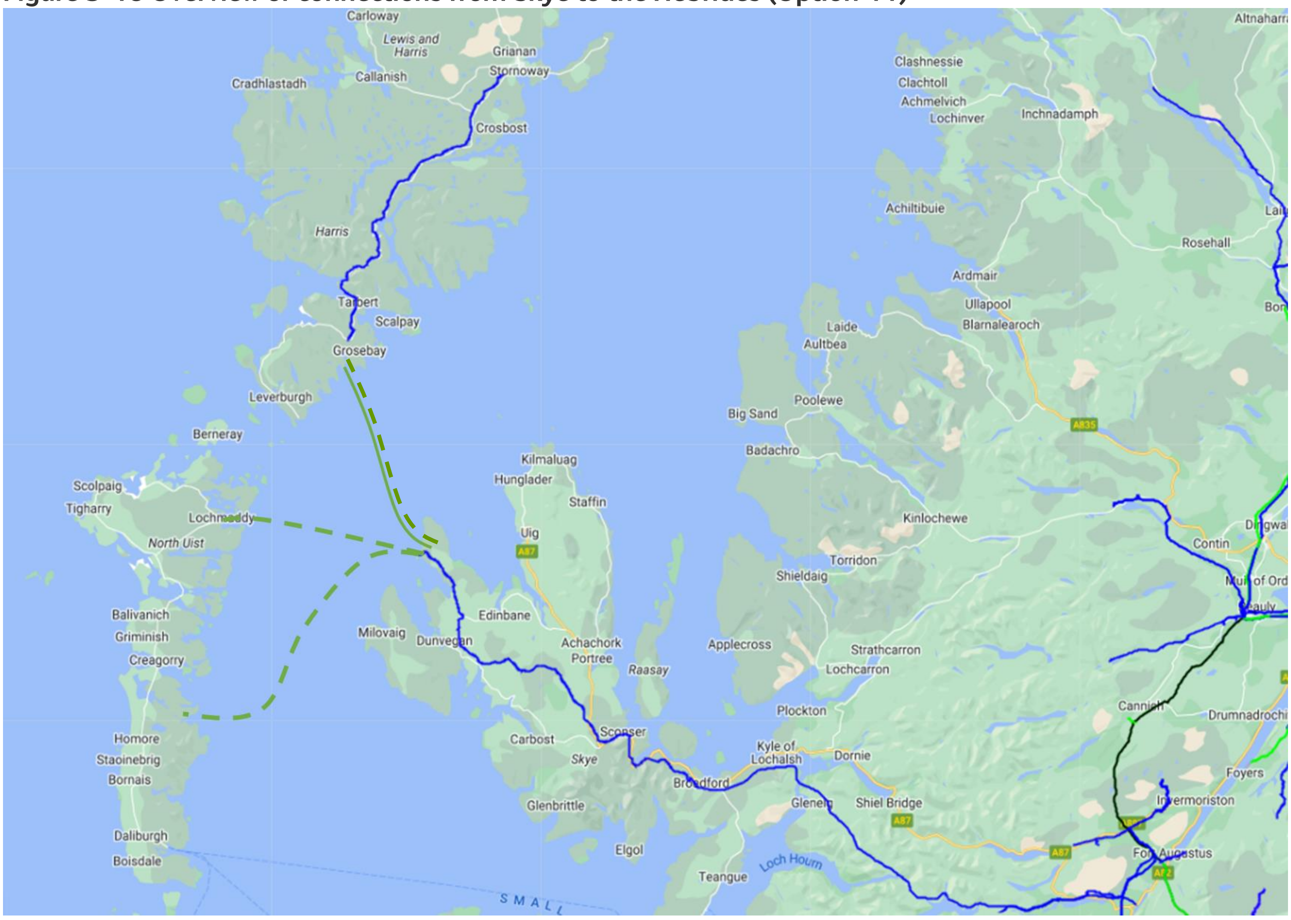
Option 11, illustrated in Figure 3-16. is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 47km,300mm^2 subsea cable between Ardmore and Loch Carnan (South Uist)
- A 33km, 300mm^2 subsea cable between Ardmore and Lochmaddy and a 16km overhead line between Lochmaddy and Clachan (North Uist)
- Retention of the existing 32.3km, 500 mm^2 subsea cable between Ardmore and Harris and the addition of a second 500 mm^2 subsea cable between Ardmore and Harris

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-16 Overview of connections from Skye to the Hebrides (Option 11)



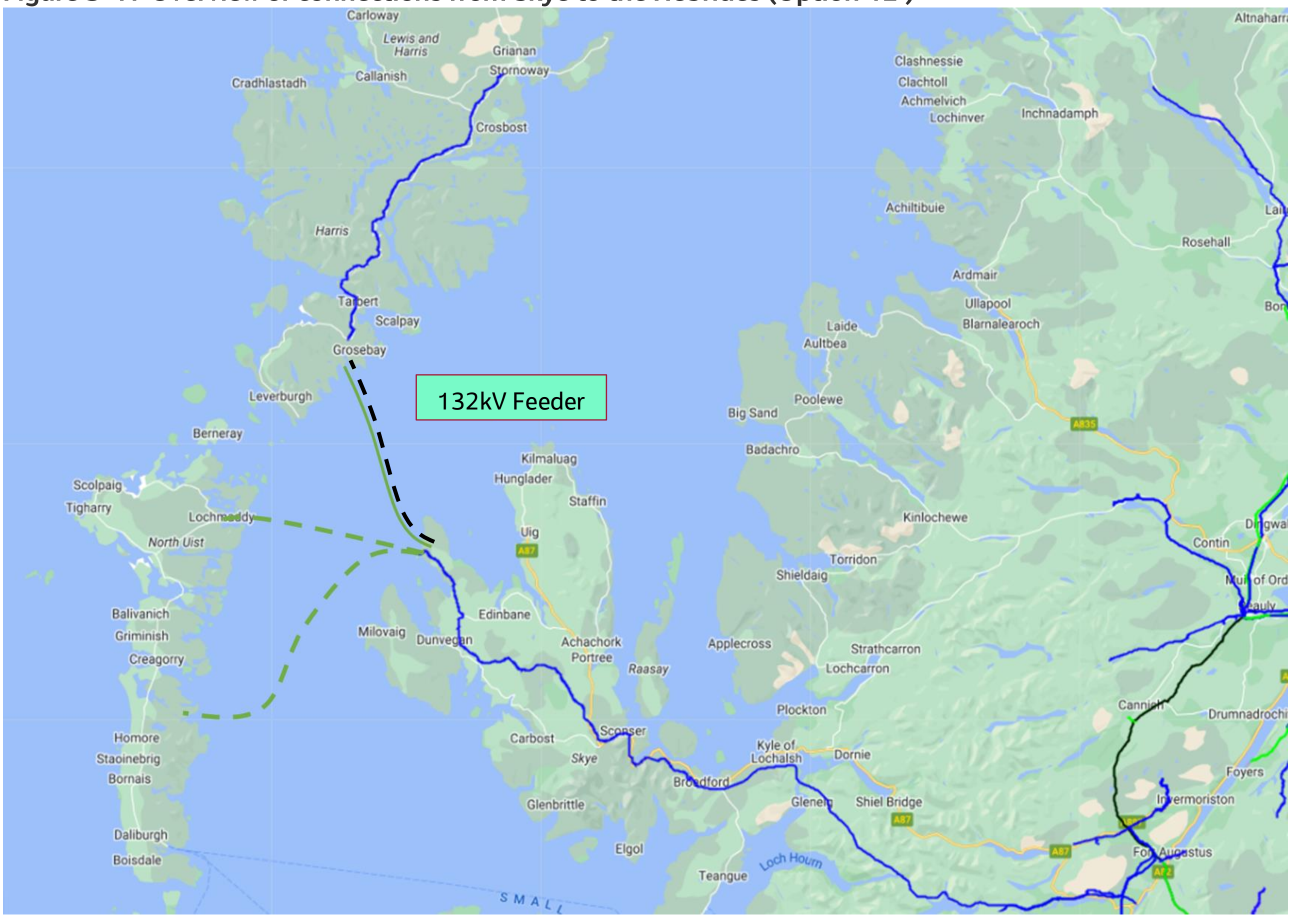
3.3.13 Option 12 : Replace Ardmore – Loch Carnan subsea cable with larger cable and add a new larger subsea cable from Ardmore to Lochmaddy with new OHL from Lochmaddy – Clachan plus new 132kV subsea/OHL from Admore to Harris

Option 12, illustrated in Figure 3-17, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 47km,300mm^2 subsea cable between Ardmore and Loch Carnan (South Uist)
- A 33km, 300mm^2 subsea cable between Ardmore and Lochmaddy and a 16km overhead line between Lochmaddy and Clachan (North Uist)
- Retention of the existing 500 mm^2, 33 kV subsea cable between Ardmore and Harris and the addition of a 132 kV feeder comprising 33 km and 5.6 km of subsea cable and OHL between Ardmore and Harris

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris. Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-17 Overview of connections from Skye to the Hebrides (Option 12)



3.3.14 Option 13: Remove Ardmore – Loch Carnan subsea cable and replace with Dunvegan – Loch Carnan OHL/subsea cable and Ardmore – Lochmaddy subsea cable with new OHL from Lochmaddy to Clachan

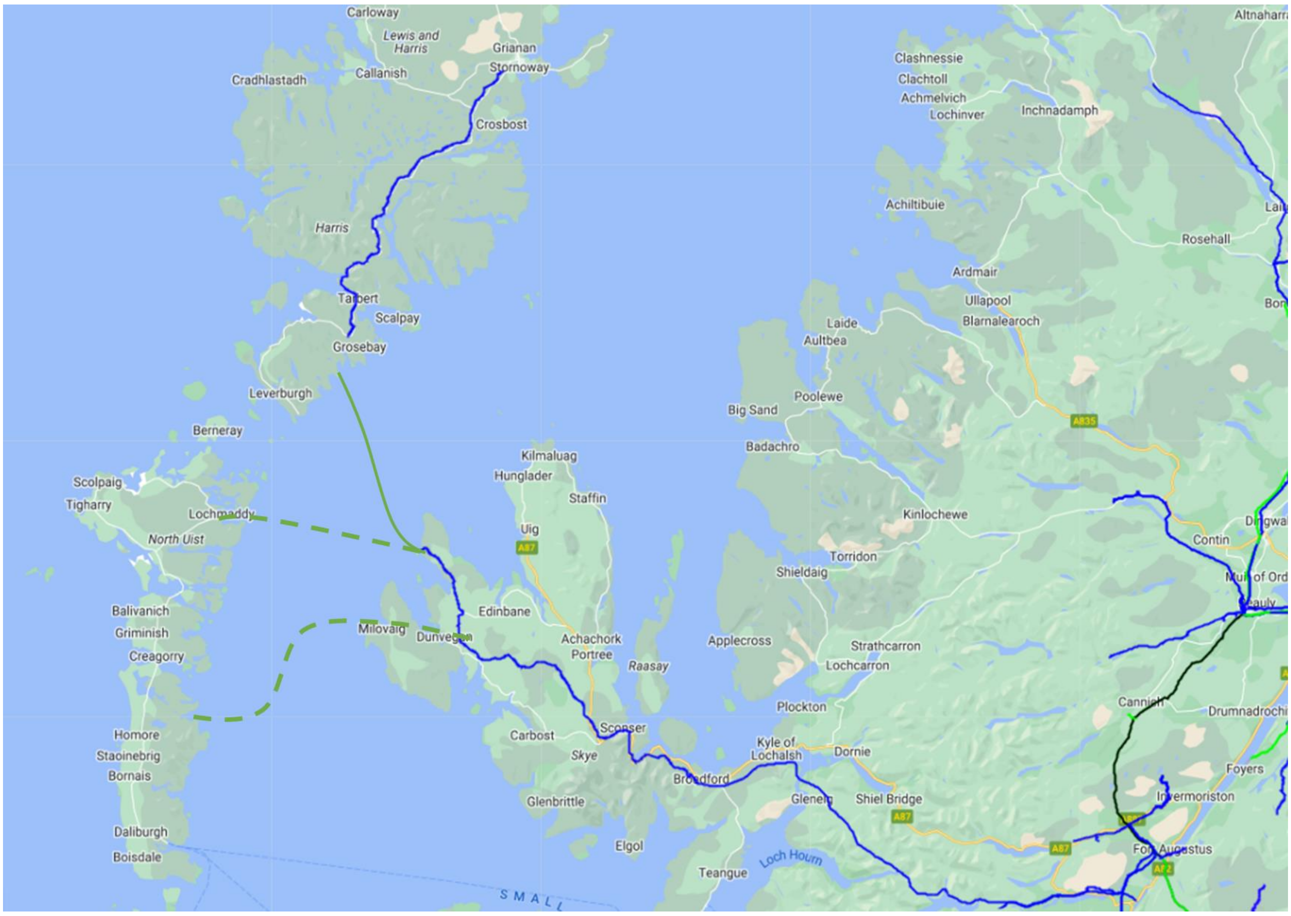
Option 13, illustrated in Figure 3-18 shows is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 16.5 km OHL between Dunvegan and Loch Pooltiel and a 38.5 km, 300mm^2 subsea cable between Loch Pooltiel and Loch Carnan (South Uist)
- A 33km subsea cable between Ardmore and Lochmaddy and a 16 km OHL between Lochmaddy and Clachan (North Uist)

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Skye to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-18 Overview of connections from Skye to the Hebrides (Option 13)



3.3.15 Option 14 : Remove Ardmore – Loch Carnan subsea cable and replace with Dunvegan – Loch Carnan OHL/subsea cable and Ardmore – Lochmaddy subsea cable with new OHL from Lochmaddy to Clachan plus new subsea/OHL from Admore to Harris

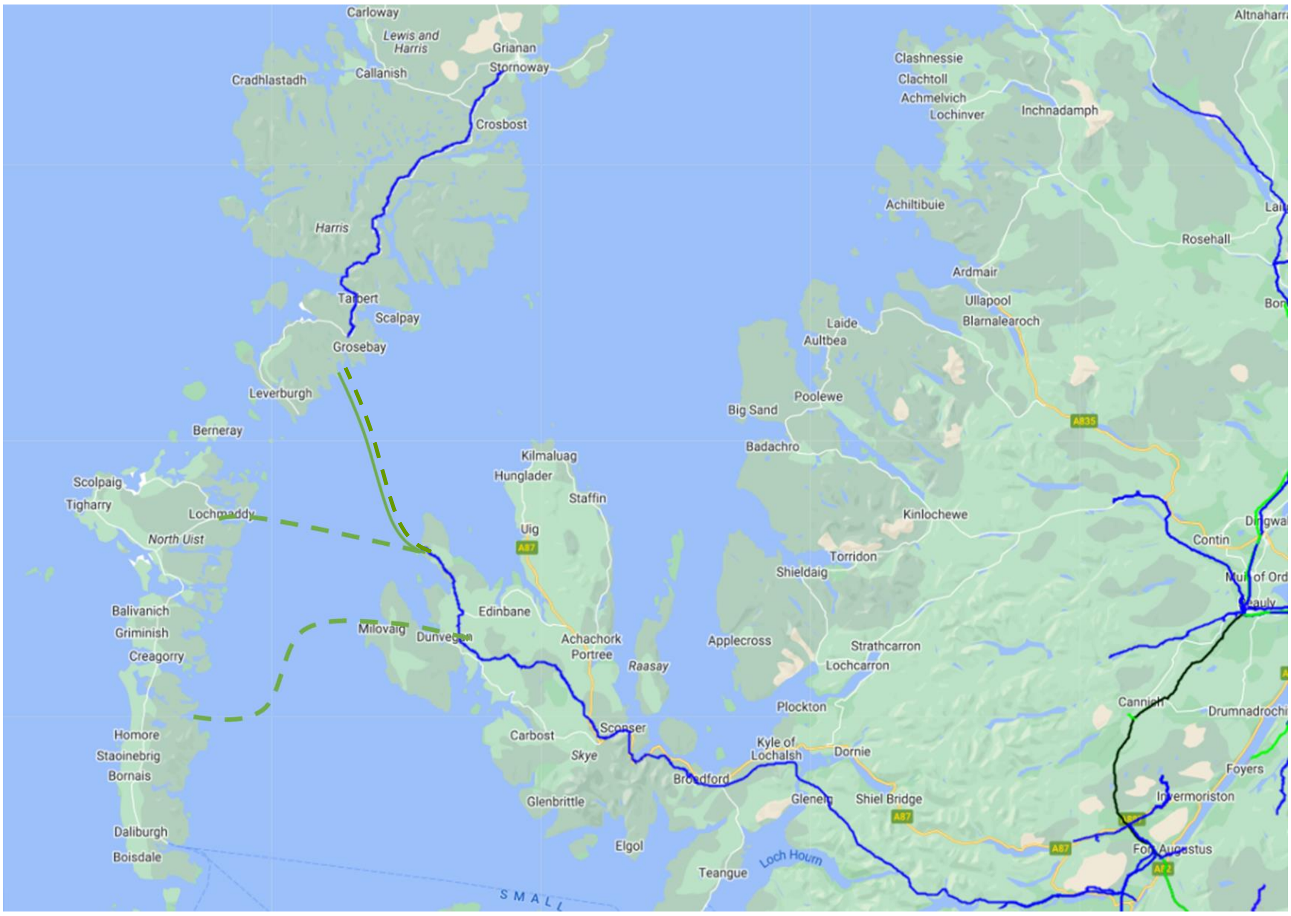
Option 14, illustrated in Figure 3-19 shows is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 16.5 km OHL between Dunvegan and Loch Pooltiel and a 38.5 km, 300mm^2 subsea cable between Loch Pooltiel and Loch Carnan (South Uist)
- A 33km subsea cable between Ardmore and Lochmaddy and a 16 km OHL between Lochmaddy and Clachan (North Uist)
- Retention of the existing 32.3km, 500 mm^2 subsea cable between Ardmore and Harris and the addition of a second 500 mm^2 subsea cable between Ardmore and Harris

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Skye to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-19 Overview of connections from Skye to the Hebrides (Option 14)



3.3.16 Option 15: Remove Ardmore – Loch Carnan subsea cable and replace with Dunvegan – Loch Carnan OHL/subsea cable and Ardmore – Lochmaddy subsea cable with new OHL from Lochmaddy to Clachan plus new 132kV subsea/OHL from Admore to Harris

Option 15, illustrated in Figure 3-20 shows is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 16.5 km OHL between Dunvegan and Loch Pooltiel and a 38.5 km, 300mm^2 subsea cable between Loch Pooltiel and Loch Carnan (South Uist)
- A 33km subsea cable between Ardmore and Lochmaddy and a 16 km OHL between Lochmaddy and Clachan (North Uist)
- Retention of the existing 500 mm^2, 33 kV subsea cable between Ardmore and Harris and the addition of a 132 kV feeder comprising 33 km and 5.6 km of subsea cable and OHL between Ardmore and Harris

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Skye to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-20 Overview of connections from Skye to the Hebrides (Option 15)

3.3.17 Option 16: Remove Ardmore – Loch Carnan subsea cable and replace with two Ardmore – Lochmaddy subsea cables with two new OHL from Lochmaddy to Clachan

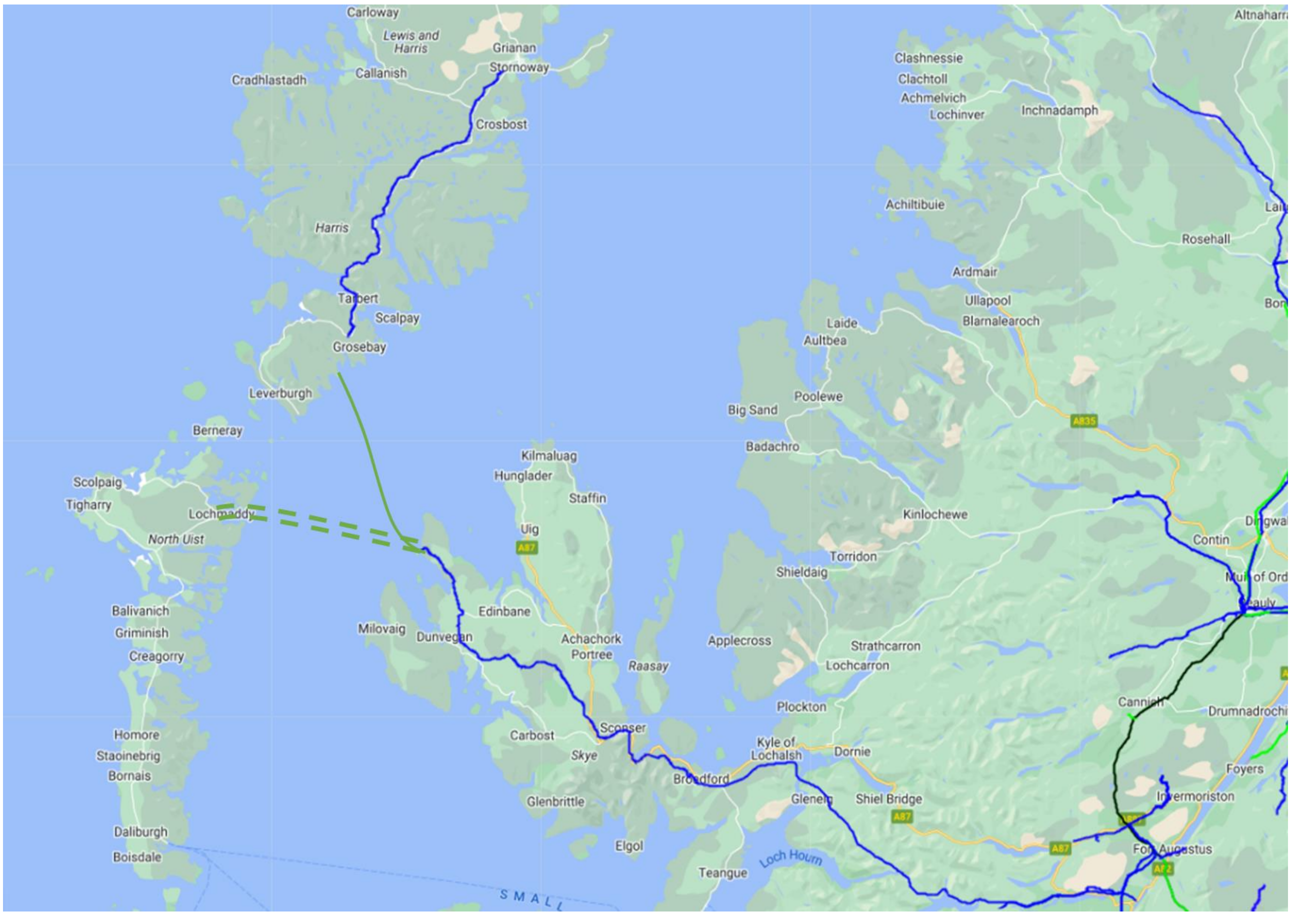
Option 16, illustrated in Figure 3-21, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- Two 33km,300mm^2 subsea cables between Ardmore and Lochmaddy (North Uist) and two 16 km OHL between Lochmaddy and Clachan.

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Skye to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-21 Overview of connections from Skye to the Hebrides (Option 16)



3.3.18 Option 17: Remove Ardmore – Loch Carnan subsea cable and replace with Dunvegan – Loch Carnan OHL/subsea cable and Harris – Lochmaddy subsea cable plus new OHL from Lochmaddy to Clachan

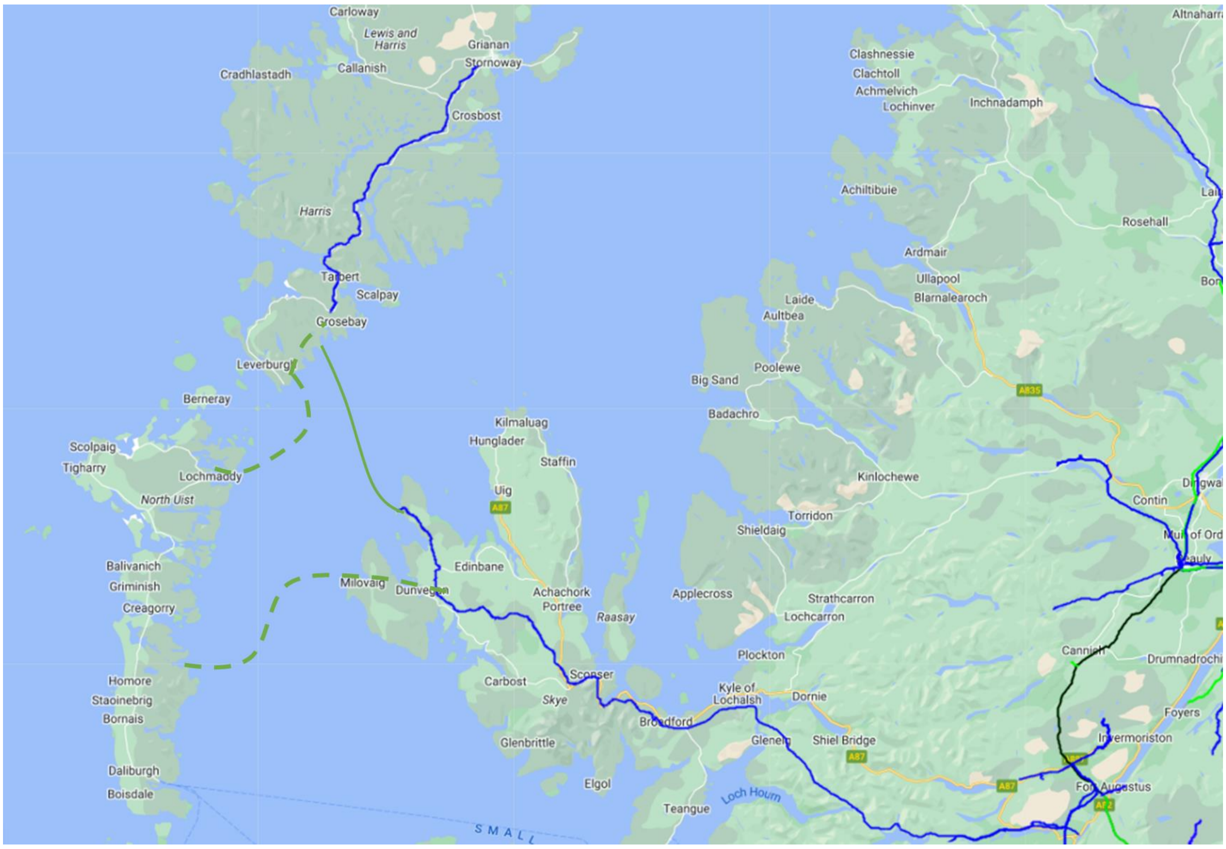
Option 17, illustrated in Figure 3-22, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 16.5 km OHL between Dunvegan and Loch Pooltiel and 38.5 km, 300mm^2 subsea cable between Loch Pooltiel and Loch Carnan (South Uist)
- A 16 km OHL and 25 km subsea cable between Harris and Lochmaddy and 16 km OHL between Lochmaddy and Clachan (North Uist)

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Skye to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-22 Overview of connections from Skye to the Hebrides (Option 17)



3.3.19 Option 18 (Overground): Remove Ardmore – Loch Carnan subsea cable and replace with Dunvegan – Loch Carnan OHL/subsea cable and Harris – Lochmaddy subsea cable plus new OHL from Lochmaddy to Clachan plus new subsea/OHL from Admore to Harris

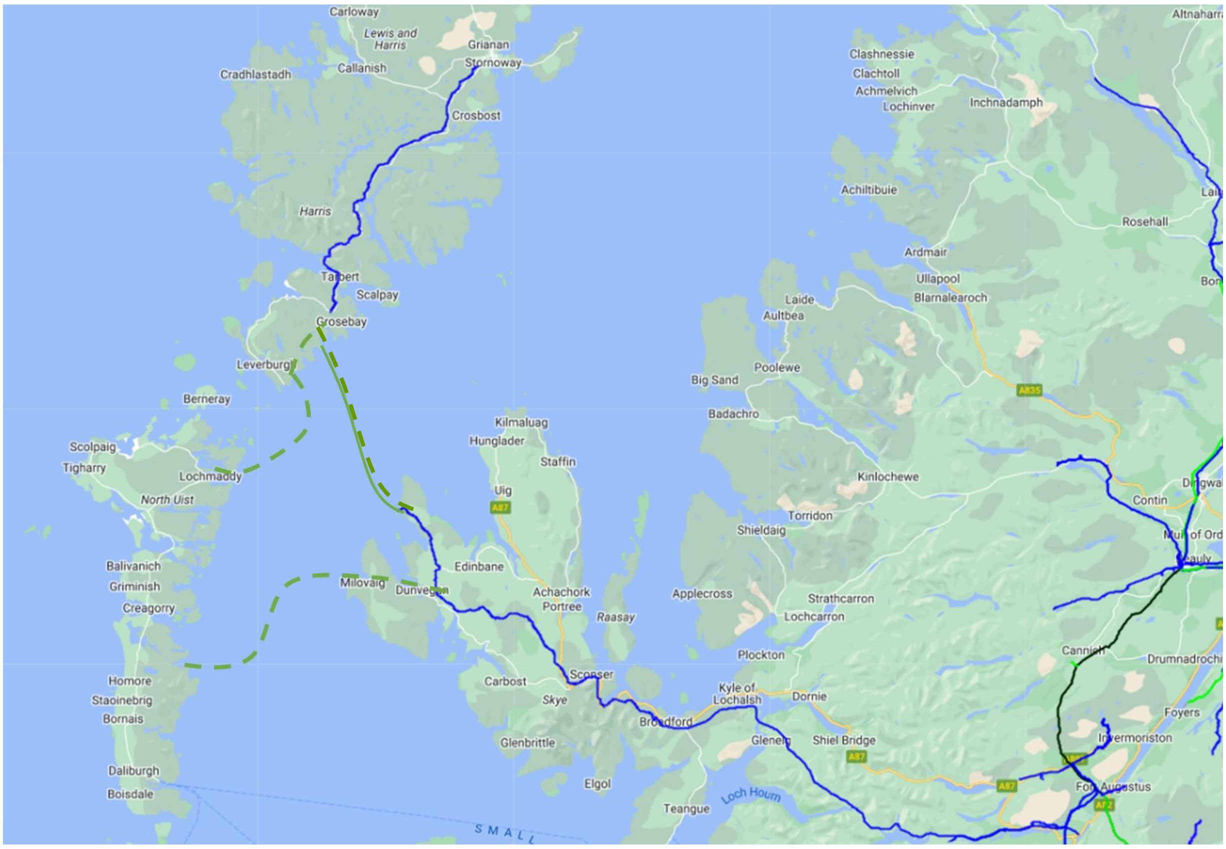
Option 18, illustrated in Figure 3-23, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 16.5 km OHL between Dunvegan and Loch Pooltiel and 38.5 km, 300mm^2 subsea cable between Loch Pooltiel and Loch Carnan (South Uist)
- A 16 km OHL and 25 km subsea cable between Harris and Lochmaddy and 16 km OHL between Lochmaddy and Clachan (North Uist)
- Retention of the existing 32.3km, 500 mm^2 subsea cable between Ardmore and Harris and the addition of a second 500 mm^2 subsea cable between Ardmore and Harris

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Skye to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-23 Overview of connections from Skye to the Hebrides (Option 18)



3.3.20 Option 19 (Underground): Remove Ardmore – Loch Carnan subsea cable and replace with Dunvegan – Loch Carnan OHL/subsea cable and Harris – Lochmaddy subsea cable plus new OHL from Lochmaddy to Clachan plus new subsea/OHL from Admore to Harris

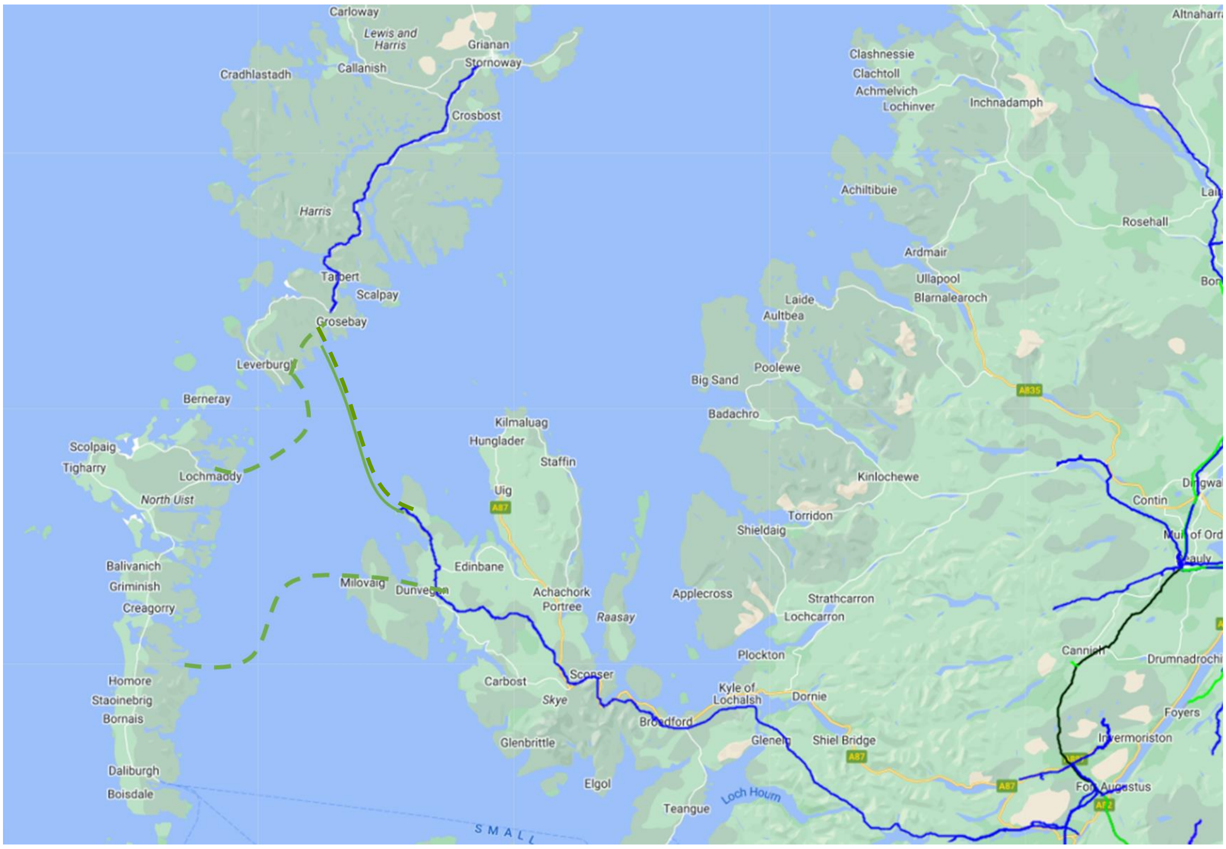
Option 19, illustrated in Figure 3-24, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 16.5 km OHL between Dunvegan and Loch Pooltiel and 38.5 km, 300mm^2 subsea cable between Loch Pooltiel and Loch Carnan (South Uist)
- A 16 km OHL and 25 km subsea cable between Harris and Lochmaddy and 16 km OHL between Lochmaddy and Clachan (North Uist)
- Retention of the existing 32.3km, 500 mm^2 subsea cable between Ardmore and Harris and the addition of a second 500 mm^2 subsea cable between Ardmore and Harris

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Skye to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-24 Overview of connections from Skye to the Hebrides (Option 19)



3.3.21 Option 20: Remove Ardmore – Loch Carnan subsea cable and replace with Dunvegan – Loch Carnan OHL/subsea cable and Harris – Lochmaddy subsea cable plus new OHL from Lochmaddy to Clachan plus new 132kV subsea/OHL from Admore to Harris

Option 20, illustrated in Figure 3-25, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 16 km OHL between Dunvegan and Loch Pooltiel and 38.5 km, 300mm^2 subsea cable between Loch Pooltiel and Loch Carnan (South Uist)
- A 16 km OHL and 25 km subsea cable between Harris and Lochmaddy and 16 km OHL between Lochmaddy and Clachan (North Uist)
- Retention of the existing 500 mm^2, 33 kV subsea cable between Ardmore and Harris and the addition of a 132 kV feeder comprising 33 km and 5.6 km of subsea cable and OHL between Ardmore and Harris

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Skye to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-25 Overview of connections from Skye to the Hebrides (Option 20)

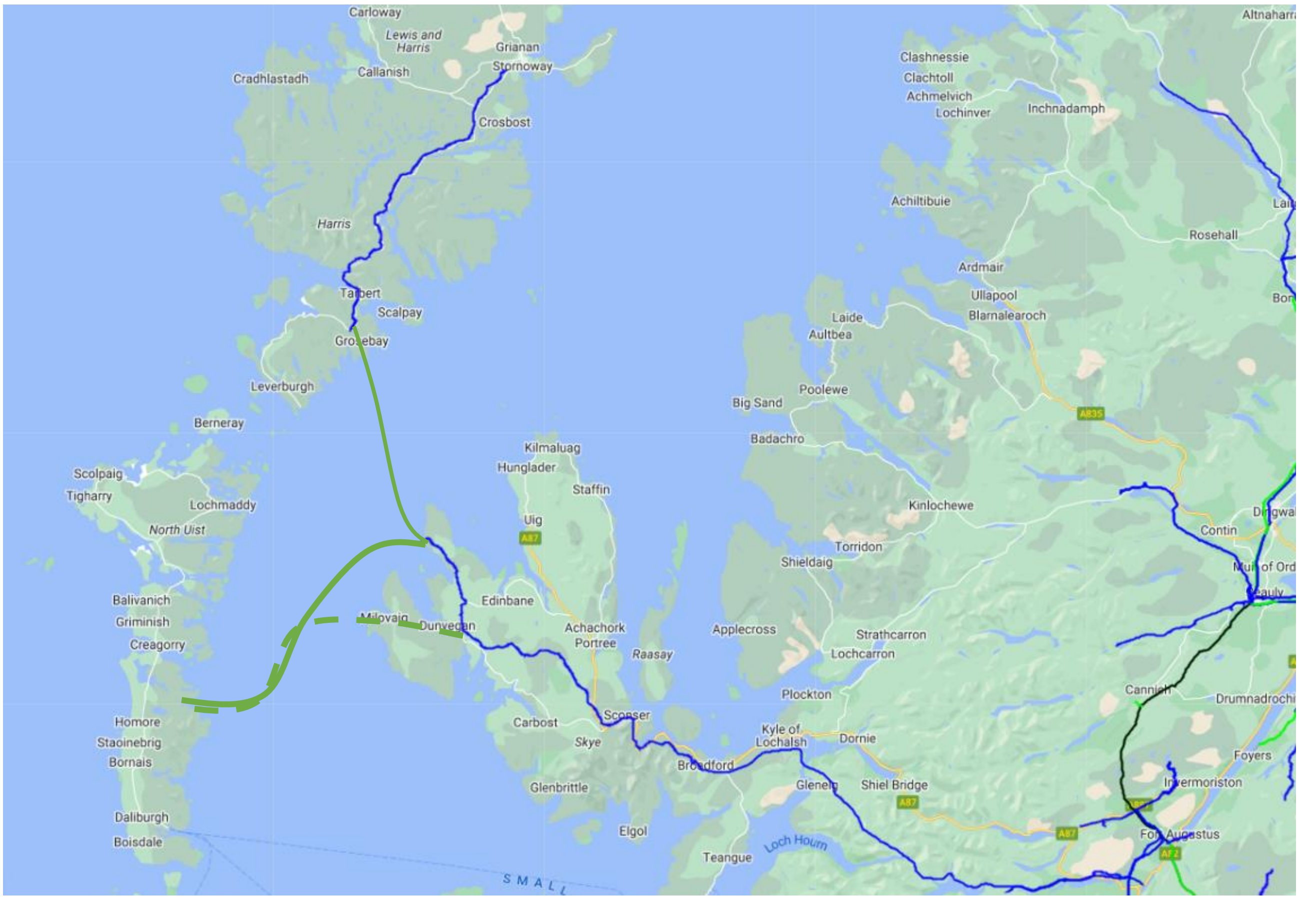
3.3.22 Option 21: Existing Ardmore – Loch Carnan subsea cable and additional Dunvegan – Loch Carnan OHL/subsea cable

Option 21, illustrated in Figure 3-26, is the retention of the existing 95mm[2] subsea cable between Ardmore and Loch Carnan (South Uist) and the addition of:

- A16.5km, OHL between Dunvegan and Loch Pooltiel and a 38.5 km, 185mm[2] subsea cable between Loch Pooltiel and Loch Carnan (South Uist)

New circuits are 33 kV and shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Loch Carnan and Ardmore to Harris.

Figure 3-26 Overview of connections from Skye to the Hebrides (Option 21)



3.3.23 Option 22: New Ardmore – Loch Carnan subsea cable and additional Dunvegan – Loch Carnan OHL/subsea cable

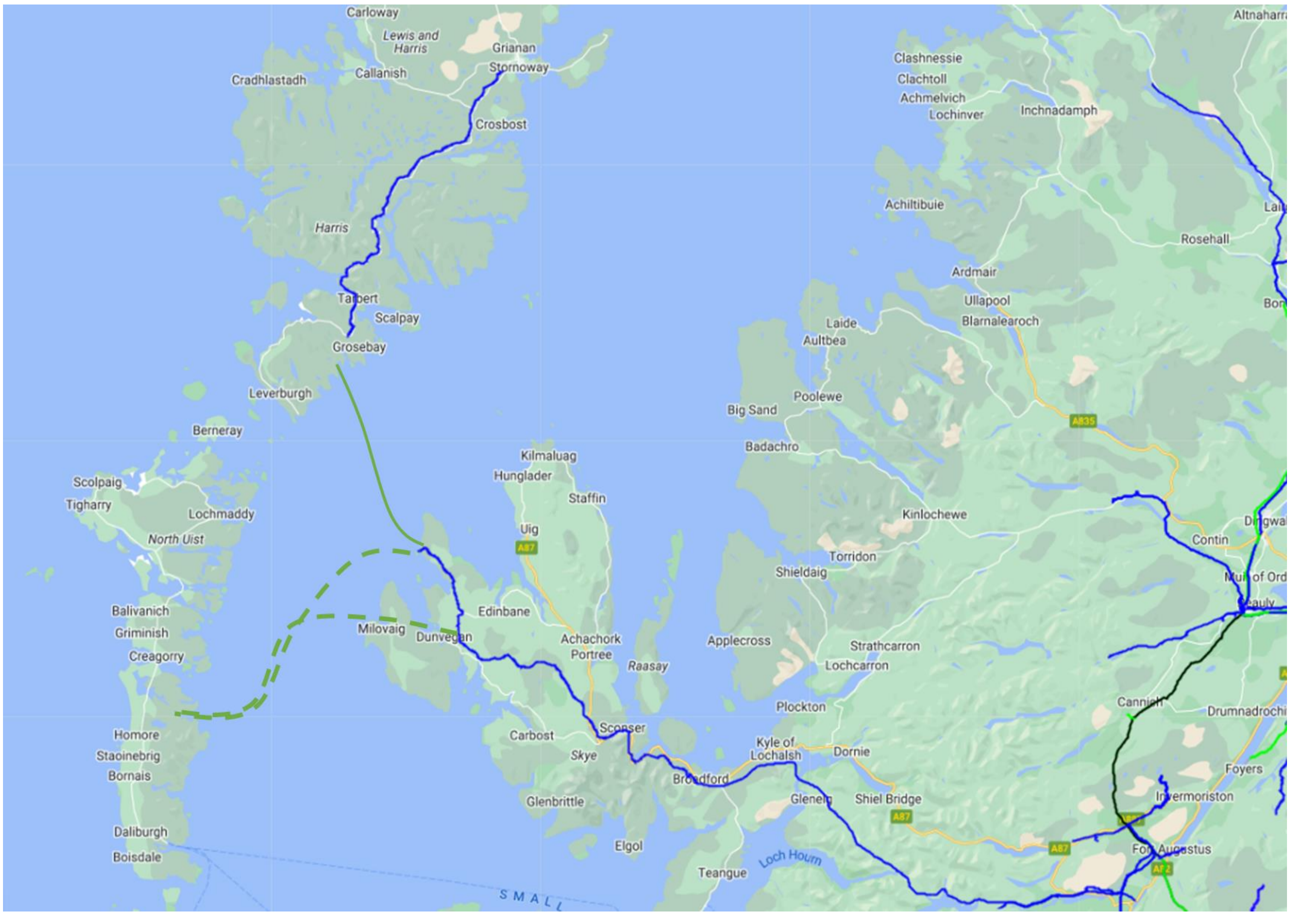
Option 22, illustrated in Figure 3-27, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 47km, 300mm^2 cable between Ardmore and Loch Carnan (South Uist)
- A16.5km, OHL between Dunvegan and Loch Pooltiel and a 38.5 km, 300mm^2 subsea cable between Loch Pooltiel and Loch Carnan (South Uist)

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-27 Overview of connections from Skye to the Hebrides (Option 22)



3.3.24 Option 23: New Ardmore – Loch Carnan subsea cable and additional Dunvegan – Loch Carnan OHL/subsea cable plus new subsea/OHL from Admore to Harris

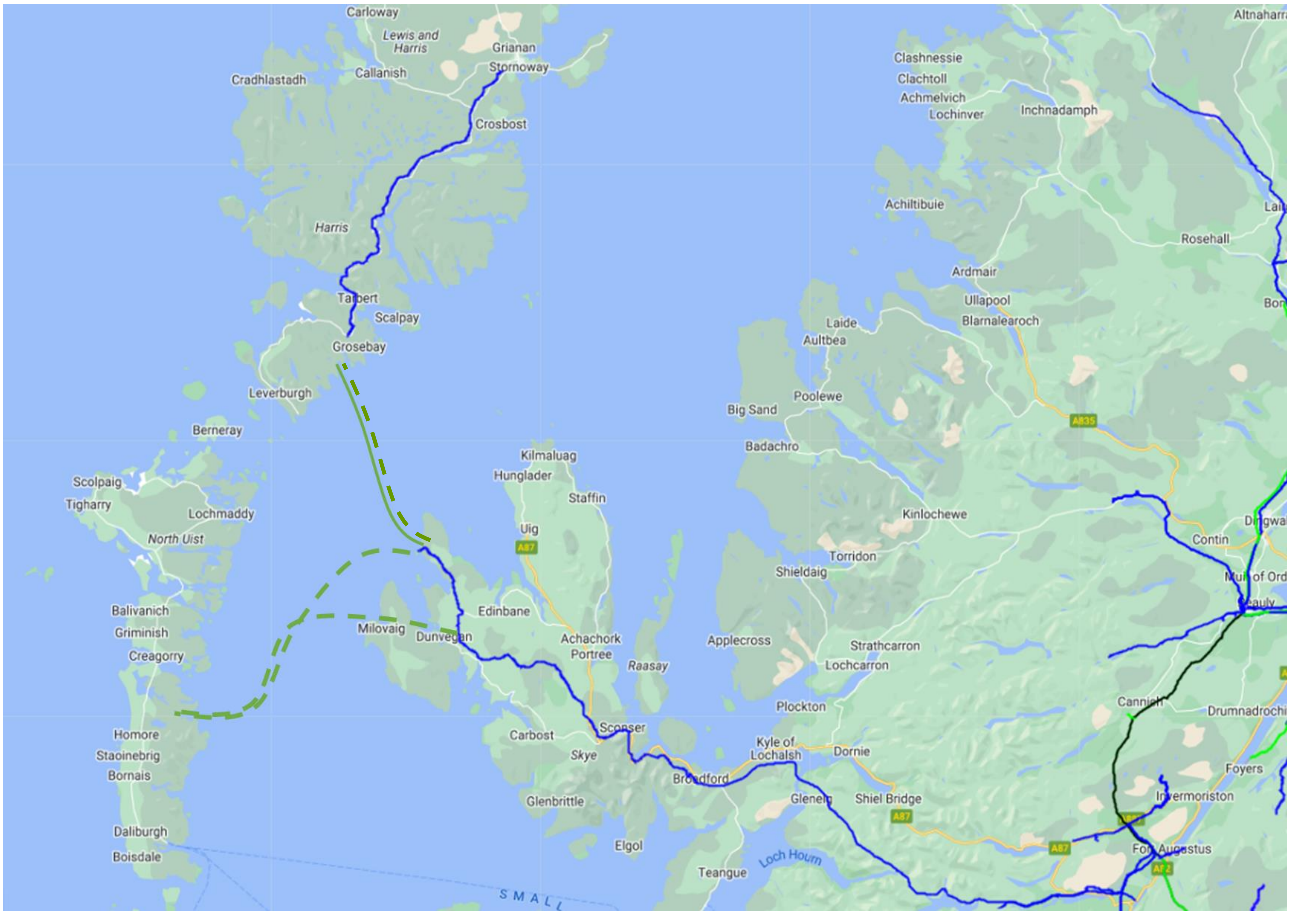
Option 23, illustrated in Figure 3-28, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 47km, 300mm^2 cable between Ardmore and Loch Carnan (South Uist)
- A16.5km, OHL between Dunvegan and Loch Pooltiel and a 38.5 km, 300mm^2 subsea cable between Loch Pooltiel and Loch Carnan (South Uist)
- Retention of the existing 32.3km, 500 mm^2 subsea cable between Ardmore and Harris and the addition of a second 500 mm^2 subsea cable between Ardmore and Harris

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-28 Overview of connections from Skye to the Hebrides (Option 23)



3.3.25 Option 24: New Ardmore – Loch Carnan subsea cable and additional Dunvegan – Loch Carnan OHL/subsea cable plus new 132kV subsea/OHL from Admore to Harris

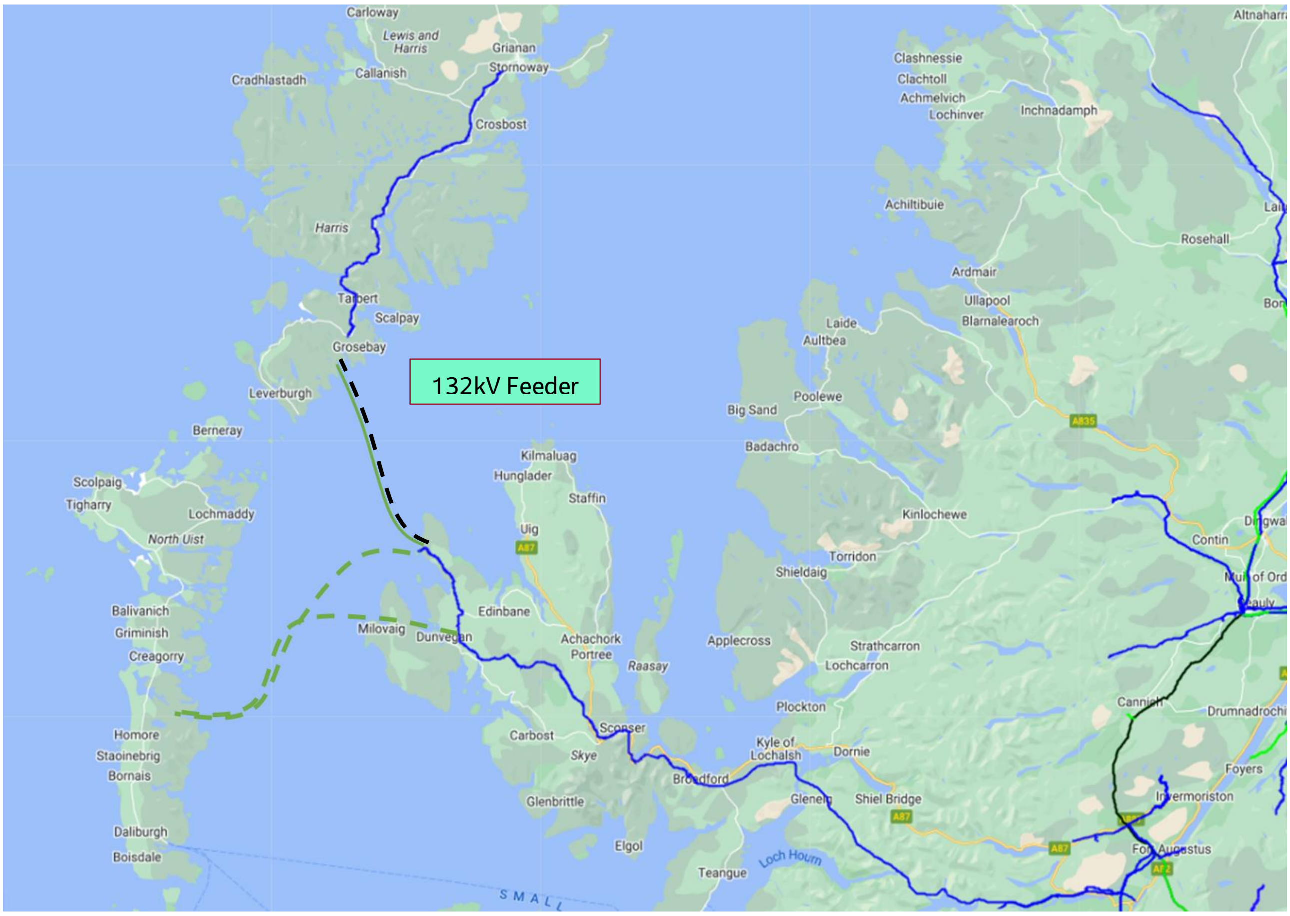
Option 12B, illustrated in Figure 3-29, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 47km, 300mm^2 cable between Ardmore and Loch Carnan (South Uist)
- A16.5km, OHL between Dunvegan and Loch Pooltiel and a 38.5 km, 300mm^2 subsea cable between Loch Pooltiel and Loch Carnan (South Uist)
- Retention of the existing 500 mm^2, 33 kV subsea cable between Ardmore and Harris and the addition of a 132 kV feeder comprising 33 km and 5.6 km of subsea cable and OHL between Ardmore and Harris

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-29 Overview of connections from Skye to the Hebrides (Option 24)



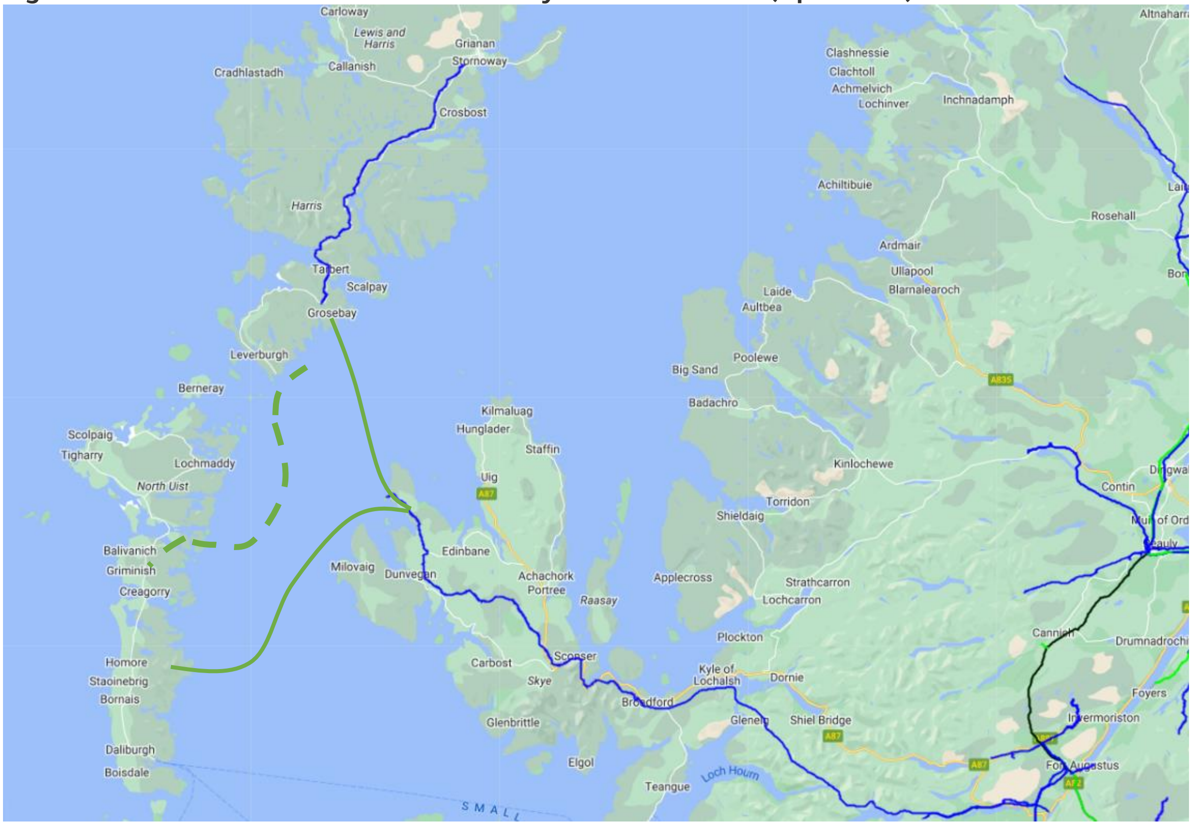
3.3.26 Option 25: Existing Ardmore – Loch Carnan subsea cable and additional Harris – Lochmaddy subsea cabe with OHL from Lochmaddy to Clachan.

Option 25, illustrated in Figure 3-30, is the retention of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) and the addition of:

- A 16 km OHL and 25 km OHL and subsea cable between Harris and Lochmaddy and 16 km OHL between Lochmaddy and Clachan (North Uist)

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Figure 3-30 Overview of connections from Skye to the Hebrides (Option 25)



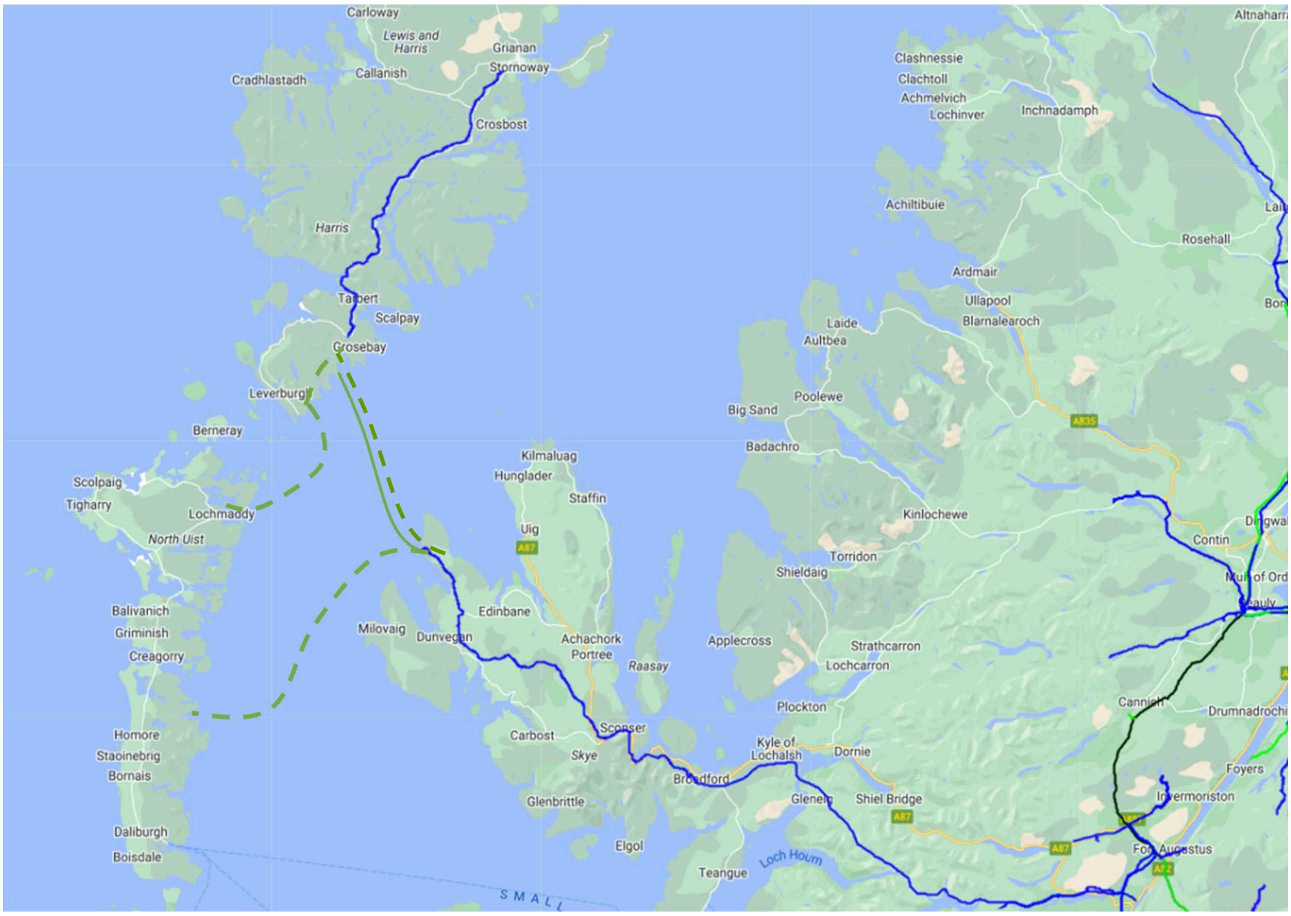
3.3.27 Option 26: New Ardmore – Loch Carnan subsea cable, additional Ardmore to Harris and new Harris – Clachan subsea cable / OHL

Option 26, illustrated in Figure 3-31, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 47 km, 300mm^2 cable between Ardmore and Loch Carnan (South Uist)
- An 16 km OHL and 25 km OHL and subsea cable between Harris and Lochmaddy and 16 km OHL between Lochmaddy and Clachan (North Uist)
- Retention of the existing 32.3 km, 500 mm^2 subsea cable between Ardmore and Harris and the addition of a second 500 mm^2 subsea cable between Ardmore and Harris.

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Figure 3-31 Overview of connections from Skye to the Hebrides (Option 26)



3.3.28 Option 27: New Ardmore – Loch Carnan subsea cable, additional Dunvegan – Loch Carnan OHL/subsea cable and additional Harris – Clachan subsea cable / OHL

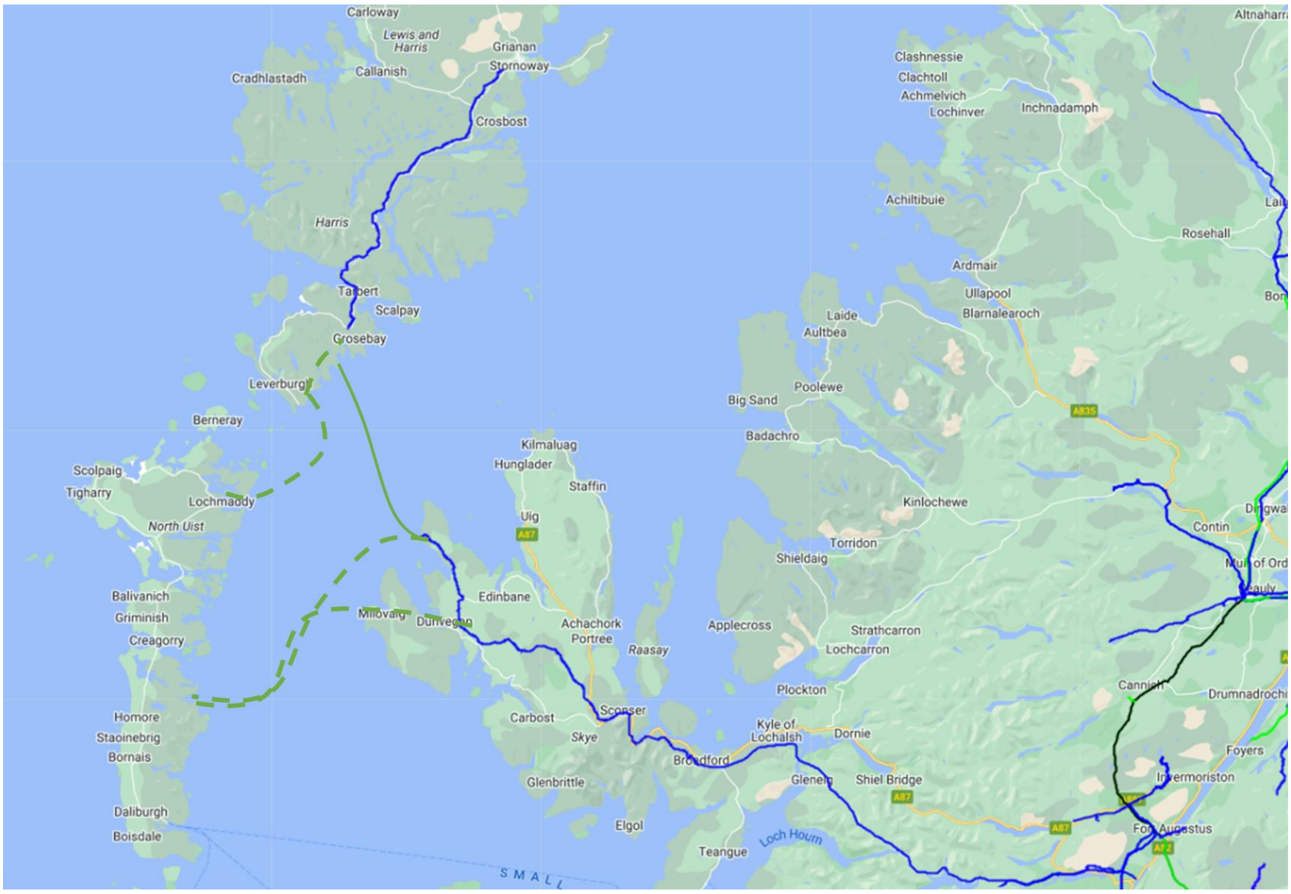
Option 27, illustrated in Figure 3-32 is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 47km, 300mm^2 cable between Ardmore and Loch Carnan (South Uist)
- A 16.5km, OHL between Dunvegan and Loch Pooltiel and a 38.5 km, 300mm^2 subsea cable between Loch Pooltiel and Loch Carnan (South Uist)
- A 16 km OHL and a 25 km subsea cable between Harris and Lochmaddy and 16 km OHL between Lochmaddy and Clachan (North Uist)

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-32 Overview of connections from Skye to the Hebrides (Option 27)



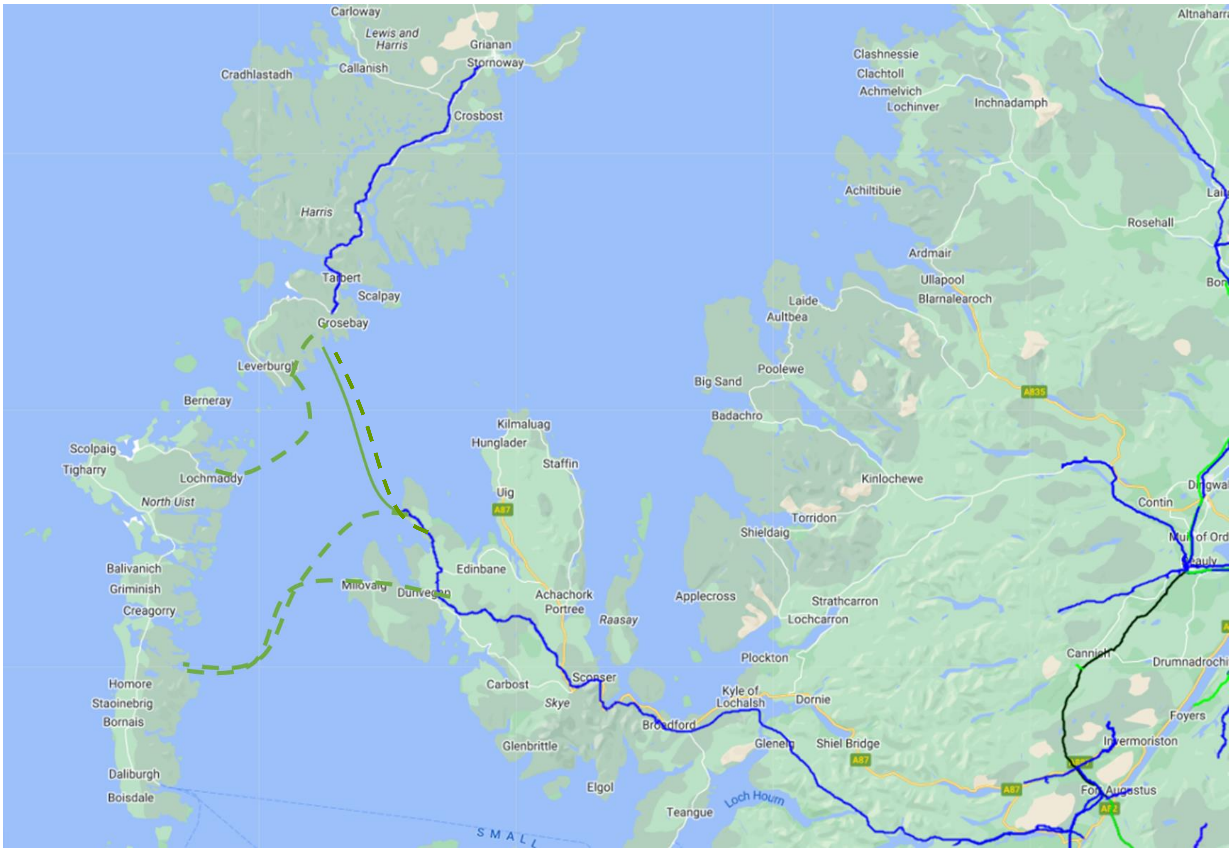
3.3.29 Option 28: New Ardmore – Loch Carnan subsea cable, additional Dunvegan – Loch Carnan OHL/subsea cable and additional Harris – Clachan subsea cable / OHL plus new subsea/OHL from Admore to Harris

Option 28, illustrated in Figure 3-33 is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 47km, 300mm^2 cable between Ardmore and Loch Carnan (South Uist)
- A 16.5km, OHL between Dunvegan and Loch Pooltiel and a 38.5 km, 300mm^2 subsea cable between Loch Pooltiel and Loch Carnan (South Uist)
- A 16 km OHL and a 25 km subsea cable between Harris and Lochmaddy and 16 km OHL between Lochmaddy and Clachan (North Uist)
- Retention of the existing 32.3km, 500 mm^2 subsea cable between Ardmore and Harris and the addition of a second 500 mm^2 subsea cable between Ardmore and Harris. The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-33 Overview of connections from Skye to the Hebrides (Option 28)



3.3.30 Option 29: New Ardmore – Loch Carnan subsea cable, additional Dunvegan – Loch Carnan OHL/subsea cable and additional Harris – Clachan subsea cable / OHL plus new 132kV subsea/OHL from Admore to Harris

Option 29, illustrated in Figure 3-34 is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 47km, 300mm^2 cable between Ardmore and Loch Carnan (South Uist)
- A 16.5km, OHL between Dunvegan and Loch Pooltiel and a 38.5 km, 300mm^2 subsea cable between Loch Pooltiel and Loch Carnan (South Uist)
- A 16 km OHL and a 25 km subsea cable between Harris and Lochmaddy and 16 km OHL between Lochmaddy and Clachan (North Uist)
- Retention of the existing 500 mm^2, 33 kV subsea cable between Ardmore and Harris and the addition of a 132 kV feeder comprising 33 km and 5.6 km of subsea cable and OHL between Ardmore and Harris .The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

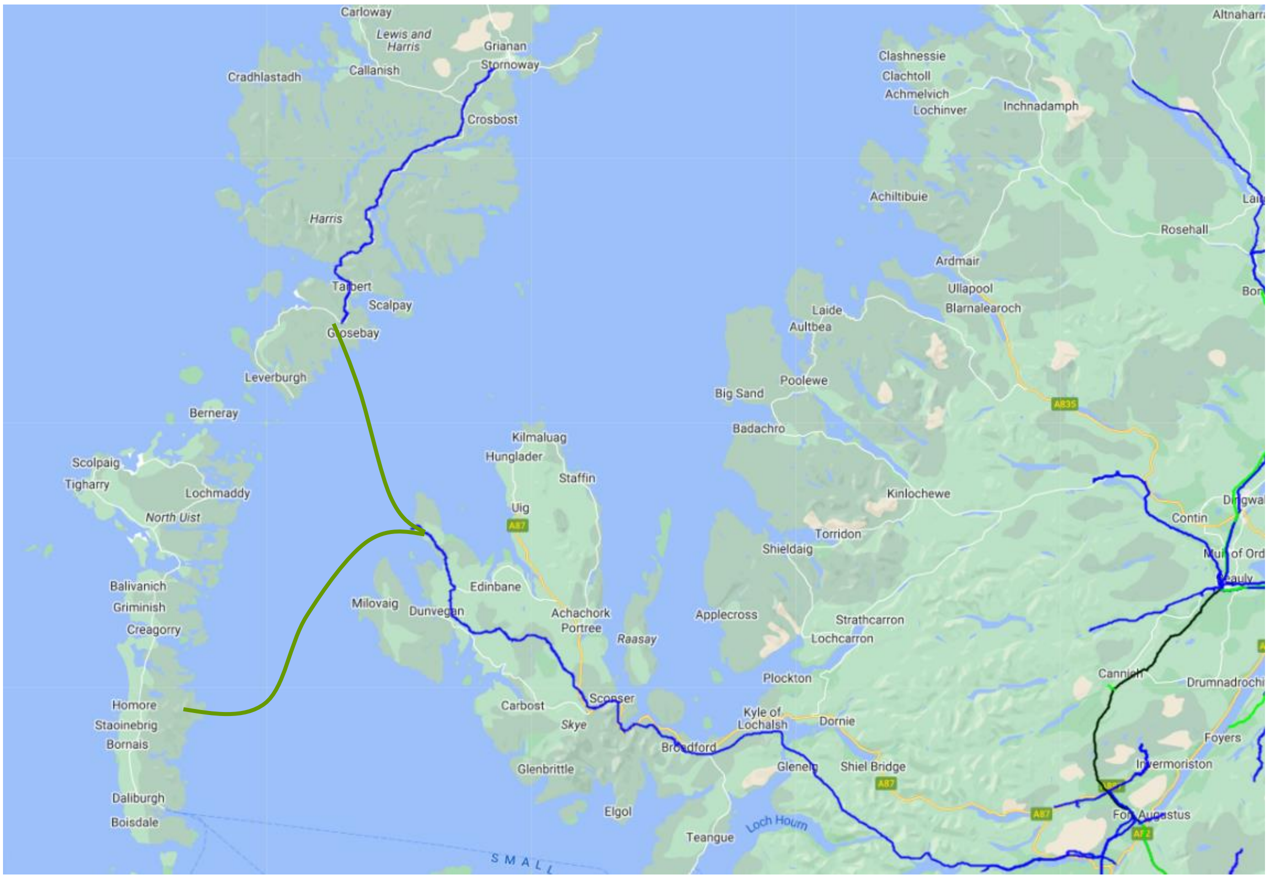
Figure 3-34 Overview of connections from Skye to the Hebrides (Option 29)

3.3.31 Option 30: Existing Ardmore – Harris subsea cable and Ardmore – Loch Carnan subsea cable with larger cable

This option which is complimentary to Option 3 and considers the Harris network supply arrangements is illustrated in Figure 3-35. The option considers the retention of the existing 32.3 km, 500 mm^2 subsea cable between Ardmore and Harris.

- A larger 185mm2 (capacity: -21.94MVA as per SSEN) subsea cable using a similar route between Ardmore and Loch Carnan (South Uist).

Figure 3-35 Overview of connections from Skye to the Hebrides (Option 30)

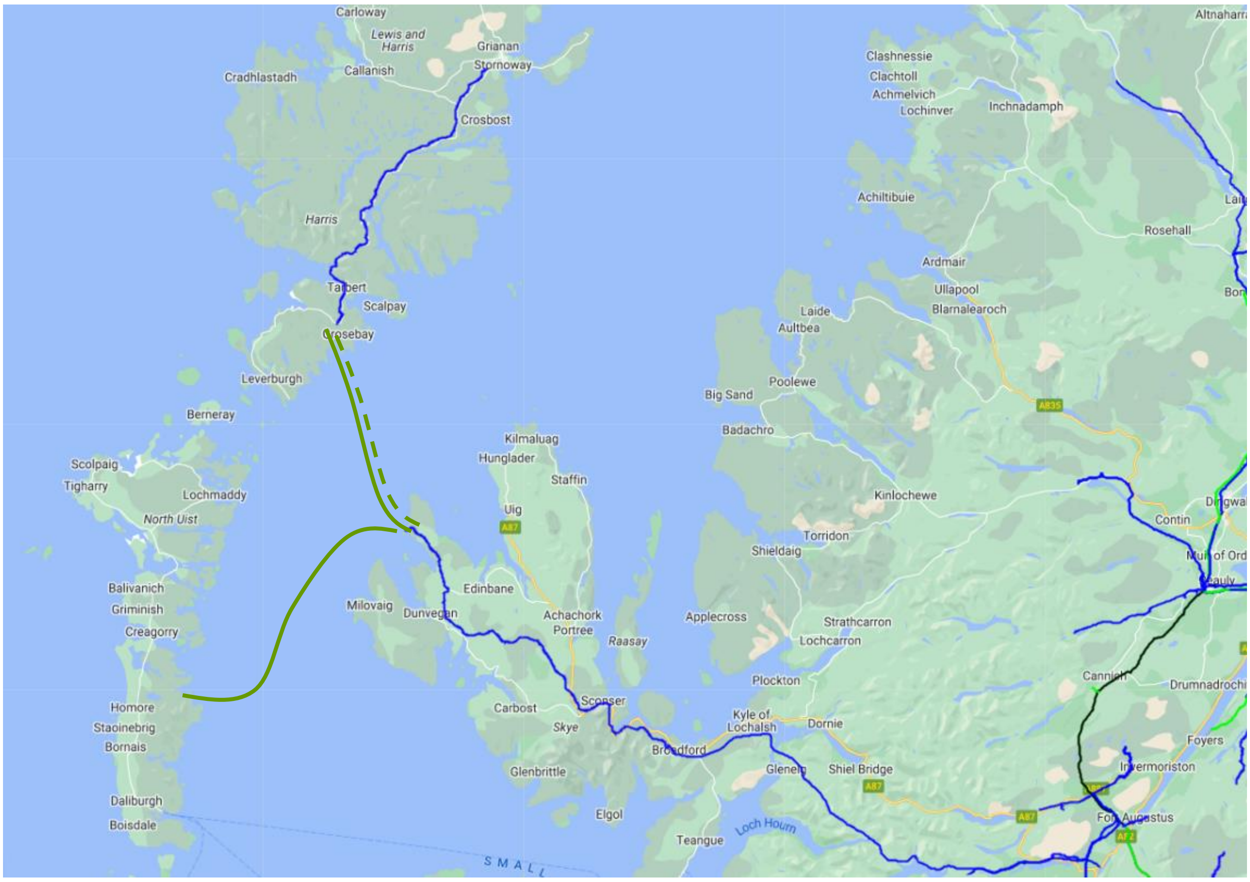


3.3.32 Option 31: Existing and new Ardmore – Harris subsea cables

Option 31, illustrated in Figure 3-36, considers the retention of the existing 32.3km, 500 mm^2 subsea cable between Ardmore and Harris and the addition of a second 500 mm^2 subsea cable between Ardmore and Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-36 Overview of connections from Skye to the Hebrides (Option 31)



3.3.33 Option 32: New 132kV feeder and the retention of existing 33kV feeder from Ardmore – Harris subsea cables

Option 17 builds on Option 13A and considers the retention of the existing 500 mm^2, 33 kV subsea cable between Ardmore and Harris and the addition of a 132 kV feeder comprising 33 km and 5.6 km of subsea cable and OHL between Ardmore and Harris. If this option is taken forward the operating arrangement of the 132 kV and 33 kV system would need to be finalised (effects of paralleling). The 132 kV feeder is illustrated in Figure 3-37.

- Retention of the existing 32.3 km, 500 mm2 subsea cable between Ardmore and Harris and the addition of a second 500 mm2 subsea cable between Ardmore and Harris.

Note:- The feeder from Ardmore to Harris was normally open during the winter scenarios when the HVDC source was operational.

Figure 3-37 Overview of connections from Skye to the Hebrides (Option 32)

4.2 Results summary

Table 4-1 Summary of Load Flow results for Summer and Winter Scenarios by Option

Option Number	Summer Scenario		Winter Scenario	
	Normal Operating Scenario	Contingency Scenario	Normal Operating Scenario	Contingency Scenario
1	✓	✗	✗	✗
2	✓	✗	✗	✗
3	✓	✗	✓	✗
4	✓	✓	✓	✗
5	✓	✓	✓	✗
6	✓	✓	✓	✗
7	✓	✓	✓	✗
8	✓	✓	✓	✓
9	✓	✓	✓	✓
10	✓	✓	✓	✗
11	✓	✓	✓	✓
12	✓	✓	✓	✓
13	✓	✓	✓	✗
14	✓	✓	✓	✓
15	✓	✓	✓	✓
16	✓	✗	✓	✗
17	✓	✓	✓	✗
18	✓	✓	✓	✓
19	✓	✓	✓	✓
20	✓	✓	✓	✓
21	✗	✓	✓	✗
22	✓	✓	✓	✗
23	✓	✓	✓	✓
24	✓	✓	✓	✓
25	✓	✓	✓	✗

Option Number	Summer Scenario		Winter Scenario	
	Normal Operating Scenario	Contingency Scenario	Normal Operating Scenario	Contingency Scenario
26	✔	✔	✔	✔
27	✔	✔	✔	✘
28	✔	✔	✔	✔
29	✔	✔	✔	✔
30	✔	✘	✔	✘
31	✔	✔	✔	✘
32	✔	✔	✔	✘

Note: ✔ Scenario is feasible

✘ Scenario is not feasible.

Table 4-2 Summary of Load Flow results for Summer and Winter Scenarios by Option

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
Option-1	1) The existing subsea cable loaded up to 42% of rated capacity i.e.14MVA. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay Transformer is loaded to 125% of capacity. 4) During the outage of existing cable from Loch Carnan to Ardmore, Loch Carnan will be islanded. 5) Region-wise losses: Loch Carnan - 0.4MW and Stornoway - 2.8 MW This option is not feasible under N-1 Contingency operating conditions.	1) The existing 95mm^2 subsea cable from Ardmore to Loch Carnan was loaded up to 134% of its rated capacity, i.e., 14MVA. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) 1x 1 MVA and 1x 2.5 MVA transformers at Gilsa and Laxay were loaded up to 123% and 183% of their rated capacity, respectively. 4) During the outage of the existing cable from Loch Carnan to Ardmore, Loch Carnan will be islanded. 5) Region-wise losses: Loch Carnan: 1.2 MW and Stornoway: 5.4 MW This option is not viable under normal operating conditions and N-1 contingency operating conditions for the subsea cable from Ardmore to Loch Carnan.	i) Additional, 1x 1 MVA and 1x 2.5 MVA transformers are considered for Gisla and Laxay substations respectively to prevent transformers overload. **Flexibility Services (from local generation or demand):** For the winter scenario, procurement of ~5MVA flexibility services in the Loch Carnan zone to avoid the cable overloading.
Option-2	1) The existing subsea cable loaded up to 37% of rated capacity i.e.16MVA. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay Transformer is loaded up to 125% of capacity. 4) During the outage of new cable from Loch Carnan to Ardmore, Loch Carnan will be	1) The new 95mm^2 subsea cable from Ardmore to Loch Carnan was loaded up to 117% of its rated capacity, i.e., 16MVA. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) 1x 1 MVA and 1x 2.5 MVA transformers at Gilsa and Laxay were loaded up to 122% and 183% of their rated capacity, respectively. 3) During the outage of the existing cable from Loch Carnan to Ardmore, Loch Carnan will be islanded.	i) Additional, 1x 1 MVA and 1x 2.5 MVA transformers are considered for Gisla and Laxay substations respectively to prevent transformers overload. **Flexibility Services (from local generation or demand):** For the winter scenario, procurement of ~3MVA flexibility services in the Loch Carnan zone to avoid the cable overloading.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
	islanded. 5) Region-wise losses: Loch Carnan - 0.4MW and Stornoway - 2.8 MW This option is not feasible under N-1 Contingency operating conditions.	4) Region-wise losses: Loch Carnan: 1.2 MW and Stornoway: 5.2 MW This option is not viable under normal operating conditions and n-1 contingency operating conditions for the subsea cable from Ardmore to Loch Carnan.	
Option-3	1) The 185 mm^2 subsea cable loaded up to 24% of its rated capacity i.e.21.94 MVA. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay Transformer is Loaded up to 125% of capacity. 4) During the outage of the new cable from Loch Carnan to Ardmore, Loch Carnan will be islanded. 5) Region-wise losses: Loch Carnan - 0.3MW and Stornoway - 2.8 MW This option is not feasible under N-1 Contingency operating conditions.	1) The 185mm^2 cable from Ardmore to Loch Carron subsea cable was loaded up to 84% of its rated capacity i.e. 21.94MVA. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones within the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Transformers at Gisla and Laxay substations were overloaded. 4) All the bus voltages and equipment loadings were within acceptable limits with the following recommendations: i) 2.5 MVAr and 0.5 MVAr fixed capacitor banks were considered for 11 kV Clachan and 11 kV ii) 1x 1 MVA and 1x 2.5 MVA transformers were considered for Gisla and Laxy substations respectively. 5) During the outage of the new cable from Loch Carnan to Ardmore, Loch Carnan is islanded. 6) Region-wise losses: Loch Carnan - 0.8MW and Stornoway - 3.9MW However, in the event of an N-1 contingency for the subsea cable from Ardmore to Loch Carnan, this option is not viable.	i) 2.5 MVAr and 0.7 MVAr fixed capacitors were considered for 11 kV Clachan and 11 kV Gisla substations. ii) 1x 1 MVA and 1x 2.5 MVA transformers are considered for Gisla and Laxay substations respectively.
Option-4	1) The existing and new subsea cables are loaded up to 27% and 23% of their rated capacity respectively. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay Transformer is Loaded up to 125% than its capacity. 4) During the outage of the new cable from Loch Carnan to Ardmore, the existing cable is loaded up to 42% of rating. 5) Region-wise losses: Loch Carnan - 0.2MW and Stornoway - 2.8 MW This option is feasible under both normal and N-1 Contingency operating conditions. However, during	1) The existing and new 95mm2 subsea cables from Ardmore to Loch Carnan were loaded up to 71% and 62% of their rated capacity, respectively. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones within the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Transformers at Gisla and Laxay substations were overloaded. 4) All the bus voltages and equipment loadings were within acceptable limits, with the following recommendations: i) 2 MVAr and 0.5 MVAr fixed capacitors were considered for the 11 kV Clachan and 11 kV Gisla substations. ii) 1x 1 MVA and 1x 2.5 MVA transformers were considered for Gisla and Laxay substations. 5) In the event of an N-1 contingency for the 95mm2 new subsea cable from Ardmore to Loch Carnan, the other run of the 95mm2 subsea cable will be overloaded up to 135% of its rating. 6) Region-wise losses: Loch Carnan: 0.74 MW and Stornoway: 3.46 MW This option is not feasible under the N-1 contingency operating condition.	i) 2 MVAr and 0.5 MVAr fixed capacitor banks were considered for 11 kV Clachan and 11 kV Gisla substations to maintain the system voltages within the acceptable limits. ii) 1x 1 MVA and 1x 2.5 MVA transformers are considered for Gisla and Laxay substations respectively to prevent transformers overload. **Flexibility Services (from local generation or demand):** For the winter scenario, procurement of ~5MVA flexibility services in the Loch Carnan zone to avoid the cable overloading.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
	contingencies at Ardmore substation will impact reliability of power supply in both regions.		
Option-5	1) The existing and new subsea cables are loaded up to 24% and 18.7% of its rated capacity respectively. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay Transformer is loaded up to 125% of capacity. 4) During the outage of the new cable from Loch Carnan to Ardmore, the existing cable is loaded up to 42% of rating. 5) Region-wise losses: Loch Carnan - 0.2MW and Stornoway - 2.8 MW This option is feasible under both normal and N-1 Contingency operating conditions. However, during contingencies at Ardmore substation will impact reliability of power supply in both regions.	1) The existing 95mm^2 and 185mm^2 new subsea cables from Ardmore to Loch Carnan were loaded up to 58% and 49% of their rated capacity, i.e., 14MVA and 21.9MVA, respectively. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones within the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Transformers at Gisla and Laxay substations were overloaded. 4) All the bus voltages and equipment loadings were within acceptable limits, with the following recommendations: i) 2.5 MVAr and 0.5 MVAr fixed capacitors were considered for 11 kV Clachan and 11 kV Gisla substations. ii) 1x 1 MVA and 1x 2.5 MVA transformers were considered for Gisla and Laxay substations. 5) In the event of an N-1 contingency for the 185mm^2 subsea cable from Ardmore to Loch Carnan, the other run of the 95mm2 subsea cable will be overloaded up to 136% of its rating. 6) Region-wise losses: Loch Carnan: 0.74 MW and Stornoway: 3.01 MW This option is not feasible under the N-1 contingency operating condition.	i) 2.5 MVAr and 0.5 MVAr fixed capacitor banks were considered for 11 kV Clachan and 11 kV Gisla substations to maintain the system voltages within the acceptable limits. i) 1x 1 MVA and 1x 2.5 MVA transformers are considered for Gisla and Laxay substations respectively to prevent transformers overload. . **Flexibility Services (from local generation or demand):** For the winter scenario, procurement of ~5MVA flexibility services in the Loch Carnan zone to avoid the cable overloading.
Option-6	1) The existing and new subsea cables are loaded up to 26% and 10.7% of rated capacity respectively. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the	1) The feeders from Ardmore to Loch Carnan and Ardmore to Clachan were loaded up to 64% and 47% of their rated capacity, respectively.	i) 1x 1 MVA, 1x 2.5 MVA, 1x6.3 MVA transformers are considered for Gisla, Laxay and Clachan (Clachan3B to Clachan1A) substations to prevent transformers overload.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
	acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay Transformer is Loaded up to 125% of capacity. 4) During the outage of the new cable from Ardmore to Clachan, the existing cable is loaded up to 42% of rating. 5) Region-wise losses: Loch Carnan - 0.2MW and Stornoway - 2.9 MW This option is feasible under both normal and N-1 Contingency operating conditions. However, during contingencies at Ardmore substation will impact reliability of power supply in both regions.	2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones within the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Transformers at Gisla and Laxay substations were overloaded. 4) All the bus voltages and equipment loadings were within acceptable limits, with the following recommendations: i) 1x 1 MVA, 1x 2.5 MVA, and 1x 6.3 MVA transformers were considered for Gisla, Laxay, and Clachan (Clachan 3B to Clachan 1A) substations. ii) 2.0 MVAr and 0.5 MVAr fixed capacitors were considered for 11 kV Clachan and 11 kV Gisla substations. 5) In the event of an N-1 contingency for the 185 mm^2 subsea cable from Ardmore to Loch Maddy, the other run of the 95 mm^2 subsea cable will be overloaded up to 135% of rating. 6) Region-wise losses: Loch Carnan: 0.86 MW and Stornoway: 2.47 MW This option is not feasible under the N-1 contingency operating condition.	ii) 2.0 MVAr and 0.5 MVAr fixed capacitor banks were considered for 11 kV Clachan and 11 kV Gisla substations to maintain the system voltages within the acceptable limits. **Flexibility Services (from local generation or demand):** For the winter scenario, procurement of ~5MVA flexibility services in the Loch Carnan zone to avoid the cable overloading.
Option-7	1) The new subsea cables are each loaded up to 16.9% of rated capacity. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay transformer is loaded up to 125% of capacity. 4) During the outage of one cable from Ardmore to Loch Carnan, the other cable is loaded up to 27% of its rating. 5) Region-wise losses: Loch Carnan - 0.1MW and Stornoway - 2.9 MW. This option is feasible under normal and N-1 Contingency operating conditions. However, during contingencies at Ardmore substation will impact reliability of power supply in both regions.	In this analysis, all generations were out of service at Loch Caran and Stornoway zones, and the observations are summarised below: 1) 2Rx3Cx300 mm^2 cables were considered at Ardmore to Loch Caran. **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) During the normal operation scenario, the two feeders from Ardmore to Loch Carnan were loaded up to 36% of rating, respectively. i) Region-wise losses: Loch Carnan: 1.16 MW and Stornoway: 5.25 MW 5) During the outage of the 33 kV HVDC infeed at Harris substation source (for the PSSE convergence, an additional 12 MVAr reactive power was intended at Harris substation). i) The feeder from Ardmore to Harris was loaded up to 184% of rating, respectively. ii) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 126% of rating. 6) During the outage of the feeder single circuit from Ardmore to Loch Carnan, i) The other circuit feeder from Ardmore to Loch Carnan was loaded up to 72% of rating, ii) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was loaded up to 101%. This option is not feasible under the N-1 contingency operating condition (In the event of 33 kV HVDC outage condition).	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 126% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install an additional 80 MVA transformer in parallel. Reinforcement option 3: Install the 132 kV circuit from Ardmore to Harris and procure a 60 MVA, 132/33 kV transformer at Harris substation. 2) In the Event of HVDC outage, the feeder from Ardmore to Harris was loaded up to 184% of rating. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: It is recommended to increase the additional run of both OHTL and subsea cable from Ardmore to Harris. Reinforcement option 2: Install the 132 kV circuit from Ardmore to Harris. 3) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 4) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 5) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. **Flexibility Services (from local generation or demand):** For the winter scenario, procurement of ~ 30MVA flexibility services in the Stornoway zone to avoid the cable overloading

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
Option-8		In this analysis, all generations were out of service at Loch Caran and Stornoway zones, and the observations are summarised below: 1) 2Rx3Cx300 mm^2 cables were considered at Ardmore to Loch Caran. **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) During the normal operation scenario, the two feeders from Ardmore to Loch Carnan were loaded up to 36% of rating, respectively. i) Region-wise losses: Loch Carnan: 1.16 MW and Stornoway: 5.25 MW 5) During the outage of the 33 kV HVDC infeed at Harris substation source. i) The 132/33 kV, 60 MVA transformer at Ardmore was over loaded. **Note:** *In order to manage the power flows when the HVDC is operational the feeder between Harris to Ardmore should be run open and the Isles of Uist should be fed from Ardmore. Under an outage of the HVDC to Harris the Ardmore feeder should be closed feeding Harris from Ardmore*. This option is feasible under both normal as well as N-1 Contingency operating conditions.	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 126% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install an additional 80 MVA transformer in parallel. Reinforcement option 3: Install the 132 kV circuit from Ardmore to Harris and procure a 60 MVA, 132/33 kV transformer at Harris substation. 2) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 3) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 4) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.
Option-9		In this analysis, all generations were out of service at Loch Caran and Stornoway zones, and the observations are summarised below: 1) 2Rx3Cx300 mm^2 cables were considered at Ardmore to Loch Caran. **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) During the normal operation scenario, the two feeders from Ardmore to Loch Carnan were loaded up to 36% of rating, respectively. i) Region-wise losses: Loch Carnan: 1.16 MW and Stornoway: 5.25 MW 5) During the outage of the 33 kV HVDC infeed at Harris substation source.	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
		i) all voltages were within acceptable limits, and no equipment overloading was observed. **Note:** *In order to manage the power flows when the HVDC is operational the feeder between Harris to Ardmore should be run open and the Isles of Uist should be fed from Ardmore. Under an outage of the HVDC to Harris the Ardmore feeder should be closed feeding Harris from Ardmore*. This option is feasible under both normal as well as N-1 Contingency operating conditions.	
Option- 10	1) The new subsea cables from Ardmore to Loch Carnan and Ardmore to Clachan are loaded up to 17.8% and 11.6% of its rating i.e. 21.94 MVA respectively. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay Transformer is loaded up to 125% of capacity. 4) During the outage of the new cable from Ardmore to Clachan, the other cable from Ardmore to Loch Carnan is loaded up to 24% of its rating 5) Region-wise losses: Loch Carnan - 0.2MW and Stornoway - 2.9 MW This option is feasible under normal as well as N-1 Contingency operating conditions. However, during contingencies at Ardmore substation will impact reliability of power supply in both regions.	In this analysis, all generators were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceed the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5 MVAr, 6 MVAr, 8 MVAr, and 2 MVAr fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) During the normal operation scenario, the feeders from Ardmore to Loch Carnan and Ardmore to Clachan were loaded up to 33% and 38% of its rating, respectively. i) Region-wise losses: Loch Carnan: 0.86 MW and Stornoway: 4.79 MW 5) During the outage of the 33 kV HVDC infeed at Harris substation source (for the PSSE convergence, an additional 12 MVAr reactive power was used at Harris substation). i) The feeder from Ardmore to Harris was loaded to 185 % of its rating, respectively. ii) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 125% of rating. 6) During the outage of the feeder single circuit from Ardmore to Clachan, i) The other circuit feeder from Ardmore to Loch Caranan was loaded up to 72% of rating. ii) The Loch Carnan 33/33 kV, 21 MVA voltage regulator was overloaded up to 101%. 7) During the outage of the feeder from Admore to Loch Carnan, the feeder from Ardmore to Clachan3b was loaded up to 72% of its rating,; all bus voltages are within the acceptable limits, and no equipment overloading was observed. 8) During the outage of the feeder from Admore to Clachan3b Loch Carnan, the feeder from Ardmore to Loch Carnan was loaded up to 72% of its rating; all bus voltages were within acceptable limits, and no equipment overloading was observed. This option is not feasible under the N-1 contingency operating condition (In the event of 33 kV HVDC outage condition).	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 125% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install the additional 80 MVA transformer in parallel. Reinforcement option 3: Install the 132 kV circuit from Ardmore to Harris and procure the 60 MVA, 132/33 kV transformer at Harris substation. 2) In the Event of HVDC outage, the feeder from Ardmore to Harris was loaded up to 185% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: It is recommended to increase the additional run of both OHTL and subsea cable from Ardmore to Harris. Reinforcement option 2: Install the 132 kV circuit from Ardmore to Harris. 3) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 4)3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 5) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. **Flexibility Services (from local generation or demand)** For the winter scenario, procurement of ~ 30MVA flexibility services in the Stornoway zone to avoid the cable overloading.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
Option-11		In this analysis, all generators were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceed the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5 MVAr, 6 MVAr, 8 MVAr, and 2 MVAr fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) During the normal operation scenario, the feeders from Ardmore to Loch Carnan and Ardmore to Clachan were loaded up to 33% and 38% of its rating, respectively. i) Region-wise losses: Loch Carnan: 0.86 MW and Stornoway: 4.79 MW 5) During the outage of the 33 kV HVDC infeed at Harris substation source. i) The 132/33 kV, 60 MVA transformer at Ardmore was over loaded. **Note:** *In order to manage the power flows when the HVDC is operational the feeder between Harris to Ardmore should be run open and the Isles of Uist should be fed from Ardmore. Under an outage of the HVDC to Harris the Ardmore feeder should be closed feeding Harris from Ardmore*. This option is feasible under both normal as well as N-1 Contingency operating conditions.	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 125% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install the additional 80 MVA transformer in parallel. Reinforcement option 3: Install the 132 kV circuit from Ardmore to Harris and procure the 60 MVA, 132/33 kV transformer at Harris substation. 2) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 3)3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 4) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.
Option-12		In this analysis, all generators were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceed the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5 MVAr, 6 MVAr, 8 MVAr, and 2 MVAr fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) During the normal operation scenario, the feeders from Ardmore to Loch Carnan and Ardmore to Clachan were loaded up to 33% and 38% of its rating, respectively. i) Region-wise losses: Loch Carnan: 0.86 MW and Stornoway: 4.79 MW 5) During the outage of the 33 kV HVDC infeed at Harris substation source. i) All voltages were within acceptable limits, and no equipment overloading was observed. **Note:** *In order to manage the power flows when the HVDC is operational the feeder between Harris to Ardmore should be run open and the Isles of Uist should be fed from Ardmore. Under an outage of the HVDC to Harris the Ardmore feeder should be closed feeding Harris*	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2)3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
		from Ardmore. This option is feasible under both normal as well as N-1 Contingency operating conditions.	
Option-13	1) The new subsea cable from Dunvegan to Loch Carnan and Ardmore to Clachan are loaded up to 48% and 25% of its rating i.e. 21.94 MVA respectively. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay transformer is loaded up to 125% than its capacity. 4) During the outage of the new cable from Dunvegan to Loch Carnan, the other cable from Ardmore to Clachan is loaded up to 25% of its rating. 5) Region-wise losses: Loch Carnan - 3.2MW and Stornoway - 2.8 MW. The losses in Loch Carnan increases due to power flow from Dunvegan - Loch Carnan - Ardmore i.e. power circulation between Dunvegan and Loch Carnan. This option is feasible under both normal as well as N-1 Contingency operating conditions. However, power circulation between Dunvegan and Ardmore makes losses in Loch Carnan region very high and may not be feasible from economic point of view. To avoid power circulation, opening of one cable is considered without paralleling and observations is given below: a) When the Ardmore to Clachan cable is opened at the Clachan end, the power is fed through Dunvegan and cable is loaded up to 25% of its rated capacity also losses are reduced in Loch Carnan. b) When the Dunvegan to Ardmore cable is opened at the Dunvegan end then all power is fed through Ardmore grid, by the Ardmore to Clachan subsea cable loaded to 25%, this tends to reduce losses.	In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5 MVAr, 6 MVAr, 8 MVAr, and 2 MVAr fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered from 7 to 10MVA. 4) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 175%; consequently an additional transformer was considered. 5) During the normal operation scenario, the feeders from Dunvegan to Loch Carnan and Ardmore to Clachan were loaded up to 36% and 35% of its rating, respectively. i) Region-wise losses: Loch Carnan: 0.86 MW and Stornoway: 4.79 MW 5) During the outage of the 33 kV HVDC infeed at Harris substation source (for the PSSE convergence, an additional 12 MVAr reactive power was intended at Harris substation). i) The feeder from Ardmore to Harris was loaded up to 194% of its rating, respectively. ii) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 113% of its rating. 6) During the outage of the feeder from Dunvegan to Loch Carnan, the other circuit feeder from Ardmore to Clachan was loaded up to 72% of its rating, respectively. All bus voltages are within acceptable limits, and no equipment overloading was observed. 7) During the outage of the feeder single circuit from Ardmore to Clachan, i) The other circuit feeder from Dunvegan to Loch Caranan was loaded up to 73% of its rating, respectively. ii) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101%. This option is not feasible under the N-1 contingency operating condition (In the event of 33 kV HVDC outage condition)	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 113% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install the additional 80 MVA transformer in parallel. Reinforcement option 3: Install the 132 kV circuit from Ardmore to Harris and procure the 60 MVA, 132/33 kV transformer at Harris substation. 2) In the Event of HVDC outage, the feeder from Ardmore to Harris was loaded up to 194% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: It is recommended to increase the additional run of both OHTL and subsea cable from Ardmore to Harris. Reinforcement option 2: Install the 132 kV circuit from Ardmore to Harris. 3)The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 4)3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 5)The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. **Flexibility Services (from local generation or demand):** For the winter scenario, procurement of ~ 30MVA flexibility services in the Stronoway zone to avoid the cable overloading.
Option-14		In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 113% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
		networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5 MVAr, 6 MVAr, 8 MVAr, and 2 MVAr fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered from 7 to 10MVA. 4) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 175%; consequently an additional transformer was considered. 5) During the normal operation scenario, the feeders from Dunvegan to Loch Carnan and Ardmore to Clachan were loaded up to 36% and 35% of its rating, respectively. i) Region-wise losses: Loch Carnan: 0.86 MW and Stornoway: 4.79 MW 5) During the outage of the 33 kV HVDC infeed at Harris substation source i) The 132/33 kV, 60 MVA transformer at Ardmore was over loaded. 6) During the outage of the feeder single circuit from Ardmore to Clachan, i) The other circuit feeder from Dunvegan to Loch Caranan was loaded up to 73% of its rating, respectively. ii) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101%. **Note:** *In order to manage the power flows when the HVDC is operational the feeder between Harris to Ardmore should be run open and the Isles of Uist should be fed from Ardmore. Under an outage of the HVDC to Harris the Ardmore feeder should be closed feeding Harris from Ardmore*. This option is feasible under both normal as well as N-1 Contingency operating conditions.	Reinforcement option 2: Install the additional 80 MVA transformer in parallel. Reinforcement option 3: Install the 132 kV circuit from Ardmore to Harris and procure the 60 MVA, 132/33 kV transformer at Harris substation. 2)The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 3)3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 4)The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.
Option-15		In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5 MVAr, 6 MVAr, 8 MVAr, and 2 MVAr fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered from 7 to 10MVA. 4) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 175%; consequently an additional transformer was considered. 5) During the normal operation scenario, the feeders from Dunvegan to Loch Carnan and Ardmore to Clachan were loaded up to 36% and 35% of its rating, respectively.	1)The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2)3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3)The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
		i) Region-wise losses: Loch Carnan: 0.86 MW and Stornoway: 4.79 MW 5) During the outage of the 33 kV HVDC infeed at Harris substation source i) All voltages were within acceptable limits, and no equipment overloading was observed. 6) During the outage of the feeder single circuit from Ardmore to Clachan, i) The other circuit feeder from Dunvegan to Loch Caranan was loaded up to 73% of its rating, respectively. ii) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101%. **Note:** *In order to manage the power flows when the HVDC is operational the feeder between Harris to Ardmore should be run open and the Isles of Uist should be fed from Ardmore. Under an outage of the HVDC to Harris the Ardmore feeder should be closed feeding Harris from Ardmore.* This option is feasible under both normal as well as N-1 Contingency operating conditions.	
Option- 16	1) The new subsea cables are each loaded up to 13% of its rating i.e. 21.94 MVA. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay Transformer is Loaded up to 125% than its capacity. 4) During the outage of one cable from Ardmore to Clachan, the other cable is loaded up to 25% of its rating. 5) Region-wise losses: Loch Carnan - 0.3 MW and Stornoway - 2.8 MW This option is feasible under both normal and N-1 Contingency operating conditions. However, during contingencies at Ardmore S/S, the supply to the whole island group will be lost. To increase the reliability beyond Admore via T Network back to Edinbane is required. However, this option is not viable if Lochmaddy has a single cable landing point.	In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5 MVAr, 6 MVAr, 8 MVAr, and 2 MVAr fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered from 7 to 10MVA. 4) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 175%; consequently, an additional transformer was considered. 5) During the normal operation scenario, the feeders from Ardmore to Clachan were loaded up to 36% of its rating, respectively. i) Region-wise losses: Loch Carnan: 1.78 MW and Stornoway: 4.48 MW 5) During the outage of the 33 kV HVDC infeed at Harris substation source (for the PSSE convergence, an additional 12 MVAr reactive power was intended at Harris substation). i) The feeder from Ardmore to Harris was loaded up to 184% of its rating, respectively. ii) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 126% of its rating. 6) During the outage of the one feeder from Ardmore to Clachan, the other circuit feeder from Ardmore to Clachan was loaded up to 72% of its rating, respectively. All bus voltages are within acceptable limits, and no equipment overloading was observed. This option is not feasible under the N-1 contingency operating condition (In the event of 33 kV HVDC outage condition)	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 126% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install the additional 80 MVA transformer in parallel. Reinforcement option 3: Install the 132 kV circuit from Ardmore to Harris and procure the 60 MVA, 132/33 kV transformer at Harris substation. 2) In the Event of HVDC outage, the feeder from Ardmore to Harris was loaded up to 184% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: It is recommended to increase the additional run of both OHTL and subsea cable from Ardmore to Harris. Reinforcement option 2: Install the 132 kV circuit from Ardmore to Harris. 3) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 4) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 5) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 6) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 175%; consequently an additional transformer was considered. **Flexibility Services (from local generation or demand):** For the winter scenario, procurement of ~ 30MVA flexibility services in the Stronoway zone to avoid the cable overloading.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
Option-17	1) The 185 mm^2 subsea cable from Dunvegan to Loch Carnan and Harris to Clachan is loaded up to 56% and 73% of its rating i.e. 21.94 MVA respectively. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Existing OHL from Harris to Harris landing point is loaded up to 105% of its rating i.e 29.3 MVA and 0.5 km line at GRAMS3B substation is loaded up to 101% of its rating i.e. 12 MVA. 4) Laxay transformer is loaded up to 125% than its capacity. 5) During the outage of cable from Dunvegan to Loch Carnan, the other cable from Harris to Clachan is loaded up to 29% of its rating and it is feasible condition. 6) Region-wise losses: Loch Carnan - 4.7 MW and Stornoway - 4.2 MW. The losses in Loch Carnan increases due to power flow from Dunvegan - Loch Carnan - Ardmore i.e. power circulation between Dunvegan and Loch Carnan. But in N-1 contingency condition it is feasible The power circulation between Dunvegan to Ardmore via Loch Carnan network during normal operating conditions can be avoided by considering opening of one of the cable as given below: a)When Harris to Clachan cable is opened at Clachan end the Dunvegan to Loch Carnan cable is loaded up to 25% of its rated capacity with losses in Loch Carnan reduced b) When Dunvegan to Loch Carnan cable is opened at Dunvegan end all power is fed through from Harris via HVDC link, by this Harris to Clachan subsea cable is loaded to 27% with reduced losses in Loch Carnan. This option is not feasible under normal operating conditions. (with the both circuits are in parallel)	In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 6 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 6MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered from 7 to 10MVA. 4) During normal operation, the 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101%. i) Region-wise losses: Loch Carnan: 2.06 MW and Stornoway: 5.80 MW 5) During the outage of the 33 kV HVDC infeed at Harris substation source (for the PSSE convergence, an additional 12 MVAr reactive power was intended at Harris substation). i) The feeder from Ardmore to Harris was loaded up to 192% of its rating, respectively. ***Note:*** *In order to manage the power flows when the HVDC is operational the feeders between Harris to Ardmore and Harris to Clachan should be run open and the Isles of Uist should be fed from Ardmore.* *Under an outage of the HVDC to Harris the Ardmore feeder should be closed feeding Harris from Ardmore.* *If the connection between Harris and Clachan is used in parallel with the feeder from Ardmore to Harris the resulting low impedance path results in power being exported from Harris to Clachan, hence the connection between Harris and Clachan should only be used if there is an outage of the supply at Ardmore or a failure of the Ardmore to Loch Carnan circuit.* 6) During the outage of the feeder from Dunvegan to Loch Carnan, i) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded up to 175%; consequently an additional transformers was considered. ii) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 115% of its rating. iii) Total 72 MW of real power is imported from Harris HVDC infeed. This option is not feasible under the N-1 contingency operating condition (In the event of 33 kV HVDC outage condition).	1) In the Event of HVDC outage, the feeder from Ardmore to Harris was loaded up to 192% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: It is recommended to increase the additional run of both OHTL and subsea cable from Ardmore to Harris. Reinforcement option 2: Install the 132 kV circuit from Ardmore to Harris. 2)The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 3)6MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 4)The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 5)The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 175%; consequently an additional transformer was considered. 6) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 115% of its rating. It is recommended to increase the rating from 6.3 to 8 MVA. 7) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101% of its rating, respectively. It is recommended to increase the rating from 21 to 25 MVA. **Flexibility Services (from local generation or demand):** For the winter scenario, procurement of ~ 30MVA flexibility services in the Stornoway zone to avoid the cable overloading.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
Option-18	-	In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6MVAr, 8MVAr, and 2MVAr capacitor fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered from 7 to 10MVA. 4) During normal operation, the 33/33 kV, 21MVA voltage regulator at Loch Carnan was loaded up to 101%. i) Region-wise losses: Loch Carnan: 2.06 MW and Stornoway: 5.82 MW 5) During the outage of the 33 kV HVDC infeed at Harris substation source: i) The feeders from Ardmore to Harris were loaded up to 89% of their rating. **Note:** *In order to manage the power flows when the HVDC is operational the feeders between Harris to Ardmore and Harris to Clachan should be run open and the Isles of Uist should be fed from Ardmore.* *Under an outage of the HVDC to Harris the Ardmore feeder should be closed feeding Harris from Ardmore.* *If the connection between Harris and Clachan is used in parallel with the feeder from Ardmore to Harris the resulting low impedance path results in power being exported from Harris to Clachan, hence the connection between Harris and Clachan should only be used if there is an outage of the supply at Ardmore or a failure of the Ardmore to Loch Carnan circuit.* In the event of a Dunvegan Source outage condition, the Harris to Clachan feeder should be energized. 6) During the outage of the feeder from Dunvegan to Loch Carnan: i) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded up to 171%; consequently, an additional transformer was considered. ii) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 110% of its rating. iii) Total 72 MW of real power is imported from Harris HVDC infeed. This option is feasible under both normal as well as N-1 Contingency operating conditions.	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101% of its rating, respectively. It is recommended to increase the rating from 21 to 25 MVA. 5) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 171%; consequently an additional transformer was considered. 6) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 110% of its rating. It is recommended to increase the rating from 6.3 to 8 MVA.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
Option-19	-	In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6MVAr, 8MVAr, and 2MVAr capacitor fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered from 7 to 10MVA. 4) During normal operation, the 33/33 kV, 21MVA voltage regulator at Loch Carnan was loaded up to 101%. i) Region-wise losses: Loch Carnan: 2.06 MW and Stornoway: 5.82 MW 5) During the outage of the 33 kV HVDC infeed at Harris substation source: i) The feeders from Ardmore to Harris were loaded up to 89% of their rating. **Note:** *In order to manage the power flows when the HVDC is operational the feeders between Harris to Ardmore and Harris to Clachan should be run open and the Isles of Uist should be fed from Ardmore.* *Under an outage of the HVDC to Harris the Ardmore feeder should be closed feeding Harris from Ardmore.* *If the connection between Harris and Clachan is used in parallel with the feeder from Ardmore to Harris the resulting low impedance path results in power being exported from Harris to Clachan, hence the connection between Harris and Clachan should only be used if there is an outage of the supply at Ardmore or a failure of the Ardmore to Loch Carnan circuit.* In the event of a Dunvegan Source outage condition, the Harris to Clachan feeder should be energized. 6) During the outage of the feeder from Dunvegan to Loch Carnan: i) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded up to 171%; consequently, an additional transformer was considered. ii) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 110% of its rating. iii) Total 72 MW of real power is imported from Harris HVDC infeed. This option is feasible under both normal as well as N-1 Contingency operating conditions.	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101% of its rating, respectively. It is recommended to increase the rating from 21 to 25 MVA. 5) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 171%; consequently an additional transformer was considered. 6) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 110% of its rating. It is recommended to increase the rating from 6.3 to 8 MVA.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
Option-20	-	In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 6 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 6MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10MVA. 4) During normal operation, the 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101%: i) Region-wise losses: Loch Carnan: 2.06 MW and Stornoway: 5.80 MW 5) During the outage of the 33 kV HVDC infeed at the Harris substation source: i) The feeder from 132 kV Ardmore to Harris was loaded up to 63% of its rating. ii) The 60 MVA, 132/33 kV transformer was loaded up to 85% of its rating. ***Note:*** *In order to manage the power flows when the HVDC is operational the feeders between Harris to Ardmore and Harris to Clachan should be run open and the Isles of Uist should be fed from Ardmore.* *Under an outage of the HVDC to Harris the Ardmore feeder should be closed feeding Harris from Ardmore.* *If the connection between Harris and Clachan is used in parallel with the feeder from Ardmore to Harris the resulting low impedance path results in power being exported from Harris to Clachan, hence the connection between Harris and Clachan should only be used if there is an outage of the supply at Ardmore or a failure of the Ardmore to Loch Carnan circuit.* 6) During the outage of the feeder from Dunvegan to Loch Carnan: i) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded up to 171%; consequently, an additional transformer was considered. ii) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 110% of its rating. iii) Total 72 MW of real power is imported from Harris HVDC infeed. This option is feasible under both normal as well as N-1 Contingency operating conditions.	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 6MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101% of its rating. It is recommended to increase the rating from 21 to 25 MVA. 5) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 171%; consequently an additional transformer was considered. 6) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 110% of its rating. It is recommended to increase the rating from 6.3 to 8 MVA.
Option-21	1) The existing subsea cable from Ardmore to Loch Carnan is loaded up to 135% of its rated capacity i.e. 14 MVA and		i) 2MVAr and 0.5 MVAr fixed capacitor banks were considered for 11 kV Clachan and 11 kV Gisla substations to maintain the system voltages within

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
	new subsea cable from Dunvegan to Loch Carnan is loaded up to 69% of its rating i.e. 21.94 MVA. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay transformer is loaded up to 125% of its capacity. 4) During the outage of the cable from Dunvegan to Loch Carnan, the other cable from Ardmore to Loch Carnan is loaded up to 42% of its rating. 5) Region-wise losses: Loch Carnan - 4.7 MW and Stornoway - 2.8 MW. The losses in Loch Carnan increases due to power flow from Dunvegan - Loch Carnan - Ardmore i.e. power circulation between Dunvegan and Loch Carnan. This option is not feasible under normal operating conditions. (with the both circuits are in parallel) But in N-1 contingency condition it is feasible	1) The existing subsea cable from Ardmore to Loch Carnan was loaded up to 58% of its derated capacity, i.e., 14 MVA, and the new feeder from Dunvegan to Loch Carnan was loaded up to 50% of its rated capacity. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones within the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Transformers at Gisla and LAXAY substations are overloaded. 4) All the bus voltages and equipment loadings are within acceptable limits, with the following recommendations: i) 2MVAr and 0.5 MVAr fixed capacitors were considered for the 11 kV Clachan and 11 kV Gisla substations. ii) 1x 1 MVA and 1x 2.5 MVA transformers are considered for Gisla and LAXAY substations. 5) During the outage of the cable from Dunvegan to Loch Carnan, the other cable from Ardmore to Loch Carnan was loaded up to 135% of its rating. 6) Losses by region: Loch Carnan (1 MW) and Stornoway (2.89 MW). According to the load flow study's results, this option is viable for normal operating conditions. This option is not feasible under N-1 contingency operating conditions.	the acceptable limits. ii) 1x 1 MVA and 1x 2.5 MVA transformers are considered for Gisla and Laxay substations to prevent transformers overload. **Flexibility Services (from local generation or demand):** For the winter scenario, procurement of ~5MVA flexibility services in the Loch Carnan zone to avoid the cable overloading.
Option-22	1) The new subsea cable from Ardmore to Loch Carnan and Dunvegan to Loch Carnan is loaded up to 79% and 65% of its rated capacity i.e. 21.94MVA respectively. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay transformer is loaded up to 125% of its capacity. 4) During the outage of cable from Dunvegan to Loch Carnan, the other cable from Ardmore to Loch Carnan is loaded up to 27% of its rating. 5) Region-wise losses: Loch Carnan - 3.1 MW and Stornoway - 2.8 MW. The losses in Loch Carnan increase due to power flow from Dunvegan - Loch Carnan - Ardmore i.e. power circulation between Dunvegan and Loch Carnan.	In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8 MVAr, and 2 MVAr fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered to be 7 to 10 MVA. 4) During normal operation, losses by region: Loch Carnan (2.01 MW) and Stornoway (5.88 MW).	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 112% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install the additional 80 MVA transformer in parallel. Reinforcement option 3: Install the 132 kV circuit from Ardmore to Harris and procure the 60 MVA, 132/33 kV transformer at Harris substation. 2) In the Event of HVDC outage, the feeder from Ardmore to Harris was loaded up to 190% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: It is recommended to increase the additional run of both OHTL and subsea cable from Ardmore to Harris. Reinforcement option 2: Install the 132 kV circuit from Ardmore to Harris.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
	This option is feasible under both normal as well as N-1 Contingency operating conditions. However, power circulation between Dunvegan and Ardmore makes losses in Loch Carnan region very high and may not be feasible from economic point of view. To avoid power circulation, opening of one cable is considered without paralleling and observations is given below: a)When Admore to Loch Carnan cable is opened the Dunvegan to Loch Carnan cable is loaded up to 25% of its rated capacity and losses are reduced in Loch Carnan. b) When Dunvegan Loch Carnan cable is opened at Dunvegan end then Admore to Loch Carnan subsea cable is loaded up to 22% of its rating and losses are minimum in Loch Carnan.	5) During the outage of the 33 kV HVDC infeed at Harris substation source (for the PSSE convergence, an additional 12 MVAr reactive power was intended at Harris substation). i) The feeder from Ardmore to Harris was loaded up to 190% of its rating, respectively. ii) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 112% of its rating. 6) During the outage of the feeder from Dunvegan to Loch Carnan, all voltages were within acceptable limits, and no equipment overloading was observed. 7) During the outage of the feeder from Ardmore to Loch Carnan, all voltages were within the acceptable limits, and the 33/33 kV voltage regulator at Loch Carnan was overloaded up to 101%. This option is not feasible under the N-1 contingency operating condition (In the event of 33 kV HVDC outage condition).	3) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 4) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 4) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. **Flexibility Services (from local generation or demand):** For the winter scenario, procurement of ~ 30MVA flexibility services in the Stornoway zone to avoid the cable overloading.
Option-23		In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8 MVAr, and 2 MVAr fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered to be 7 to 10 MVA. 4) During normal operation, losses by region: Loch Carnan (2.01 MW) and Stornoway (5.88 MW). 5) During the outage of the 33 kV HVDC infeed at Harris substation source i) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 112% of its rating. 6) During the outage of the feeder from Dunvegan to Loch Carnan, all voltages were within acceptable limits, and no equipment overloading was observed. 7) During the outage of the feeder from Ardmore to Loch Carnan, all voltages were within the acceptable limits, and the 33/33 kV voltage regulator at Loch Carnan was overloaded up to 101%. This option is feasible under both normal as well as N-1 Contingency operating conditions.	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 112% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install the additional 80 MVA transformer in parallel. Reinforcement option 3: Install the 132 kV circuit from Ardmore to Harris and procure the 60 MVA, 132/33 kV transformer at Harris substation. 2) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 3) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 4) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
Option-24		In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8 MVAr, and 2 MVAr fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered to be 7 to 10 MVA. 4) During normal operation, losses by region: Loch Carnan (2.01 MW) and Stornoway (5.88 MW). 5) During the outage of the 33 kV HVDC infeed at Harris substation source i) All voltages were within acceptable limits, and no equipment overloading was observed. 6) During the outage of the feeder from Dunvegan to Loch Carnan, all voltages were within acceptable limits, and no equipment overloading was observed. 7) During the outage of the feeder from Ardmore to Loch Carnan, all voltages were within the acceptable limits, and the 33/33 kV voltage regulator at Loch Carnan was overloaded up to 101%. This option is feasible under both normal as well as N-1 Contingency operating conditions.	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.
Option-25	1) The existing subsea cable from Ardmore to Loch Carnan is loaded up to 26% of its rated capacity i.e. 14 MVA and new subsea cable from Harris to Clachan is loaded up to 11% of its rating i.e. 21.94 MVA. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively.All the bus voltages are within the acceptable limits of ±6%. 3) Laxay transformer is loaded up to 125% than its capacity. 4) During the outage of cable from Harris to Clachan, the other cable from Ardmore to Loch Carnan is loaded up to 42% of its rating. Also during the outage of existing cable from Ardmore to Harris, power to Stornoway is supplied via HVDC source near it.. 5) Region-wise losses: Loch Carnan - 0.2 MW and	1) The existing subsea cable from Ardmore to Loch Carnan was loaded up to 68% of its rated capacity, i.e., 14 MVA, and the feeder from Harris to Clachan was loaded up to 52% of its rated capacity, respectively. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Transformers at Gisla and Laxay substations were overloaded. 4) All the bus voltages and equipment loadings were within acceptable limits, with the following recommendations: i) 2.5MVAr and 0.5 MVAr fixed capacitors were considered for 11 kV Clachan and 11 kV Gisla substations. ii) 1x 1 MVA and 1x 2.5 MVA transformers were considered for Gisla and Laxay substations. 4) During the outage of the feeder from Harris to Clachan, the other feeder from Ardmore to Loch Carnan was loaded up to 136% of its rating. Also, during the outage of the existing feeder from Ardmore to Harris, power will be supplied to the Stornoway network through the HVDC source at the Harris substation. 5) Region-wise losses: Loch Carnan: 0.9 MW and Stornoway: 2.7 MW.	i) 2.5MVAr and 0.5 MVAr fixed capacitor banks were considered for 11 kV Clachan and 11 kV Gisla substations to maintain the system voltages within the acceptable limits. ii) 1x 1 MVA and 1x 2.5 MVA transformers are considered for Gisla and Laxay substations to prevent transformers overload. **Flexibility Services (from local generation or demand):** For the winter scenario, procurement of ~5MVA flexibility services in the Loch Carnan zone to avoid the cable overloading.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
	Stornoway - 2.8 MW. This option is feasible under both normal as well as N-1 Contingency operating conditions. The reliability of power supply to both Loch Carnan and Stornoway is improved due to two sources of power i.e., HVDC supply to Harris grid and 33kV supply from Ardmore grid substation.	This option is not feasible under the N-1 contingency operating condition.	
Option-26	1) The new subsea cables from Ardmore to Loch Carnan and Harris to Clachan are loaded up to 17% and 10% of their rated capacity i.e. 21.94 MVA respectively. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay transformer is loaded up to 125% of its capacity. 4) During the outage of cable from Harris to Clachan, the other cable from Ardmore to Loch Carnan is loaded up to 24% of its rating. Also, during the outage of existing cable from Ardmore to Harris, power to Stornoway is supplied via HVDC source at Harris substation. 5) Region-wise losses: Loch Carnan - 0.2 MW and Stornoway - 2.8 MW. 6) The two subsea cables from Ardmore to Harris are loaded to up to 45% and 45% of their rated capacity respectively. This option is feasible under both normal as well as N-1 contingency operating conditions in both Loch Carnan and Stornoway regions. Reliability of power supply to both Loch Carnan and Stornoway is enhanced due two sources of power i.e., HVDC supply at Harris and Ardmore grid substation.	In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarized below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, consequently required reactive power compensation at Stornoway and Loch Carnan zones as 16 MVAr and 6 MVAr respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 6MVAr, 6 MVAr, 8MVAr and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33kV Battery point 1A and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered from 7 to 10MVA. 4) During normal operation, 33/33 kV, 21MVA voltage regulator at Loch Carnan was over loaded upto 101%. i) Losses by region: Loch Carnan (1.15 MW) and Stornoway (6.16 MW). 5) During the outage of the 33 kV HVDC infeed at Harris substation source (for the PSSE convergence, an additional 12 MVAr reactive power was intended at Harris substation). i) The feeders from Ardmore to Harris were loaded up to 88% of their rating. ii) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 123% of its rating. **Note:** *In order to manage the power flows when the HVDC is operational the feeders between Harris to Ardmore and Harris to Clachan should be run open and the Isles of Uist should be fed from Ardmore.* *Under an outage of the HVDC to Harris the Ardmore feeder should be closed feeding Harris from Ardmore.* *If the connection between Harris and Clachan is used in parallel with the feeder from Ardmore to Harris the resulting low impedance path results in power being exported from Harris to Clachan, hence the connection between Harris and Clachan should only be used if there is an outage of the supply at Ardmore or a failure of the Ardmore to Loch Carnan circuit.* 6) During the outage of the feeder from Ardmore to Loch Carnan, i) The transformer at Clachan (Clachan3B to Clachan1A) substation was 175% loaded, consequently an additional transformer was considered.	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 123% of its rating. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install an additional 80 MVA transformer in parallel. Reinforcement option 3: Install a 132 kV circuit from Ardmore to Harris and procure a 60 MVA, 132/33 kV transformer at Harris substation. 2) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 3) 6MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 4) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 5) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101% of its rating, respectively. It is recommended to increase the rating from 21 to 25 MVA.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
		ii) The transformer at Clachan (Clachan3A to Clachan1A) substation was 115% loaded. iii) Total 72 MW real power is import from Harris HVDC infeed. This option is feasible under both normal as well as N-1 Contingency operating conditions.	
Option-27	1) The new subsea cable from Ardmore to Loch Carnan, Dunvegan to Loch Carnan and Harris to Clachan are loaded up to 58%, 63% and 22% of its rated capacity i.e. 21.94MVA respectively. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay Transformer is loaded up to 125% than its capacity. 4) During the outage of cable from Clachan to Harris, the other cable from Ardmore to Loch Carnan is loaded up to 79% of its rating. 5) Region-wise losses: Loch Carnan - 2.4 MW and Stornoway - 2.8 MW. The losses in Loch Carnan increases due to power flow from Dunvegan - Loch Carnan - Ardmore i.e. power circulation between Dunvegan and Loch Carnan. This option is feasible under both normal as well as N-1 Contingency operating conditions. However, power circulation between Dunvegan and Ardmore makes losses in Loch Carnan region very high and may not be feasible from economic point of view. To avoid power circulation the opening of two cable without paralleling is considered as follows: a) When Admore to Loch Carnan and Harris to Clachan cables are opened then the Dunvegan to Loch Carnan cable is loaded with 25% of its capacity and reduces the losses in Loch Carnan. b) When Dunvegan to Loch Carnan and Harris to Clachan cables are opened then the Admore to Loch Carnan subsea cable is loaded to 24% of its rated capacity and reduces the losses in Loch Carnan.	In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered from 7 to 10MVA. 4) During normal operation, the 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101%. i) Losses by region: Loch Carnan (1.28 MW) and Stornoway (5.17 MW). 5) During the outage of the 33 kV HVDC infeed at Harris substation source (for the PSSE convergence, an additional 12 MVAr reactive power was intended at Harris substation): i) The feeder from Ardmore to Harris was loaded up to 192% of its rating, respectively. **Note:** *In order to manage the power flows when the HVDC is operational the feeders between Harris to Ardmore and Harris to Clachan should be run open and the Isles of Uist should be fed from Ardmore.* *Under an outage of the HVDC to Harris the Ardmore feeder should be closed feeding Harris from Ardmore.* *If the connection between Harris and Clachan is used in parallel with the feeder from Ardmore to Harris the resulting low impedance path results in power being exported from Harris to Clachan, hence the connection between Harris and Clachan should only be used if there is an outage of the supply at Ardmore or a failure of the Ardmore to Loch Carnan circuit.* 6) During the outage of the feeder from Dunvegan to Loch Carnan: i) The transformer at Clachan (Clachan3B to Clachan1A) substation was 175% loaded; consequently an additional transformer was considered. ii) The transformer at Clachan (Clachan3A to Clachan1A) substation was 115% loaded. iii) The total 72 MW of real power is imported from Harris HVDC infeed.	1) In the Event of HVDC outage, the feeder from Ardmore to Harris was loaded up to 192% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: It is recommended to increase the additional run of both OHTL and subsea cable from Ardmore to Harris. Reinforcement option 2: Install the 132 kV circuit from Ardmore to Harris. 2) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 3) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 4) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 5) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 175%; consequently an additional transformer was considered. 6) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 115% of its rating. It is recommended to increase the rating from 6.3 to 8 MVA. **Flexibility Services (from local generation or demand)** For the winter scenario, procurement of ~ 30MVA flexibility services in the Stornoway zone to avoid the cable overloading.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
		This option is not feasible under the N-1 contingency operating condition (In the event of 33 kV HVDC outage condition).	
Option-28		In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered from 7 to 10MVA. 4) During normal operation, the 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101%. i) Losses by region: Loch Carnan (1.28 MW) and Stornoway (5.17 MW). 5) During the outage of the 33 kV HVDC infeed at Harris substation source i) All voltages were within acceptable limits, and no equipment overloading was observed. **Note:** *In order to manage the power flows when the HVDC is operational the feeders between Harris to Ardmore and Harris to Clachan should be run open and the Isles of Uist should be fed from Ardmore.* *Under an outage of the HVDC to Harris the Ardmore feeder should be closed feeding Harris from Ardmore.* *If the connection between Harris and Clachan is used in parallel with the feeder from Ardmore to Harris the resulting low impedance path results in power being exported from Harris to Clachan, hence the connection between Harris and Clachan should only be used if there is an outage of the supply at Ardmore or a failure of the Ardmore to Loch Carnan circuit.* 6) During the outage of the feeder from Dunvegan to Loch Carnan: i) The transformer at Clachan (Clachan3B to Clachan1A) substation was 175% loaded; consequently an additional transformer was considered.	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 175%; consequently an additional transformer was considered. 5) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 115% of its rating. It is recommended to increase the rating from 6.3 to 8 MVA.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
		ii) The transformer at Clachan (Clachan3A to Clachan1A) substation was 115% loaded. iii) The total 72 MW of real power is imported from Harris HVDC infeed. This option is feasible under both normal as well as N-1 Contingency operating conditions.	
Option-29		In this analysis, all generations were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: **Voltage Levels:** Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV. Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered from 7 to 10MVA. 4) During normal operation, the 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101%. i) Losses by region: Loch Carnan (1.28 MW) and Stornoway (5.17 MW). 5) During the outage of the 33 kV HVDC infeed at Harris substation source i) All voltages were within acceptable limits, and no equipment overloading was observed. **Note:** *In order to manage the power flows when the HVDC is operational the feeders between Harris to Ardmore and Harris to Clachan should be run open and the Isles of Uist should be fed from Ardmore.* *Under an outage of the HVDC to Harris the Ardmore feeder should be closed feeding Harris from Ardmore.* *If the connection between Harris and Clachan is used in parallel with the feeder from Ardmore to Harris the resulting low impedance path results in power being exported from Harris to Clachan, hence the connection between Harris and Clachan should only be used if there is an outage of the supply at Ardmore or a failure of the Ardmore to Loch Carnan circuit.* 6) During the outage of the feeder from Dunvegan to Loch Carnan: i) The transformer at Clachan (Clachan3B to Clachan1A) substation was 175% loaded; consequently an additional transformer was considered. ii) The transformer at Clachan (Clachan3A to Clachan1A) substation was 115% loaded. iii) The total 72 MW of real power is imported from Harris HVDC infeed. This option is feasible under both normal as well as N-1 Contingency operating conditions.	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 175%; consequently an additional transformer was considered. 5) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 115% of its rating. It is recommended to increase the rating from 6.3 to 8 MVA.

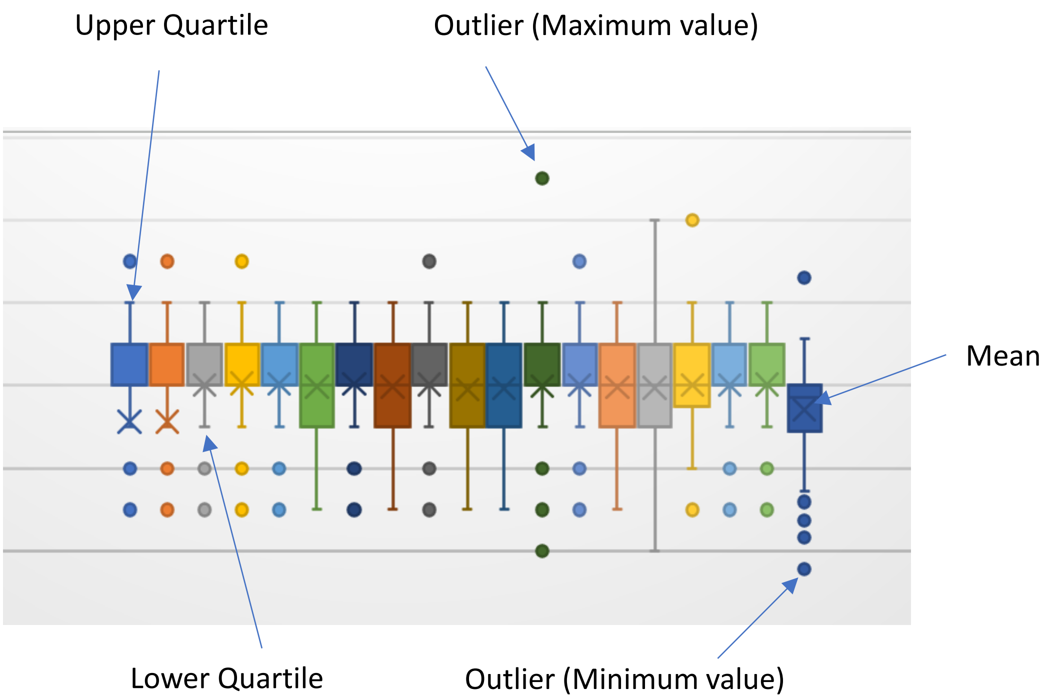
OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
Option-30	1) The existing 500mm^2 subsea cable loaded up to 52% of its rated capacity i.e., 35 MVA. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay transformer is loaded up to 125% than its capacity. 4) During the outage of this cable from Ardmore to Stornoway, Stornoway will be islanded. 5) Region-wise losses: Loch Carnan - 0.3MW and Stornoway - 2.9 MW This option is not feasible under N-1 Contingency operating conditions.	1) The 500-mm^2 subsea cable from Ardmore to Harris was loaded up to 22% of its rated capacity. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Transformers at Gisla and Laxay substations were overloaded. 4) All the bus voltages and equipment loadings were within acceptable limits, with the following recommendations: i) 1x 185 mm^2 cable was selected for the Ardmore to Loch Carnan subsea cable. ii) 2.5 MVAr and 0.5 MVAr fixed capacitors were considered for 11 kV Clachan and 11 kV Gisla substations. iii) 1x 1 MVA and 1x 2.5 MVA transformers were considered for Gisla and Laxay substations. iv) 2x 3.5 MVAr switched and fixed shunt reactors at Loch Carron were taken out of service. 5) During the outage of this cable from Ardmore to Harris, the Stornoway grid will be islanded. Region-wise losses: Loch Carnan: 0.8 MW and Stornoway: 3.9 MW This option is not feasible under N-1 contingency operating conditions.	i) 1x 185 mm^2 cable was selected for the Admore to Loch Carron subsea cable. ii) 2.5 MVAr and 0.5 MVAr fixed capacitors were considered for 11 kV Clachan and 11 kV Gisla substations. iii) 1x 1 MVA and 1x 2.5 MVA transformers are considered for Gisla and Laxay substations. iv) 2x 3.5 MVAr switched and fixed shunt reactors at Loch Carron are taken out of service.
Option-31	1) The existing and new subsea cables are loaded up to 26% and 26% of its rated capacity respectively. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay transformer is loaded up to 125% than its capacity. 4) During the outage of the new cable from Ardmore to Harris, the existing cable is loaded up to 52% of its rating. 5) Region-wise losses: Loch Carnan - 0.3MW and Stornoway - 2.5 MW This option is feasible under both normal and N-1 Contingency operating conditions. However, to increase reliability beyond Admore via T Network back to Edinbane is required	In this analysis, all generators were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: Voltage Levels: Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 6 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 6MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered from 7 to 10MVA. 4) During normal operation, 33/33 kV, 21MVA voltage regulator at Loch Carnan was over loaded upto 101%. i) Losses by region: Loch Carnan (1.15 MW) and Stornoway (6.16 MW). 5) During the outage of the 33 kV HVDC infeed at Harris substation source (for the PSSE convergence, an additional 12 MVAr reactive power was intended at Harris substation). i) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 109% of its rating. ii) The feeders from Ardmore to Harris were loaded up to 73% of their rating. 6) During the outage of Ardmore to Loch Carnan feeder the complete Loch Carnan zone will be islanded. This option is not feasible under N-1 contingency operating conditions.	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 109% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install the additional 80 MVA transformer in parallel. Reinforcement option 3: Install the 132 kV circuit from Ardmore to Harris and procure the 60 MVA, 132/33 kV transformer at Harris substation. 2) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 3) 6MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 4)The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 5) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101% of its rating, respectively. It is recommended to increase the rating from 21 to 25 MVA.

OPTIONS	Summer Minimum Scenario	Winter Maximum Scenario	Remarks with respect to the 2050 demand/ generation
Option-32	1)The 132kV feeder from Ardmore to Harris is loaded up to 31% of its rated capacity with existing 33kV cable kept open. 2) Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. 3) Laxay transformer is loaded up to 125% of capacity. 4) Region-wise losses: Loch Carnan - 0.3MW and Stornoway - 2.2MW This option is feasible under both normal and N-1 contingency operating conditions in both Loch Carnan and Stornoway regions. Existing 33kV cable from Ardmore to Harris is kept open during normal operating conditions and it is closed when there is outage on new 132kV cable from Ardmore to Harris.	In this analysis, all generators were out of service at Loch Carnan and Stornoway zones, and the observations are summarised below: Voltage Levels: Voltage levels at 33 kV and 11 kV substation buses in the Loch Carnan and Stornoway zones exceeded the acceptable limits, ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage, respectively. To maintain the acceptable limits, we consequently required reactive power compensation at the Stornoway and Loch Carnan zones of 16 MVAr and 3.5 MVAr, respectively. 1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was considered from 7 to 10MVA. 4) During normal operation, 33/33 kV, 21MVA voltage regulator at Loch Carnan was over loaded up to 101%. i) Losses by region: Loch Carnan (1.18 MW) and Stornoway (6.16 MW). 5) During the outage of the 33 kV HVDC infeed at Harris substation source (for the PSSE convergence, an additional 12 MVAr reactive power was intended at Harris substation). i) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 67% of its rating. ii) The 132 kV feeder from Ardmore to Harris was loaded up to 50% of its rating. 6) During the outage of Ardmore to Loch Carnan feeder the complete Loch Carnan zone will be islanded This option is not feasible under N-1 contingency operating conditions.	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101% of its rating, respectively. It is recommended to increase the rating from 21 to 25 MVA.

4.2.1 Load flow results summary profiles

Appendix B contains the full load flow results for the options. The following sections contain a summary of voltage and equipment loading for each option and summer and winter conditions using a "box and whisker" chart. The charts can be interpreted as in the Figure 4-1 below. The box covers the interquartile interval where 50% of the data lie.

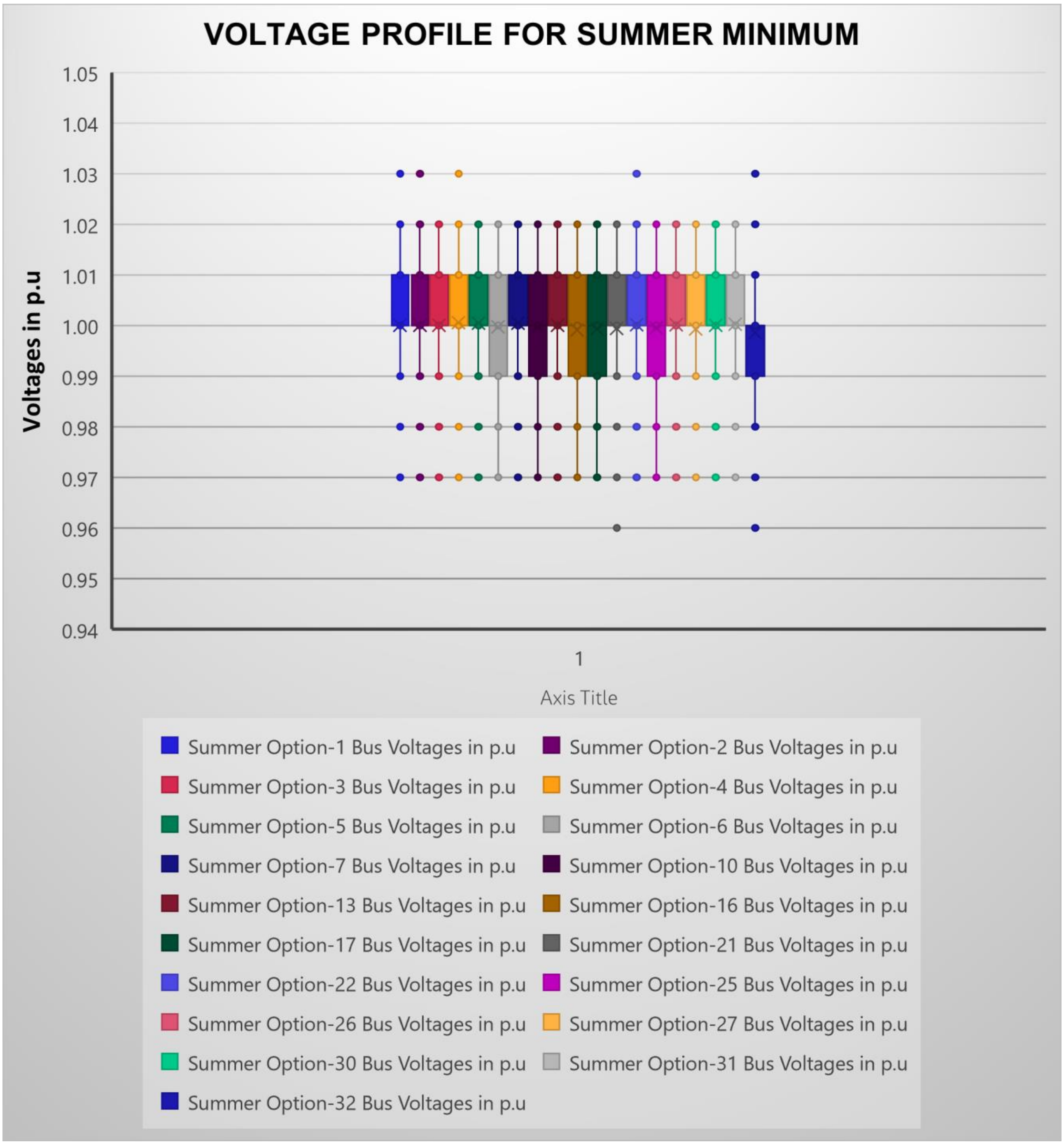
Figure 4-1 Box and Whisker chart interpretation



4.2.2 Summary voltage profile for the summer minimum

The load flow summary voltages profile for the summer minimum is shown in the Figure 4-2. It is observed that all bus voltages are within acceptable limits, except for options 1 and 2 ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage.

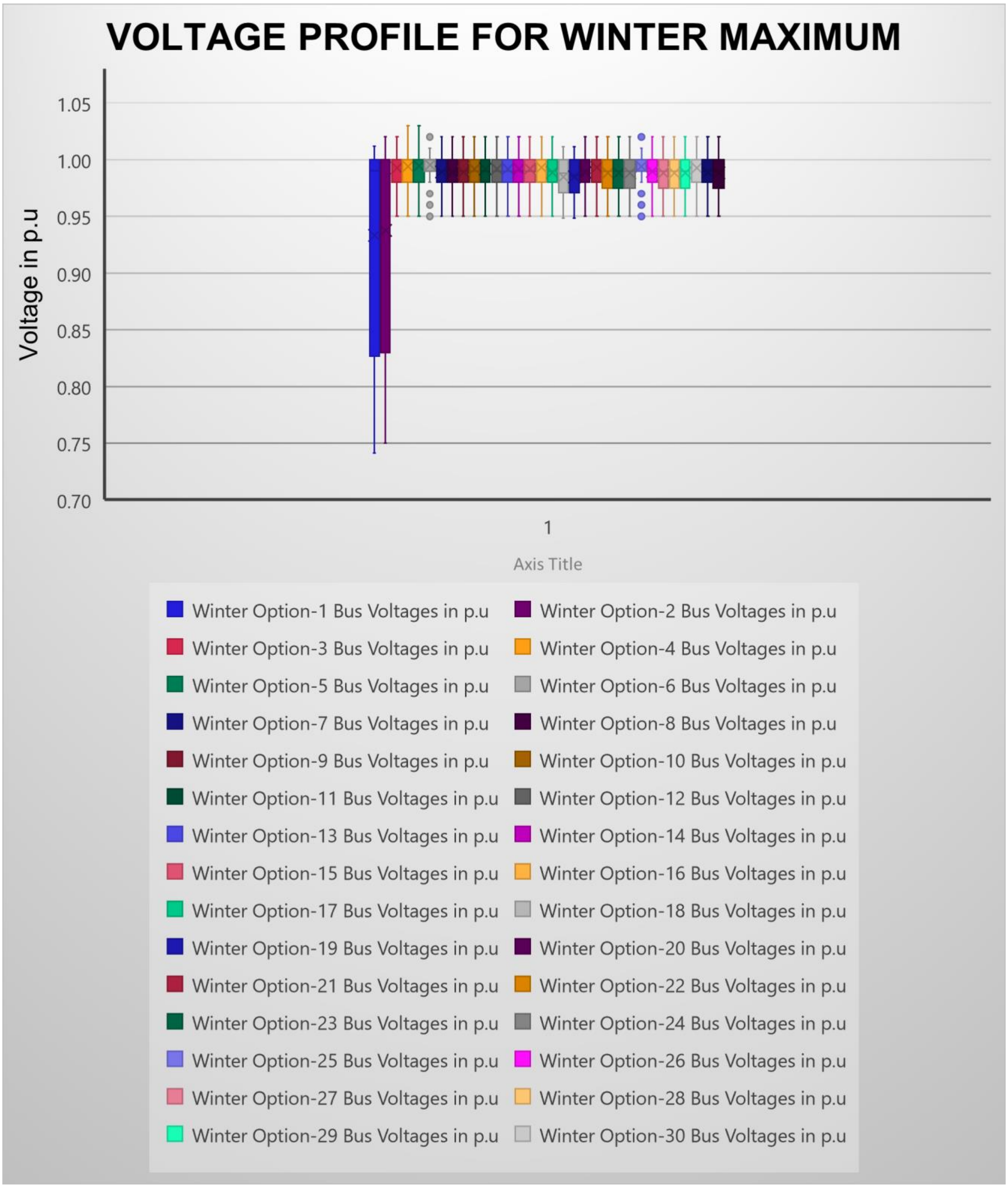
Figure 4-2 Load flow summary voltages profile for the summer minimum



4.2.3 Summary voltage profile for the winter maximum

The load flow summary voltages profile for the winter maximum is shown in the Figure 4-3. It is observed that all bus voltages are within acceptable limits, except for options 1 and 2 ranging from 94% to 101.2% and 103% for networks with 33 kV/LV connections and 33 kV networks of their nominal voltage.

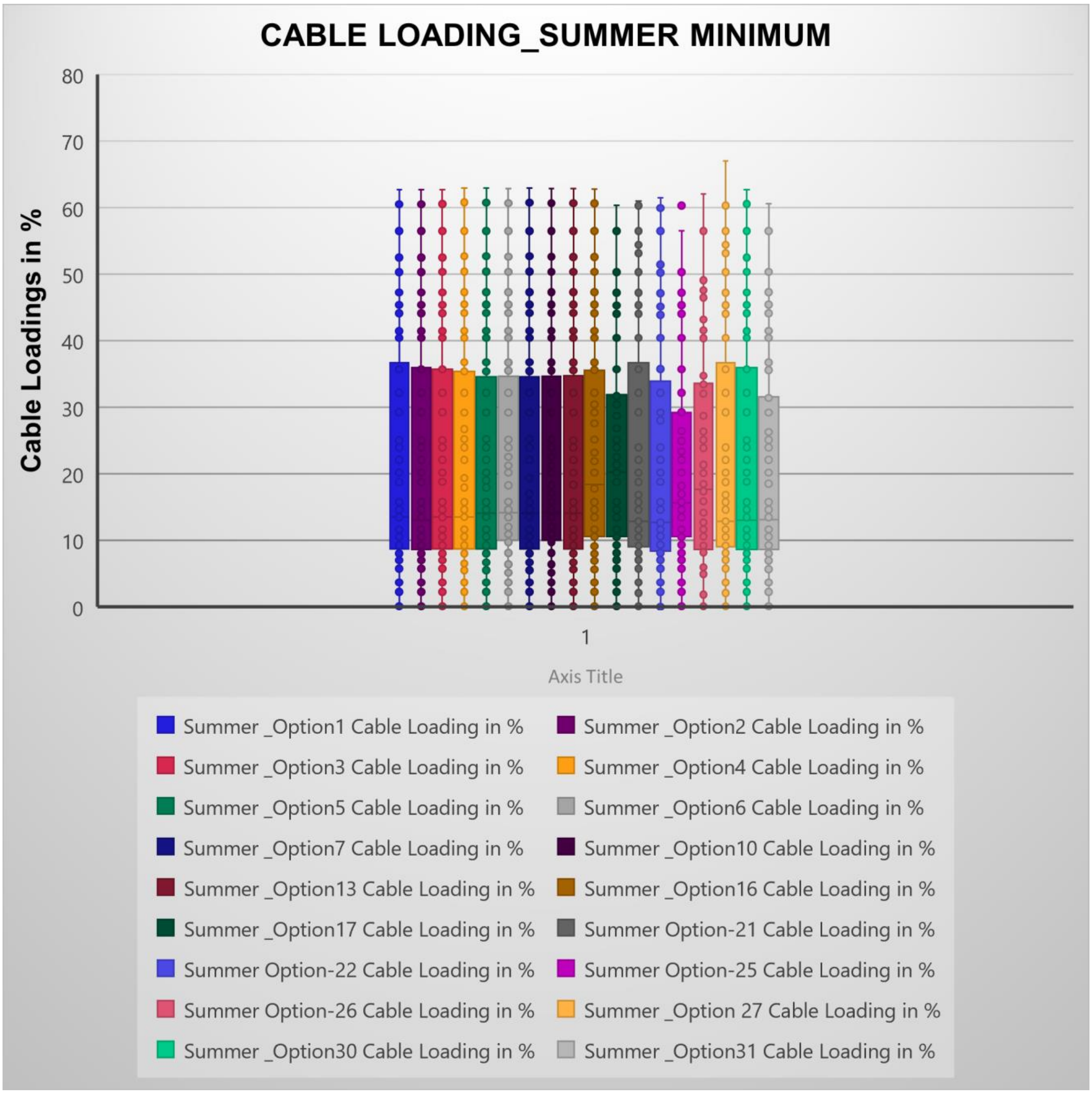
Figure 4-3 Load flow summary voltages profile for the winter maximum



4.2.4 Summary cable loadings for the summer minimum

The load flow cable loading percentage summary for the summer minimum is shown in Figure 4-4. All cable loadings are below 100% of their rated capacity.

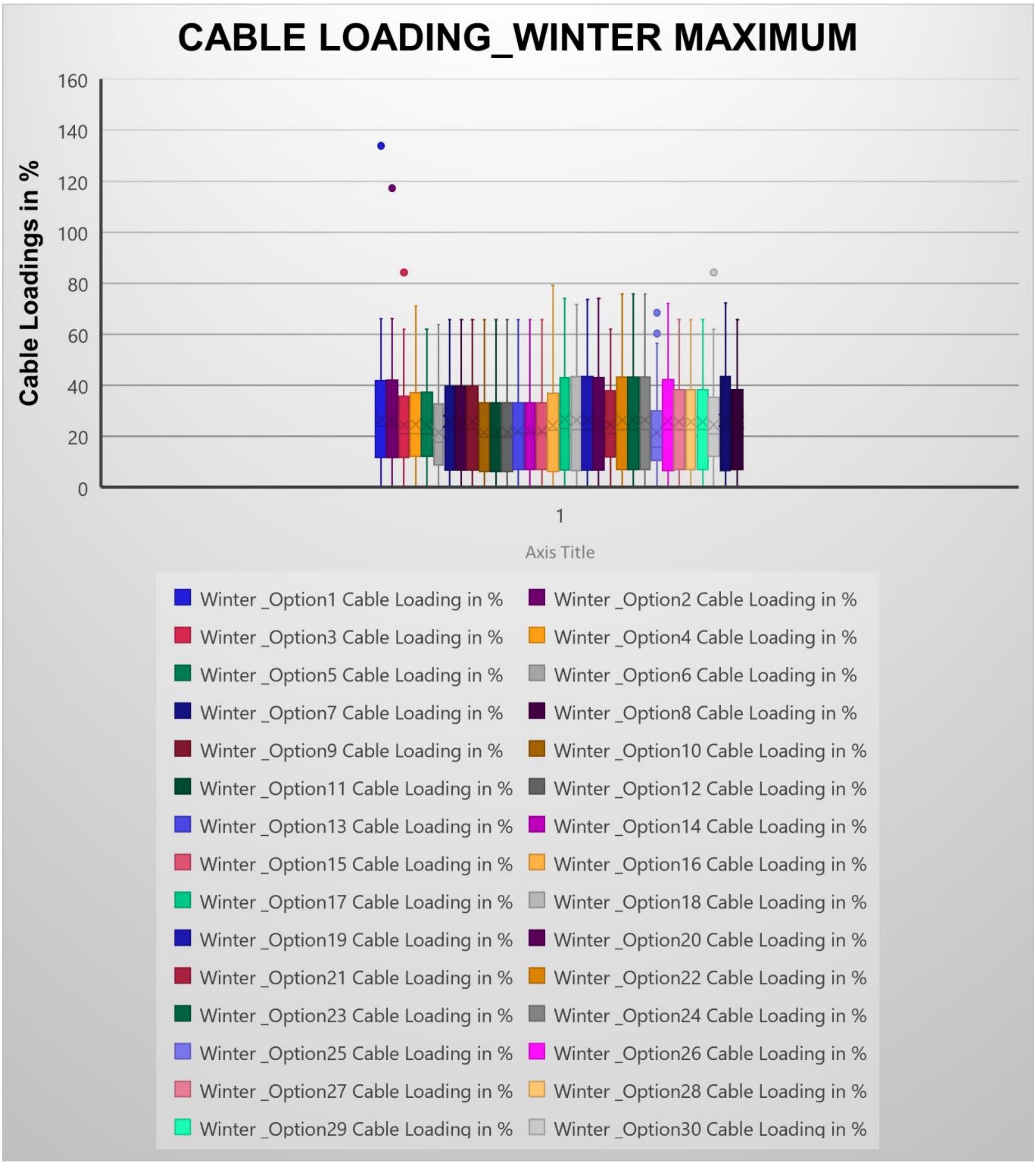
Figure 4-4 Load flow summary cable loading for summer minimum



4.2.5 Summary cable loadings for the winter maximum

The load flow cable loading percentage summary for the winter maximum is shown in Figure 4-5 . All cable loadings are below 100% of their rated capacity, except for options 1 and 2.

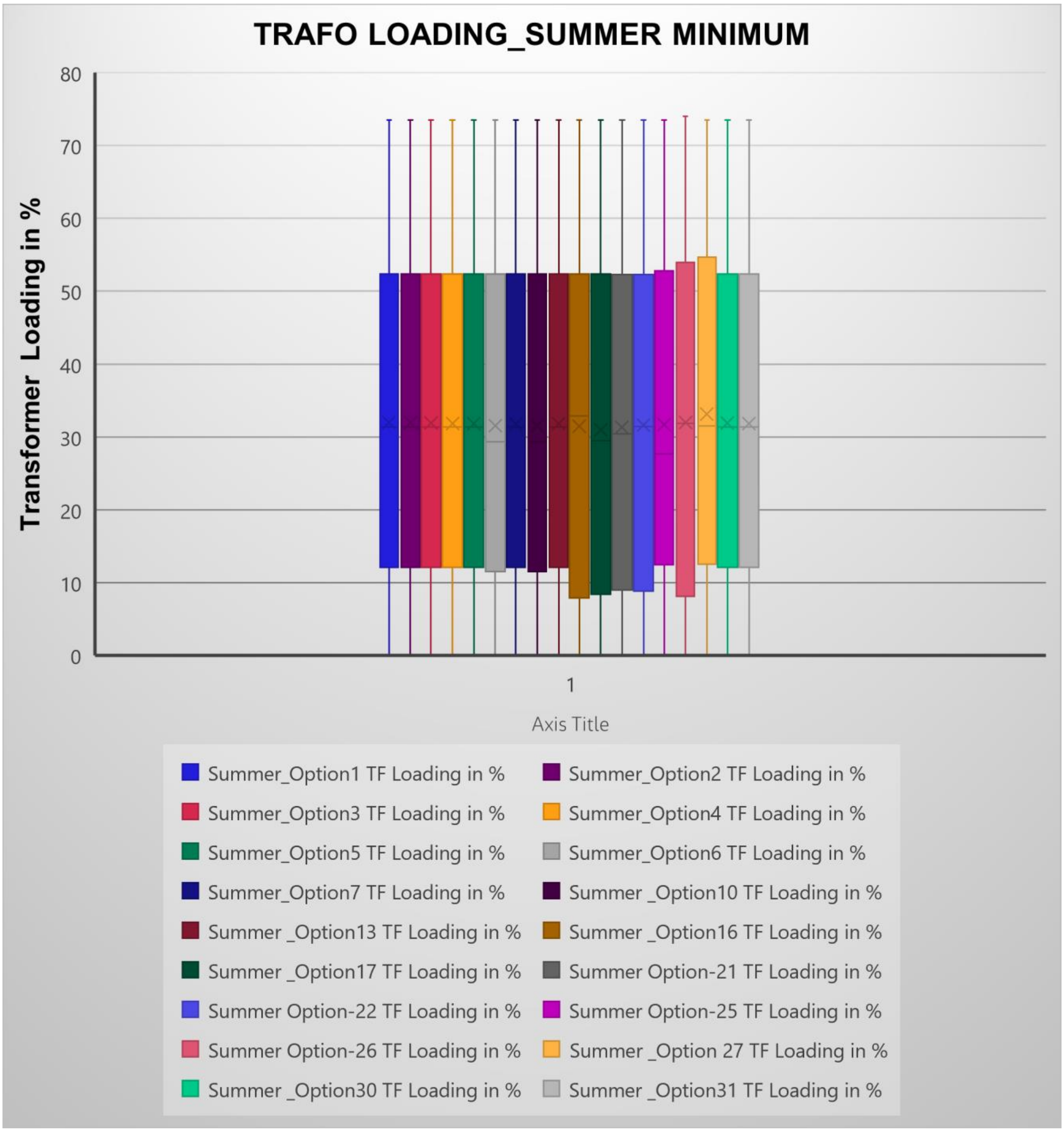
Figure 4-5 Load flow summary cable loading for winter maximum



4.2.6 Summary transformer loadings for the summer minimum

The load flow transformer loading percentage summary for the summer minimum is shown in the Figure 4-6. All transformer loadings are below 100% of their rated capacity.

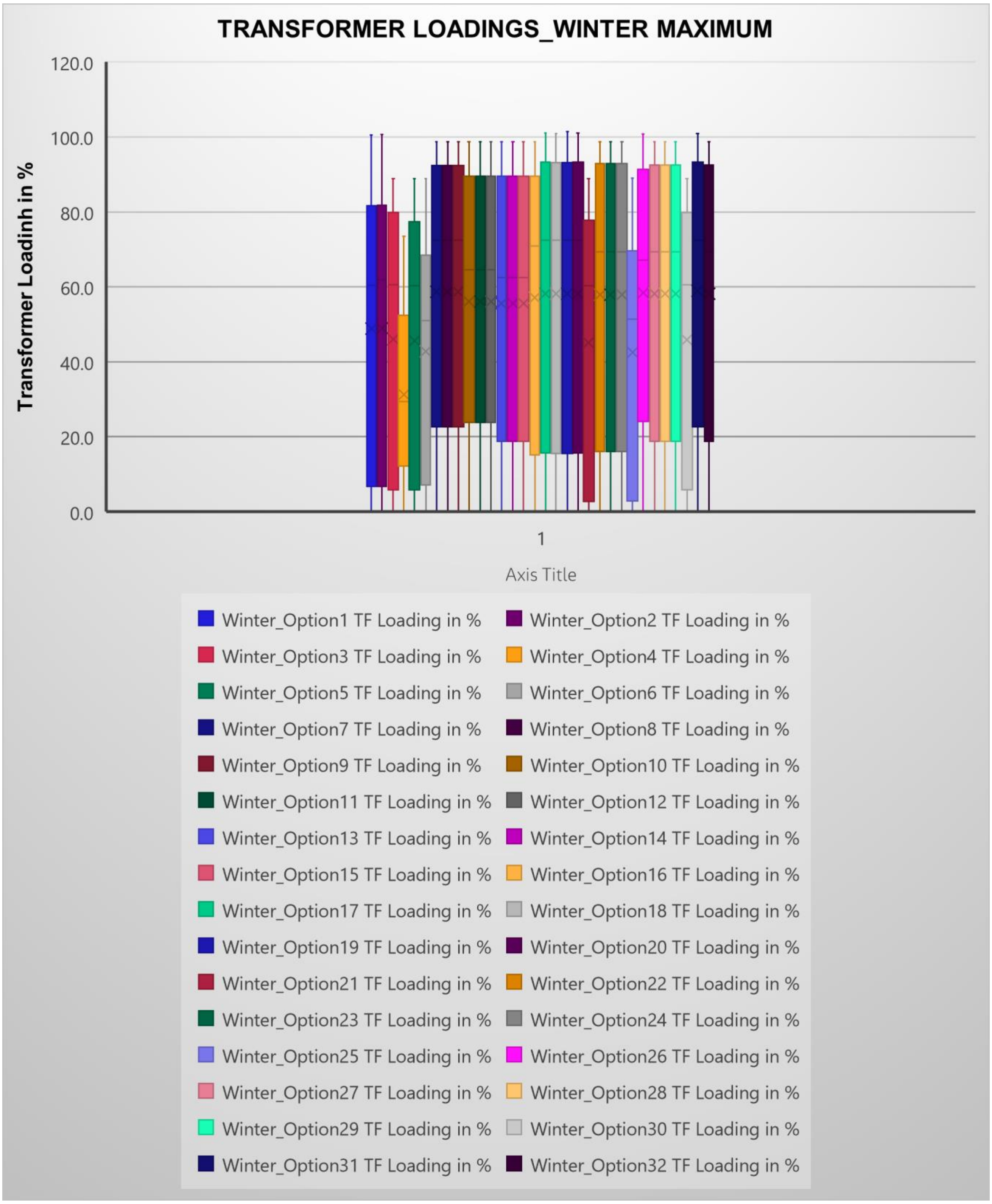
Figure 4-6 Load flow transformer loading summary for the summer minimum.



4.2.7 Summary transformer loadings for the winter maximum

The load flow transformer loading percentage summary for the winter maximum is shown in the Figure 4-7. All transformer loadings are below 100% of their rated capacity.

Figure 4-7 Load flow transformer loadings summary for the winter maximum



5. SHORT CIRCUIT ANALYSIS

5.1 Definition of Terms

IEC standards use the following definitions, which are relevant in the short cicuit calculations.

- **Initial Symmetrical Short circuit current (I"k) -** This is the rms value of the AC symmetrical component of an available short circuit current applicable at the instant of short circuit if the impedance remains at zero-time value.
- **Peak Short Circuit Current (ip) -** This is the maximum possible instantaneous value of the available short circuit current.
- **Symmetrical Short Circuit Breaking Current (Ib) -** This is the rms value of an integral cycle of the symmetrical AC component of the available short circuit current at the instant of contact separation of the first pole of a switching device.
- **Steady-State Short Circuit Current (Ik) -** This is the rms value of the short circuit current, which remains after the decay of the transient phenomena.

The primary objective for performing a maximum short circuit study is to assess whether the equipment short circuit ratings are adequate. The short circuit study is performed using IEC 60909 calculation module available within PSS/E software. The maximum short circuit currents have been evaluated based on IEC 60909 calculations. The peak short circuit current calculation is based on method C.

It is important to note that there exists a situation wherein momentary paralleling occurs when the transfer from one incomer to the other takes place for redundant transformer switchgear (secondary selective configuration). The maximum short circuit study does not consider this momentary paralleling due to the very short duration of such paralleling (not greater than 1 second) and a fault occurring during such transfers of very short duration being very rare.

5.2 Short Circuit Study Methodology

The short circuit case studies have been performed to check the existing SSEN switchgear ratings as per the switchgear rating provided by the SSEN [10].
For maximum ultimate short circuit calculations, all existing, new, and future planned system and loads (i.e., all future substation circuits and transformers, generation & loads) were considered.
The short circuit current computations were based on: -

- IEC 60909 calculations for 33 kV and 11 kV switchgears/CB's, which will be based on IEC 62271-100 standard.
- According to IEC 60909, voltage factor C was considered as tabulated in **Table 5-1**.
  Table 5-1

Table 5-1 IEC 60909 Voltage factor C

Nominal system Voltage Un	Voltage factor c for the calculation	
	Maximum short circuit currents c_{max}	Minimum short circuit currents c_{min}
High voltage >1KV to 230kV	1.1	1
High voltage > 230kV	1.1	1

5.3 Short Circuit Study Cases

To assess the maximum short circuit level to select the HV switchgear short circuit duty, the short circuit studies have been carried out based on the worst-case options with respect to number of generation sources and cable arrangement.

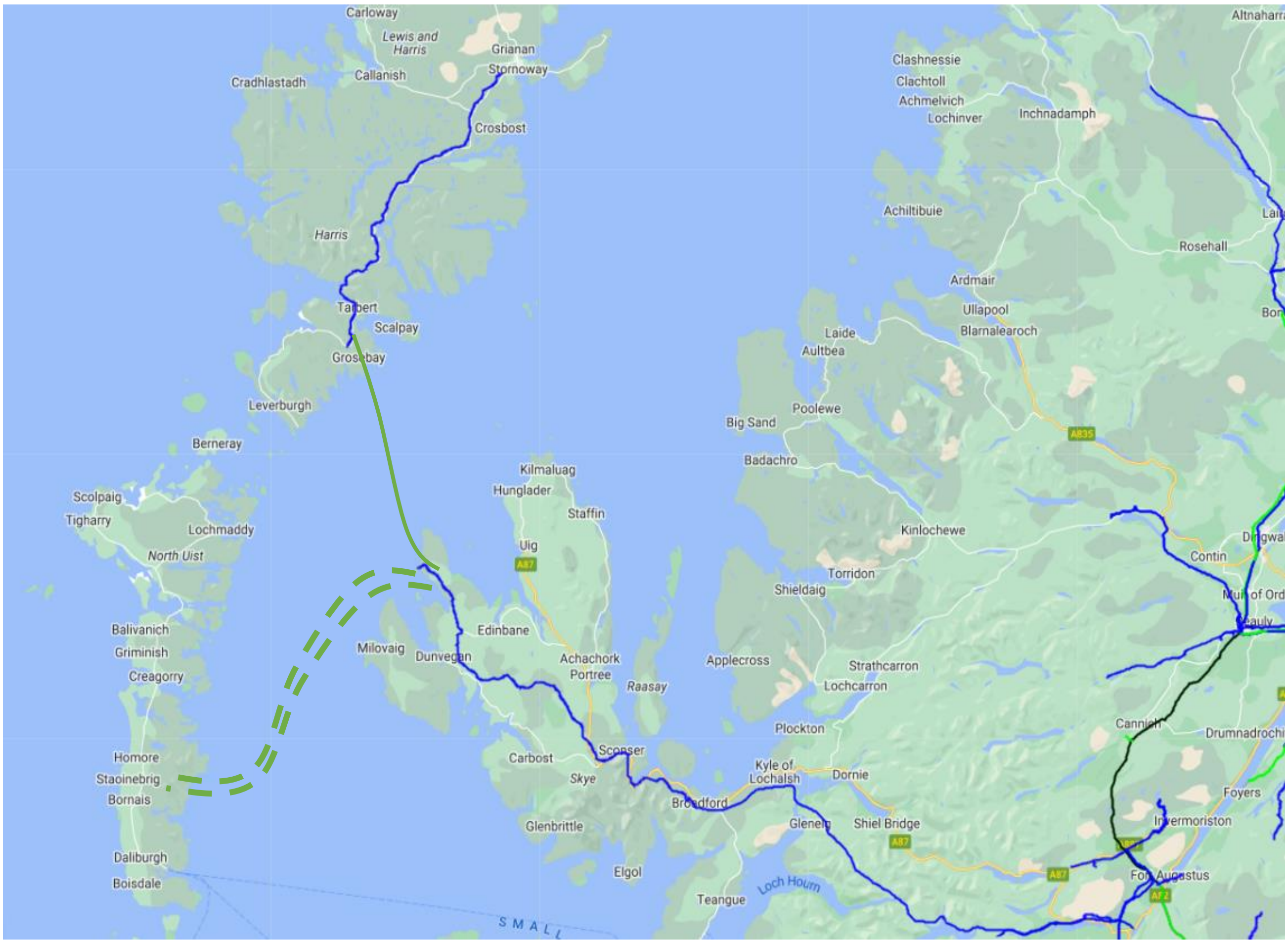
5.3.1 Case-1: Replace Ardmore – Loch Carnan subsea cable with two larger cables (Option 7)

Case-1, illustrated in Figure 5-1, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- Two 48km,185mm^2 subsea cables between Ardmore and Loch Carnan (South Uist)

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Figure 5-1 Case1: Overview of connections from Skye to the Hebrides



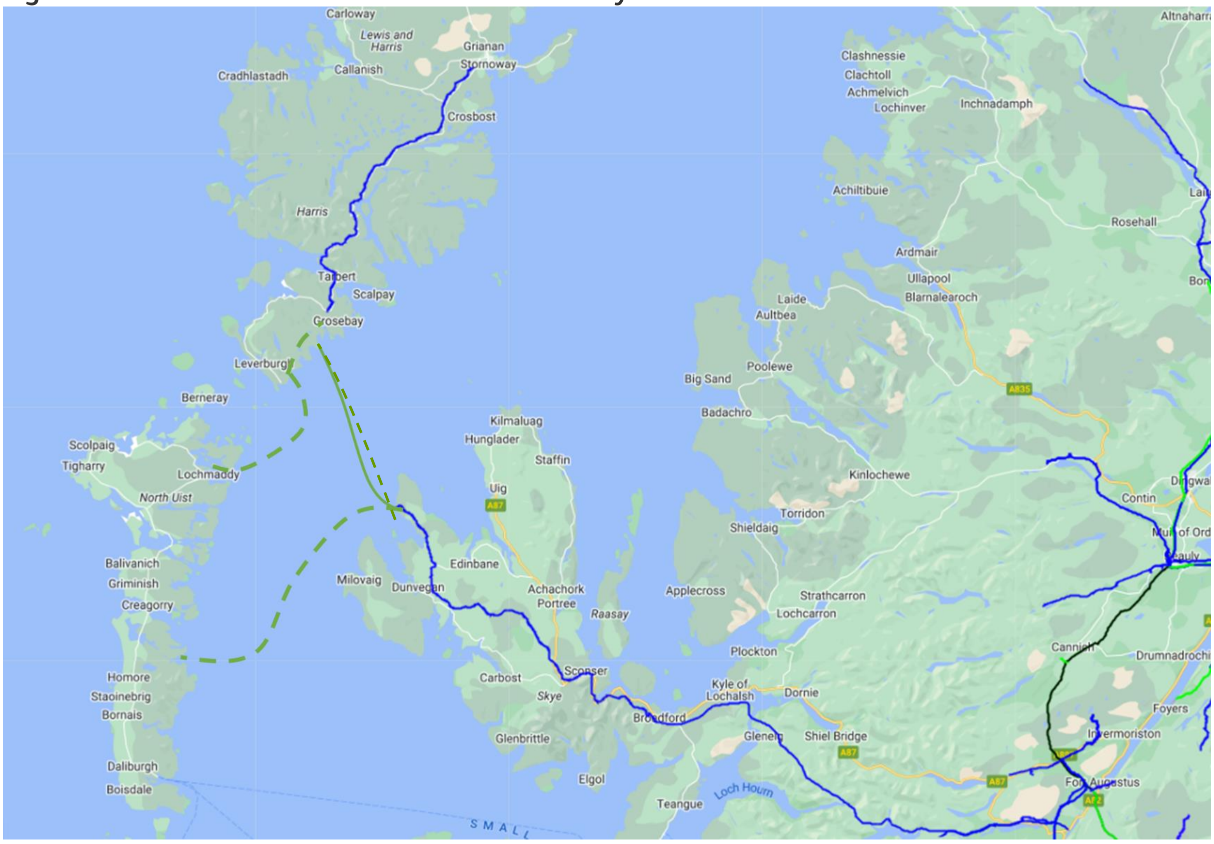
5.3.2 Case-2: New Ardmore – Loch Carnan subsea cable and additional Harris – Clachan subsea cable / OHL (Option 13A)

Case-2, illustrated in Figure 5-2, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 48km, 185mm^2 cable between Ardmore and Loch Carnan (South Uist)
- An 16 km OHL and 25 km OHL and subsea cable between Harris and Lochmaddy and 16 km OHL between Lochmaddy and Clachan (North Uist)

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Ardmore to Harris.

Figure 5-2 Case-2 Overview of connections from Skye to the Hebrides



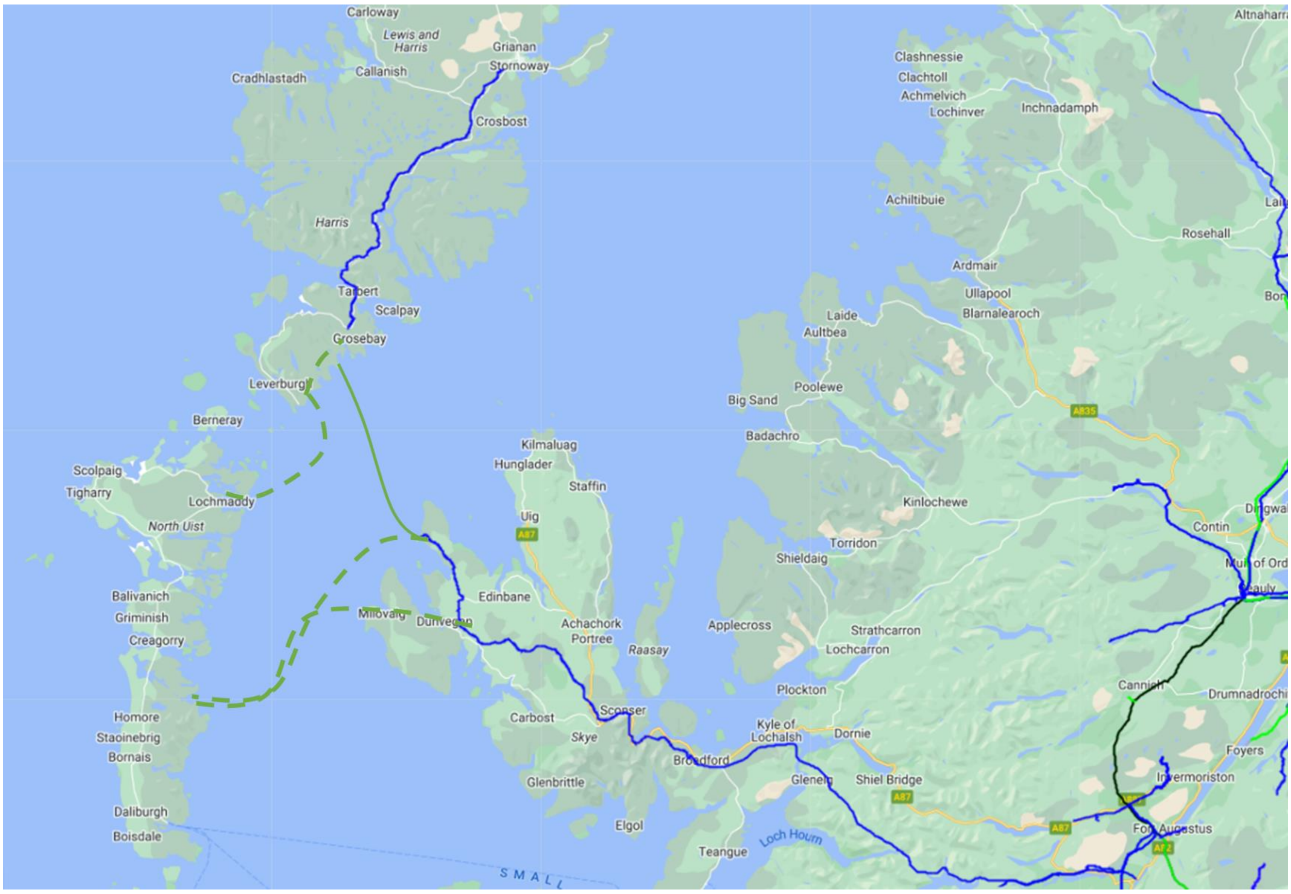
5.3.3 Case-3: New Ardmore – Loch Carnan subsea cable, additional Dunvegan – Loch Carnan OHL/subsea cable and additional Harris – Clachan subsea cable / OHL (Option 14)

Case-3, illustrated in Figure 5-3, is the decommission of the existing 95mm^2 subsea cable between Ardmore and Loch Carnan (South Uist) with:

- A 48km, 185mm^2 cable between Ardmore and Loch Carnan (South Uist)
- A16.5km, OHL between Dunvegan and Loch Pooltiel and a 38.5 km, 185mm^2 subsea cable between Loch Pooltiel and Loch Carnan (South Uist)
- A 16 km OHL and 25 km OHL subsea cable between Harris and Lochmaddy and 16 km OHL between Lochmaddy and Clachan (North Uist).

The new circuits are 33 kV and are shown with a dashed green line. The green solid line is the existing subsea cable from Skye to Harris.

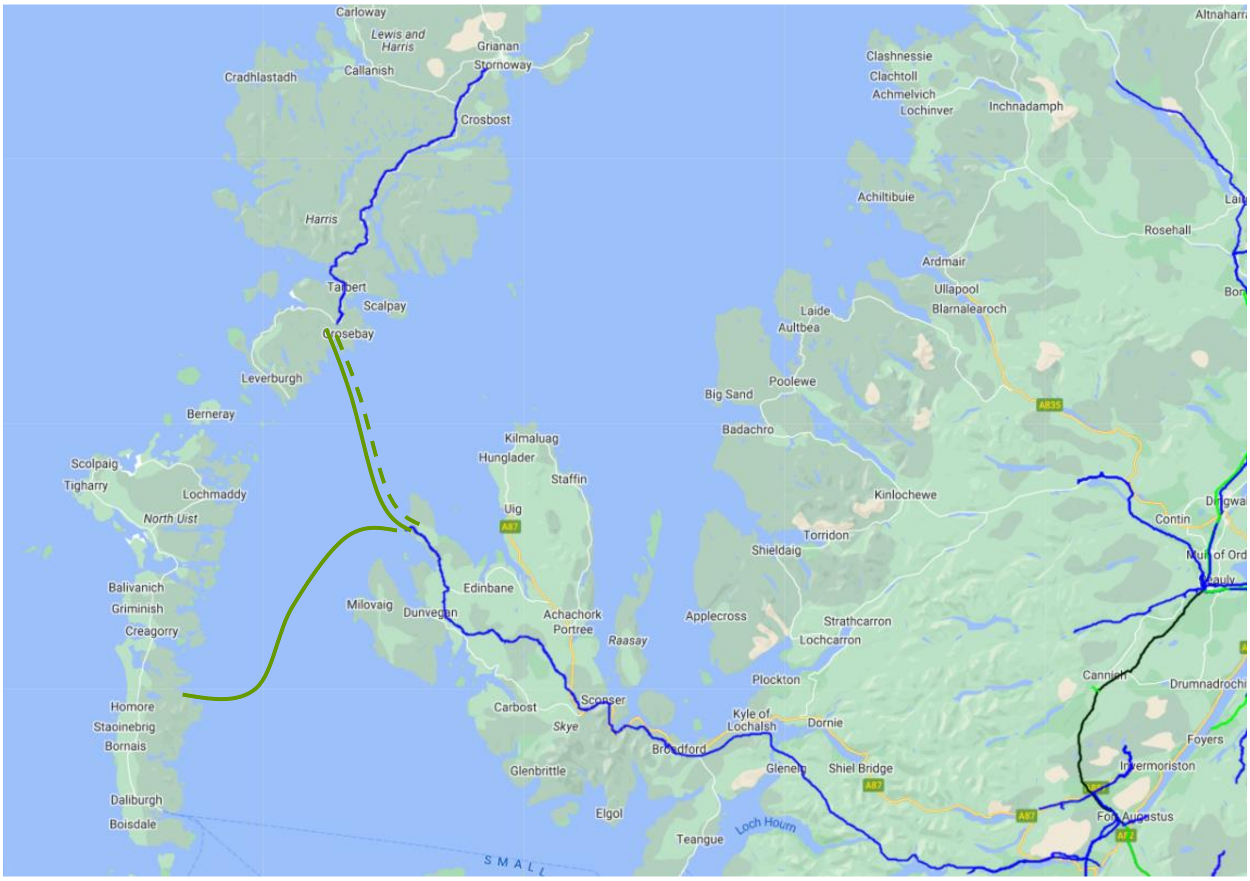
Figure 5-3 Case-3 Overview of connections from Skye to the Hebrides



5.3.4 Case-4: Existing and new Ardmore – Harris subsea cables (Option 16)

Case 4, illustrated in Figure 5-4, considers the retention of the existing 500 mm^2 subsea cable between Ardmore and Harris and the addition of a second 500 mm^2 subsea cable between Ardmore and Harris

Figure 5-4 Overview of connections from Skye to the Hebrides



5.4 Summary of short circuit results

5.4.1 Case-1 Short Circuit study results

The maximum short circuit currents calculated at 33 kV and 11 kV switchgear/CB, as summarised for Case-1 Summer_Min and Winter_Max scenarios, are tabulated in Table 5-2 and Table 5-3.

PASS: Switchgear short circuit rating > actual fault current

FAIL: Switchgear short circuit rating< actual fault current

Table 5-2 Case 1: Short Circuit Results for Summer Scenario

Case 1- Summer_Min									
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault Calculated values from ETAP IEC 60909		Single Phase to ground fault Calculated values from ETAP IEC 60909		Remarks
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
20930	ARMO3-	33.00	62.50	25.00	20.73	7.97	1.80	1.07	PASS
84001	LOCHCA3B	33.00	78.75	31.50	4.51	2.15	5.01	2.27	PASS
84004	DRIMOR3C	33.00	20.00	8.00	2.88	1.53	2.26	1.15	PASS
84005	DRIMOR1A	11.00	46.00	18.40	5.28	2.54	6.52	3.06	PASS
84008	AIRD3C	33.00	33.41	13.10	2.39	1.32	1.62	0.98	PASS
84009	AIRD1A	11.00	33.41	13.10	6.17	2.96	8.26	3.87	PASS
84012	CLACHN3B	33.00	62.50	25.00	2.31	1.18	1.82	0.90	PASS
84013	CLACHN1A	11.00	62.50	25.00	6.66	3.36	5.64	2.56	PASS
84016	POLLAC3C	33.00	30.00	12.00	1.25	0.75	0.86	0.53	PASS
84017	POLLAC1A	11.00	32.75	13.10	3.02	1.70	4.12	2.25	PASS
84018	LOCHCA1A	11.00	33.41	13.10	11.08	5.11	15.04	6.82	PASS
84021	LOCHCAR3W	33.00	62.50	25.00	4.34	2.09	4.95	2.25	PASS
85608	Laxay3B	33.00	46.00	18.40	2.66	1.61	1.47	0.81	PASS

Case 1- Summer_Min									
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault		Single Phase to ground fault		Remarks
					Calculated values from ETAP IEC 60909		Calculated values from ETAP IEC 60909		
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
85609	Laxay1A	11.00	46.00	18.40	6.09	3.41	8.14	4.42	PASS
85612	ARNMWF3-	33.00	62.50	25.00	6.04	3.02	4.61	2.65	PASS
85614	CALLAD1A	11.00	46.00	18.40	4.20	2.38	5.54	3.03	PASS
85616	Gisla3A	33.00	62.50	25.00	1.01	0.63	0.56	0.38	PASS
85617	Gisla1A	11.00	62.50	25.00	2.63	1.51	3.50	1.95	PASS
85619	ARNISH3B	33.00	50.00	20.00	6.64	3.11	6.38	3.07	PASS
85620	ARNISH1A	11.00	62.50	25.00	10.85	4.56	13.21	5.42	PASS
85621	BATTER3A	33.00	62.50	25.00	7.99	3.64	9.17	4.17	PASS
85622	BATTER1A	11.00	33.41	13.10	18.65	8.14	24.88	10.71	PASS
85624	COLL3A	33.00	25.00	10.00	3.62	2.03	2.35	1.45	PASS
85625	COLL1A	11.00	33.41	13.10	7.31	3.49	9.05	4.20	PASS
85627	BARVAS1A	11.00	46.00	18.40	9.58	4.35	12.05	5.40	PASS
85628	STORNO3-	33.00	62.50	25.00	8.59	3.80	10.02	4.38	PASS
85636	STOCKI3A	33.00	20.00	8.00	3.45	1.48	0.01	0.01	PASS
85637	STOCKI1A	11.00	43.75	17.50	5.71	2.43	6.97	2.95	PASS
85638	TARBER3A	33.00	43.75	17.50	2.29	1.19	0.01	0.01	PASS
85639	TARBET1A	11.00	46.00	18.40	4.45	2.14	5.65	2.65	PASS
85640	CALLAN3D	33.00	25.00	10.00	1.85	1.15	1.10	0.73	PASS
85645	GALSN3B	33.00	62.50	25.00	5.25	2.38	4.66	2.07	PASS
85646	PENTRD3B	33.00	62.50	25.00	7.50	3.47	9.33	4.18	PASS
85651	HARG3-	33.00	25.00	10.00	7.91	3.74	1.70	1.08	PASS
85654	PENTRD3A	33.00	62.50	25.00	7.85	3.57	9.75	4.28	PASS

Table 5-3 Case 1: Short Circuit Results for winter Scenario

Case-1 Winter_Max									
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault Calculated values from ETAP IEC 60909		Single Phase to ground fault Calculated values from ETAP IEC 60909		Remarks
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
20930	ARMO3-	33.00	62.50	25.00	20.46	7.85	1.80	1.07	PASS
84001	LOCHCA3B	33.00	78.75	31.50	4.01	1.96	0.51	0.21	PASS
84004	DRIMOR3C	33.00	20.00	8.00	2.71	1.44	0.52	0.21	PASS
84005	DRIMOR1A	11.00	46.00	18.40	4.95	2.40	5.94	2.84	PASS
84008	AIRD3C	33.00	33.41	13.10	2.18	1.22	0.41	0.19	PASS
84009	AIRD1A	11.00	33.41	13.10	6.01	2.89	7.46	3.55	PASS
84012	CLACHN3B	33.00	62.50	25.00	2.12	1.10	0.48	0.20	PASS
84013	CLACHN1A	11.00	62.50	25.00	5.84	3.02	1.68	1.17	PASS
84016	POLLAC3C	33.00	30.00	12.00	1.21	0.72	0.34	0.16	PASS
84017	POLLAC1A	11.00	32.75	13.10	2.94	1.65	3.95	2.16	PASS
84018	LOCHCA1A	11.00	33.41	13.10	10.07	4.75	13.11	6.14	PASS
84021	LOCHCAR3W	33.00	62.50	25.00	3.85	1.90	0.51	0.21	PASS
85608	Laxay3B	33.00	46.00	18.40	2.79	1.68	0.94	0.52	PASS
85609	Laxay1A	11.00	46.00	18.40	6.32	3.50	8.22	4.43	PASS
85612	ARNMWF3-	33.00	62.50	25.00	6.15	3.08	4.58	2.62	PASS
85614	CALLAD1A	11.00	46.00	18.40	4.22	2.39	5.54	3.03	PASS
85616	Gisla3A	33.00	62.50	25.00	1.01	0.63	0.56	0.38	PASS
85617	Gisla1A	11.00	62.50	25.00	2.83	1.69	3.98	2.33	PASS
85619	ARNISH3B	33.00	50.00	20.00	6.78	3.18	6.31	3.03	PASS
85620	ARNISH1A	11.00	62.50	25.00	10.97	4.61	13.12	5.39	PASS

Case-1 Winter_Max									
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault Calculated values from ETAP IEC 60909		Single Phase to ground fault Calculated values from ETAP IEC 60909		Remarks
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
85621	BATTER3A	33.00	62.50	25.00	8.19	3.74	9.00	4.09	PASS
85622	BATTER1A	11.00	33.41	13.10	19.02	8.31	23.91	10.30	PASS
85624	COLL3A	33.00	25.00	10.00	3.73	2.07	2.31	1.42	PASS
85625	COLL1A	11.00	33.41	13.10	7.71	3.64	8.54	3.96	PASS
85627	BARVAS1A	11.00	46.00	18.40	9.63	4.37	11.93	5.35	PASS
85628	STORNO3-	33.00	62.50	25.00	8.83	3.90	9.84	4.30	PASS
85636	STOCKI3A	33.00	20.00	8.00	3.46	1.49	0.01	0.01	PASS
85637	STOCKI1A	11.00	43.75	17.50	5.72	2.43	6.91	2.92	PASS
85638	TARBER3A	33.00	43.75	17.50	2.30	1.19	0.01	0.01	PASS
85639	TARBET1A	11.00	46.00	18.40	4.46	2.14	5.63	2.65	PASS
85640	CALLAN3D	33.00	25.00	10.00	1.86	1.16	1.10	0.73	PASS
85645	GALSN3B	33.00	62.50	25.00	5.28	2.40	4.32	1.92	PASS
85646	PENTRD3B	33.00	62.50	25.00	7.67	3.55	9.19	4.11	PASS
85651	HARG3-	33.00	25.00	10.00	7.96	3.75	1.70	1.08	PASS
85654	PENTRD3A	33.00	62.50	25.00	8.04	3.66	9.59	4.21	PASS

5.4.2 Case-2 Short Circuit study results

The maximum short circuit currents calculated at 33 kV and 11 kV switchgear/CB, as summarised for Case-2 Summer_Min and Winter_Max scenarios, are tabulated in Table 5-4 and Table 5-5.

PASS: Switchgear short circuit rating > actual fault current

FAIL: Switchgear short circuit rating< actual fault current

Table 5-4 Case 2: Short Circuit Results for Summer Scenario

Case-2 Summer_Min									
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault Calculated values from ETAP IEC 60909		Single Phase to ground fault Calculated values from ETAP IEC 60909		Remarks
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
20930	ARMO3-	33.00	62.50	25.00	30.13	12.91	6.63	3.02	PASS
84001	LOCHCA3B	33.00	78.75	31.50	3.96	2.19	4.53	2.32	PASS
84004	DRIMOR3C	33.00	20.00	8.00	2.81	1.61	2.64	1.48	PASS
84005	DRIMOR1A	11.00	46.00	18.40	5.22	2.65	6.42	3.14	PASS
84008	AIRD3C	33.00	33.41	13.10	2.55	1.48	1.66	1.03	PASS
84009	AIRD1A	11.00	33.41	13.10	6.72	3.46	8.82	4.36	PASS
84012	CLACHN3B	33.00	62.50	25.00	3.70	2.11	2.88	1.57	PASS
84013	CLACHN1A	11.00	62.50	25.00	8.94	4.72	6.51	2.96	PASS
84016	POLLAC3C	33.00	30.00	12.00	1.22	0.75	0.85	0.53	PASS
84017	POLLAC1A	11.00	32.75	13.10	2.95	1.71	4.02	2.25	PASS
84018	LOCHCA1A	11.00	33.41	13.10	9.97	5.27	13.50	6.90	PASS
84021	LOCHCAR3W	33.00	62.50	25.00	3.84	2.13	4.48	2.29	PASS
85608	Laxay3B	33.00	46.00	18.40	2.86	1.78	1.50	0.83	PASS
85609	Laxay1A	11.00	46.00	18.40	6.44	3.67	8.46	4.65	PASS
85612	ARNMWF3-	33.00	62.50	25.00	7.46	3.86	4.99	2.92	PASS

Case-2 Summer_Min									
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault Calculated values from ETAP IEC 60909		Single Phase to ground fault Calculated values from ETAP IEC 60909		Remarks
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
85614	CALLAD1A	11.00	46.00	18.40	4.36	2.50	5.68	3.14	PASS
85616	Gisla3A	33.00	62.50	25.00	1.02	0.65	0.56	0.38	PASS
85617	Gisla1A	11.00	62.50	25.00	2.68	1.55	3.54	1.99	PASS
85619	ARNISH3B	33.00	50.00	20.00	8.69	4.10	7.24	3.50	PASS
85620	ARNISH1A	11.00	62.50	25.00	12.44	5.16	14.38	5.84	PASS
85621	BATTER3A	33.00	62.50	25.00	11.10	5.07	11.02	4.99	PASS
85622	BATTER1A	11.00	33.41	13.10	23.47	10.15	29.02	12.34	PASS
85624	COLL3A	33.00	25.00	10.00	3.92	2.26	2.41	1.50	PASS
85625	COLL1A	11.00	33.41	13.10	7.61	3.67	9.28	4.33	PASS
85627	BARVAS1A	11.00	46.00	18.40	10.03	4.60	12.41	5.59	PASS
85628	STORNO3-	33.00	62.50	25.00	12.35	5.38	12.29	5.29	PASS
85636	STOCKI3A	33.00	20.00	8.00	5.63	2.26	0.01	0.01	PASS
85637	STOCKI1A	11.00	43.75	17.50	7.24	2.98	8.06	3.34	PASS
85638	TARBER3A	33.00	43.75	17.50	3.11	1.66	0.01	0.01	PASS
85639	TARBET1A	11.00	46.00	18.40	5.35	2.57	6.36	2.97	PASS
85640	CALLAN3D	33.00	25.00	10.00	1.94	1.23	1.12	0.75	PASS
85645	GALSN3B	33.00	62.50	25.00	5.55	2.57	4.78	2.14	PASS
85646	PENTRD3B	33.00	62.50	25.00	10.07	4.71	11.18	4.99	PASS
85651	HARG3-	33.00	25.00	10.00	86.09	33.59	10.04	4.16	FAIL
85654	PENTRD3A	33.00	62.50	25.00	10.75	4.90	11.80	5.14	PASS

Jacobs

Table 5-5 Case 2: Short Circuit Results for Winter Scenario

Case-2 Winter_Max									
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault Calculated values from ETAP IEC 60909		Single Phase to ground fault Calculated values from ETAP IEC 60909		Remarks
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
20930	ARMO3-	33.00	62.50	25.00	28.39	11.76	12.98	6.23	PASS
84001	LOCHCA3B	33.00	78.75	31.50	4.34	2.40	1.34	0.71	PASS
84004	DRIMOR3C	33.00	20.00	8.00	3.03	1.75	1.24	0.67	PASS
84005	DRIMOR1A	11.00	46.00	18.40	5.29	2.69	6.41	3.20	PASS
84008	AIRD3C	33.00	33.41	13.10	2.84	1.65	0.89	0.52	PASS
84009	AIRD1A	11.00	33.41	13.10	7.43	3.74	9.27	4.58	PASS
84012	CLACHN3B	33.00	62.50	25.00	4.93	2.76	2.54	1.31	PASS
84013	CLACHN1A	11.00	62.50	25.00	11.84	6.21	2.66	1.84	PASS
84016	POLLAC3C	33.00	30.00	12.00	1.25	0.78	0.59	0.35	PASS
84017	POLLAC1A	11.00	32.75	13.10	3.02	1.75	4.10	2.32	PASS
84018	LOCHCA1A	11.00	33.41	13.10	10.76	5.63	14.48	7.51	PASS
84021	LOCHCAR3W	33.00	62.50	25.00	4.15	2.32	1.32	0.71	PASS
85608	Laxay3B	33.00	46.00	18.40	2.96	1.82	0.95	0.53	PASS
85609	Laxay1A	11.00	46.00	18.40	6.60	3.71	8.63	4.73	PASS
85612	ARNMWF3-	33.00	62.50	25.00	7.32	3.76	5.06	2.98	PASS
85614	CALLAD1A	11.00	46.00	18.40	4.35	2.49	5.72	3.16	PASS
85616	Gisla3A	33.00	62.50	25.00	1.03	0.65	0.56	0.38	PASS
85617	Gisla1A	11.00	62.50	25.00	2.87	1.73	4.04	2.39	PASS

Case-2 Winter_Max									
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault Calculated values from ETAP IEC 60909		Single Phase to ground fault Calculated values from ETAP IEC 60909		Remarks
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
85619	ARNISH3B	33.00	50.00	20.00	8.47	3.97	7.42	3.60	PASS
85620	ARNISH1A	11.00	62.50	25.00	12.29	5.10	14.64	5.94	PASS
85621	BATTER3A	33.00	62.50	25.00	10.75	4.88	11.41	5.19	PASS
85622	BATTER1A	11.00	33.41	13.10	23.01	9.92	29.14	12.42	PASS
85624	COLL3A	33.00	25.00	10.00	3.98	2.27	2.39	1.49	PASS
85625	COLL1A	11.00	33.41	13.10	7.95	3.78	8.81	4.11	PASS
85627	BARVAS1A	11.00	46.00	18.40	10.00	4.58	12.41	5.61	PASS
85628	STORNO3-	33.00	62.50	25.00	11.92	5.16	12.82	5.53	PASS
85636	STOCKI3A	33.00	20.00	8.00	5.19	2.09	0.01	0.01	PASS
85637	STOCKI1A	11.00	43.75	17.50	6.99	2.88	8.30	3.43	PASS
85638	TARBER3A	33.00	43.75	17.50	2.97	1.56	0.01	0.01	PASS
85639	TARBET1A	11.00	46.00	18.40	5.21	2.49	6.54	3.06	PASS
85640	CALLAN3D	33.00	25.00	10.00	1.94	1.22	1.12	0.75	PASS
85645	GALSN3B	33.00	62.50	25.00	5.53	2.56	4.46	2.00	PASS
85646	PENTRD3B	33.00	62.50	25.00	9.79	4.55	11.62	5.20	PASS
85651	HARG3-	33.00	25.00	10.00	37.24	15.06	38.61	15.08	FAIL
85654	PENTRD3A	33.00	62.50	25.00	10.42	4.72	12.28	5.36	PASS

5.4.3 Case-3 Short Circuit study results

The maximum short circuit currents calculated at 33 kV and 11 kV switchgear/CB, as summarised for Case-3 Summer_Min and Winter_Max scenarios, are tabulated in Table 5-6 andTable 5-7 Table 5-5.

PASS: Switchgear short circuit rating > actual fault current

FAIL: Switchgear short circuit rating< actual fault current

Table 5-6 Case 3: Short Circuit Results for Summer_Min Scenario

Case-3 Summer_Min									
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault Calculated values from ETAP IEC 60909		Single Phase to ground fault Calculated values from ETAP IEC 60909		Remarks
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
20930	ARMO3-	33.00	62.50	25.00	21.82	10.36	6.10	3.02	PASS
84001	LOCHCA3B	33.00	78.75	31.50	5.24	2.83	5.61	2.79	PASS
84004	DRIMOR3C	33.00	20.00	8.00	3.67	1.91	3.23	1.65	PASS
84005	DRIMOR1A	11.00	46.00	18.40	5.59	2.86	6.84	3.36	PASS
84008	AIRD3C	33.00	33.41	13.10	3.26	1.71	2.00	1.11	PASS
84009	AIRD1A	11.00	33.41	13.10	7.28	3.74	9.55	4.71	PASS
84012	CLACHN3B	33.00	62.50	25.00	4.73	2.38	3.44	1.70	PASS
84013	CLACHN1A	11.00	62.50	25.00	9.61	5.18	6.01	3.09	PASS
84016	POLLAC3C	33.00	30.00	12.00	1.51	0.82	1.01	0.55	PASS
84017	POLLAC1A	11.00	32.75	13.10	3.14	1.81	4.26	2.39	PASS
84018	LOCHCA1A	11.00	33.41	13.10	12.51	6.34	16.85	8.27	PASS
84021	LOCHCAR3W	33.00	62.50	25.00	5.75	2.73	6.32	2.75	PASS
85608	Laxay3B	33.00	46.00	18.40	2.73	1.75	1.39	0.83	PASS
85609	Laxay1A	11.00	46.00	18.40	6.19	3.63	8.19	4.62	PASS
85612	ARNMWF3-	33.00	62.50	25.00	8.23	3.69	5.63	2.88	PASS

Case-3 Summer_Min									
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault Calculated values from ETAP IEC 60909		Single Phase to ground fault Calculated values from ETAP IEC 60909		Remarks
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
85614	CALLAD1A	11.00	46.00	18.40	4.16	2.48	5.47	3.12	PASS
85616	Gisla3A	33.00	62.50	25.00	1.09	0.65	0.63	0.38	PASS
85617	Gisla1A	11.00	62.50	25.00	2.44	1.54	3.26	1.98	PASS
85619	ARNISH3B	33.00	50.00	20.00	9.62	3.89	8.18	3.43	PASS
85620	ARNISH1A	11.00	62.50	25.00	12.22	5.05	14.23	5.77	PASS
85621	BATTER3A	33.00	62.50	25.00	12.16	4.75	12.35	4.84	PASS
85622	BATTER1A	11.00	33.41	13.10	22.78	9.73	28.51	12.05	PASS
85624	COLL3A	33.00	25.00	10.00	4.29	2.23	2.72	1.50	PASS
85625	COLL1A	11.00	33.41	13.10	7.42	3.64	9.11	4.31	PASS
85627	BARVAS1A	11.00	46.00	18.40	9.98	4.56	12.39	5.56	PASS
85628	STORNO3-	33.00	62.50	25.00	13.48	5.02	13.75	5.12	PASS
85636	STOCKI3A	33.00	20.00	8.00	5.85	2.07	0.01	0.01	PASS
85637	STOCKI1A	11.00	43.75	17.50	6.94	2.87	7.84	3.27	PASS
85638	TARBER3A	33.00	43.75	17.50	3.38	1.55	0.01	0.01	PASS
85639	TARBET1A	11.00	46.00	18.40	5.18	2.49	6.22	2.92	PASS
85640	CALLAN3D	33.00	25.00	10.00	1.85	1.22	1.10	0.75	PASS
85645	GALSN3B	33.00	62.50	25.00	6.25	2.54	5.28	2.13	PASS
85646	PENTRD3B	33.00	62.50	25.00	11.08	4.44	12.52	4.84	PASS
85651	HARG3-	33.00	25.00	10.00	37.96	14.13	10.72	4.29	FAIL
85654	PENTRD3A	33.00	62.50	25.00	11.80	4.60	13.21	4.98	PASS

Table 5-7 Case 3: Short Circuit Results for Winter_Max Scenario

Case-3 Winter_Max									
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault Calculated values from ETAP IEC 60909		Single Phase to ground fault Calculated values from ETAP IEC 60909		Remarks
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
20930	ARMO3-	33.00	62.50	25.00	25.01	10.32	8.56	4.28	PASS
84001	LOCHCA3B	33.00	78.75	31.50	5.08	2.67	1.25	0.66	PASS
84004	DRIMOR3C	33.00	20.00	8.00	3.25	1.84	1.17	0.62	PASS
84005	DRIMOR1A	11.00	46.00	18.40	5.50	2.75	6.62	3.24	PASS
84008	AIRD3C	33.00	33.41	13.10	2.90	1.69	0.84	0.49	PASS
84009	AIRD1A	11.00	33.41	13.10	7.48	3.73	9.30	4.54	PASS
84012	CLACHN3B	33.00	62.50	25.00	4.12	2.33	1.93	1.02	PASS
84013	CLACHN1A	11.00	62.50	25.00	10.50	5.66	2.61	1.81	PASS
84016	POLLAC3C	33.00	30.00	12.00	1.30	0.80	0.57	0.34	PASS
84017	POLLAC1A	11.00	32.75	13.10	3.12	1.79	4.22	2.36	PASS
84018	LOCHCA1A	11.00	33.41	13.10	12.22	6.08	16.22	7.97	PASS
84021	LOCHCAR3W	33.00	62.50	25.00	4.83	2.57	1.24	0.65	PASS
85608	Laxay3B	33.00	46.00	18.40	2.96	1.81	0.95	0.53	PASS
85609	Laxay1A	11.00	46.00	18.40	6.60	3.71	8.60	4.70	PASS
85612	ARNMWF3-	33.00	62.50	25.00	7.31	3.75	5.02	2.95	PASS
85614	CALLAD1A	11.00	46.00	18.40	4.35	2.49	5.70	3.15	PASS
85616	Gisla3A	33.00	62.50	25.00	1.03	0.65	0.56	0.38	PASS
85617	Gisla1A	11.00	62.50	25.00	2.87	1.73	4.04	2.38	PASS
85619	ARNISH3B	33.00	50.00	20.00	8.44	3.95	7.31	3.53	PASS

Case-3 Winter_Max									
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault Calculated values from ETAP IEC 60909		Single Phase to ground fault Calculated values from ETAP IEC 60909		Remarks
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
85620	ARNISH1A	11.00	62.50	25.00	12.26	5.08	14.49	5.88	PASS
85621	BATTER3A	33.00	62.50	25.00	10.70	4.85	11.15	5.05	PASS
85622	BATTER1A	11.00	33.41	13.10	22.93	9.88	28.58	12.15	PASS
85624	COLL3A	33.00	25.00	10.00	3.97	2.26	2.38	1.49	PASS
85625	COLL1A	11.00	33.41	13.10	7.95	3.78	8.79	4.10	PASS
85627	BARVAS1A	11.00	46.00	18.40	9.99	4.58	12.37	5.58	PASS
85628	STORNO3-	33.00	62.50	25.00	11.85	5.12	12.49	5.37	PASS
85636	STOCKI3A	33.00	20.00	8.00	5.14	2.07	0.01	0.01	PASS
85637	STOCKI1A	11.00	43.75	17.50	6.96	2.86	8.15	3.37	PASS
85638	TARBER3A	33.00	43.75	17.50	2.96	1.55	0.01	0.01	PASS
85639	TARBET1A	11.00	46.00	18.40	5.20	2.49	6.45	3.01	PASS
85640	CALLAN3D	33.00	25.00	10.00	1.94	1.22	1.12	0.75	PASS
85645	GALSN3B	33.00	62.50	25.00	5.53	2.55	4.45	1.99	PASS
85646	PENTRD3B	33.00	62.50	25.00	9.75	4.52	11.36	5.06	PASS
85651	HARG3-	33.00	25.00	10.00	34.95	14.12	31.36	12.39	FAIL
85654	PENTRD3A	33.00	62.50	25.00	10.38	4.69	11.99	5.21	PASS

Jacobs

5.4.4 Case-4 Short Circuit study results

The maximum short circuit currents calculated at 33 kV and 11 kV switchgear/CB, as summarised for Case-4 Summer_Min and Winter_Max scenarios, are tabulated in Table 5-8Table 5-4 and.Table 5-9.

PASS: Switchgear short circuit rating > actual fault current

FAIL: Switchgear short circuit rating< actual fault current

Table 5-8 Case 4: Short Circuit Results for Summer_Min Scenario

Case-4 Summer_Min									
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault Calculated values from ETAP IEC 60909		Single Phase to ground fault Calculated values from ETAP IEC 60909		Remarks
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
20930	ARMO3-	33.00	62.50	25.00	21.02	8.11	1.78	1.06	PASS
84001	LOCHCA3B	33.00	78.75	31.50	3.48	1.74	4.14	1.97	PASS
84004	DRIMOR3C	33.00	20.00	8.00	2.49	1.32	2.44	1.30	PASS
84005	DRIMOR1A	11.00	46.00	18.40	4.83	2.34	6.06	2.87	PASS
84008	AIRD3C	33.00	33.41	13.10	2.10	1.15	1.53	0.92	PASS
84009	AIRD1A	11.00	33.41	13.10	5.58	2.71	7.56	3.58	PASS
84012	CLACHN3B	33.00	62.50	25.00	2.07	1.06	1.73	0.86	PASS
84013	CLACHN1A	11.00	62.50	25.00	6.01	3.03	5.31	2.42	PASS
84016	POLLAC3C	33.00	30.00	12.00	1.16	0.69	0.83	0.51	PASS
84017	POLLAC1A	11.00	32.75	13.10	2.84	1.59	3.90	2.13	PASS
84018	LOCHCA1A	11.00	33.41	13.10	8.93	4.31	12.39	5.89	PASS
84021	LOCHCAR3W	33.00	62.50	25.00	3.39	1.70	4.10	1.95	PASS
85608	Laxay3B	33.00	46.00	18.40	2.71	1.65	1.48	0.82	PASS
85609	Laxay1A	11.00	46.00	18.40	6.17	3.47	8.24	4.49	PASS
85612	ARNMWF3-	33.00	62.50	25.00	6.37	3.20	4.72	2.73	PASS

Case-4 Summer_Min										
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault Calculated values from ETAP IEC 60909		Single Phase to ground fault Calculated values from ETAP IEC 60909		Remarks
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
85614	CALLAD1A	11.00	46.00	18.40	4.24	2.41	5.59	3.06	PASS
85616	Gisla3A	33.00	62.50	25.00	1.01	0.64	0.56	0.38	PASS
85617	Gisla1A	11.00	62.50	25.00	2.64	1.52	3.52	1.96	PASS
85619	ARNISH3B	33.00	50.00	20.00	7.12	3.32	6.66	3.20	PASS
85620	ARNISH1A	11.00	62.50	25.00	11.26	4.71	13.60	5.55	PASS
85621	BATTER3A	33.00	62.50	25.00	8.68	3.94	9.74	4.41	PASS
85622	BATTER1A	11.00	33.41	13.10	19.82	8.60	26.20	11.20	PASS
85624	COLL3A	33.00	25.00	10.00	3.69	2.09	2.36	1.47	PASS
85625	COLL1A	11.00	33.41	13.10	7.39	3.54	9.12	4.25	PASS
85627	BARVAS1A	11.00	46.00	18.40	9.70	4.41	12.17	5.46	PASS
85628	STORNO3-	33.00	62.50	25.00	9.41	4.12	10.72	4.64	PASS
85636	STOCKI3A	33.00	20.00	8.00	3.89	1.64	0.01	0.01	PASS
85637	STOCKI1A	11.00	43.75	17.50	6.09	2.56	7.33	3.07	PASS
85638	TARBER3A	33.00	43.75	17.50	2.48	1.29	0.01	0.01	PASS
85639	TARBET1A	11.00	46.00	18.40	4.68	2.24	5.88	2.75	PASS
85640	CALLAN3D	33.00	25.00	10.00	1.87	1.17	1.11	0.74	PASS
85645	GALSN3B	33.00	62.50	25.00	5.32	2.43	4.70	2.09	PASS
85646	PENTRD3B	33.00	62.50	25.00	8.08	3.73	9.90	4.41	PASS
85651	HARG3-	33.00	25.00	10.00	10.67	4.90	1.74	1.07	PASS
85654	PENTRD3A	33.00	62.50	25.00	8.50	3.84	10.38	4.53	PASS

Table 5-9 Case 4: Short Circuit Results for Winter_Max Scenario

Case-4 Winter_Max										
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault		Single Phase to ground fault		Remarks
					Calculated values from ETAP IEC 60909		Calculated values from ETAP IEC 60909		
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
20930	ARMO3-	33.00	62.50	25.00	20.81	8.00	1.78	1.06	PASS
84001	LOCHCA3B	33.00	78.75	31.50	2.99	1.55	0.49	0.20	PASS
84004	DRIMOR3C	33.00	20.00	8.00	2.27	1.21	0.50	0.20	PASS
84005	DRIMOR1A	11.00	46.00	18.40	4.42	2.18	5.34	2.62	PASS
84008	AIRD3C	33.00	33.41	13.10	1.86	1.04	0.40	0.18	PASS
84009	AIRD1A	11.00	33.41	13.10	5.31	2.60	6.57	3.23	PASS
84012	CLACHN3B	33.00	62.50	25.00	1.85	0.97	0.46	0.20	PASS
84013	CLACHN1A	11.00	62.50	25.00	5.12	2.68	1.63	1.13	PASS
84016	POLLAC3C	33.00	30.00	12.00	1.10	0.66	0.33	0.16	PASS
84017	POLLAC1A	11.00	32.75	13.10	2.72	1.53	3.65	2.02	PASS
84018	LOCHCA1A	11.00	33.41	13.10	7.82	3.93	10.23	5.15	PASS
84021	LOCHCAR3W	33.00	62.50	25.00	2.90	1.52	0.49	0.20	PASS
85608	Laxay3B	33.00	46.00	18.40	2.84	1.72	0.94	0.52	PASS
85609	Laxay1A	11.00	46.00	18.40	6.39	3.56	8.32	4.51	PASS
85612	ARNMWF3-	33.00	62.50	25.00	6.47	3.26	4.69	2.70	PASS
85614	CALLAD1A	11.00	46.00	18.40	4.26	2.42	5.58	3.06	PASS
85616	Gisla3A	33.00	62.50	25.00	1.02	0.64	0.56	0.38	PASS
85617	Gisla1A	11.00	62.50	25.00	2.84	1.70	3.99	2.34	PASS
85619	ARNISH3B	33.00	50.00	20.00	7.25	3.39	6.58	3.16	PASS
85620	ARNISH1A	11.00	62.50	25.00	11.37	4.75	13.52	5.52	PASS
85621	BATTER3A	33.00	62.50	25.00	8.88	4.03	9.56	4.33	PASS

Case-4 Winter_Max									
Bus No	Substation	Voltage	Specified Switchgear, Short Circuit Values		Three Phase to ground fault Calculated values from ETAP IEC 60909		Single Phase to ground fault Calculated values from ETAP IEC 60909		Remarks
			IP	Ik''	IP	Ik''	IP	Ik''	
		kV	kAp	kArms	kAp	kArms	kAp	kArms	
85622	BATTER1A	11.00	33.41	13.10	20.16	8.75	25.18	10.78	PASS
85624	COLL3A	33.00	25.00	10.00	3.79	2.13	2.33	1.44	PASS
85625	COLL1A	11.00	33.41	13.10	7.78	3.68	8.61	4.00	PASS
85627	BARVAS1A	11.00	46.00	18.40	9.74	4.43	12.06	5.42	PASS
85628	STORNO3-	33.00	62.50	25.00	9.64	4.22	10.53	4.56	PASS
85636	STOCKI3A	33.00	20.00	8.00	3.89	1.64	0.01	0.01	PASS
85637	STOCKI1A	11.00	43.75	17.50	6.09	2.55	7.26	3.04	PASS
85638	TARBER3A	33.00	43.75	17.50	2.48	1.29	0.01	0.01	PASS
85639	TARBET1A	11.00	46.00	18.40	4.68	2.24	5.86	2.74	PASS
85640	CALLAN3D	33.00	25.00	10.00	1.88	1.18	1.11	0.74	PASS
85645	GALSN3B	33.00	62.50	25.00	5.35	2.45	4.36	1.94	PASS
85646	PENTRD3B	33.00	62.50	25.00	8.24	3.81	9.76	4.34	PASS
85651	HARG3-	33.00	25.00	10.00	10.69	4.90	1.74	1.07	PASS
85654	PENTRD3A	33.00	62.50	25.00	8.68	3.93	10.22	4.46	PASS

5.5 Short circuit study summary

- Maximum fault level values for 3-phase and 1-phase ground faults reported are calculated in consideration of the IEC 60909 C-factor (voltage correction factor) of 1.1. The significance of using C-Factor is to accommodate variations in voltage at the respective bus.
- A short-circuit study was conducted for different scenarios for both summer minimum and winter maximum cases, as specified in Section 5.3.
- 3 phase and 1 phase to ground short circuit results are reported in Table 5-2, to Table 5-9.
- Based on the short circuit study results, it has been observed that all calculated fault currents for both 33 kV and 11 kV substations in all investigated scenarios fall below the corresponding switchgear's short circuit current ratings, with the exception of case 2 and case 3 short circuit results at the 33 kV Harris substation.
- Based on the short circuit study analysis, it is suggested that in the event of a future connection of an HVDC system to the 33 kV Harris substation, an upgrade of the 33 kV Harris switchgear's withstand symmetrical short circuit rating from 10 kA to 25 kA should be considered to ensure safe and reliable operation.

6. OPTION ASSESSMENT

A number of reinforcement options were considered in the load flow and short circuit analysis for the whole power system in the Hebrides considering new connections to Skye, connections between the Isle of Lewis and Harris and the Isles of Uist and support from the future HVDC link from the Isle of Lewis and Harris to the mainland.

Both summer and winter scenarios were considered to ensure the varying demand and support from local generation combinations were all accounted for. Contingency N-1 analysis was also undertaken.

The amount of flexibility that would need to be procured to prevent the need for reinforcement by 2050 is detailed in Table 4-2 and is large, hence it is not proposed that flexibility is used as an enduring solution. However, it is possible that smaller amounts of flexibility could be used to defer the need for the reinforcement by a few years and it is suggested that this is considered in the next stage of the study with the CBA assessment.

No switchgear short circuit ratings were exceeded with the exception of the Harris 10 kA equipment which is likely to be exceeded once the HVDC is in service and for which detailed analysis should be undertaken once final network arrangements are known to consider the need for replacement with 25 kA equipment.

The options which are acceptable for both summer and winter conditions in 2050 under both normal and contingency operating arrangements, proposed subsea cables and overhead transmission lines which are recommended for further consideration and cost benefit assessment are summarised in Table 6-1.

Table 6-1 Summary of options assessment for further consideration

Option No	Description	Number of Sources on Skye / mainland
Option-8	Replace Ardmore – Loch Carnan subsea cable with two larger cables (subsea cable 300mm^2) Additional feeder from Ardmore – Harris substations (500mm^2 subsea cable & OHL (150mm CU conductor with a thermal rating of 29.8 MVA))	Two sources: • Ardmore, Skye • Mainland Scotland (HVDC source)
Option-9	Replace Ardmore – Loch Carnan subsea cable with two larger cables (subsea cable 300mm^2) Additional feeder from Ardmore – Harris substations (132kV, 185mm^2 subsea cable & OHL 175mm^2 CU conductor.)	Two sources: • Ardmore, Skye • Mainland Scotland (HVDC source)
Option-11	Replace Ardmore – Loch Carnan subsea cable with larger cable (subsea cable 300mm^2) and add a new larger size cable / OHL Ardmore – Clachan (subsea cable 300mm^2 and 150mm OHL)	Two sources: • Ardmore, Skye • Mainland Scotland (HVDC source)

Option No	Description	Number of Sources on Skye / mainland
	Additional feeder from Ardmore – Harris substations (500mm^2 subsea cable & OHL (150mm CU conductor with a thermal rating of 29.8 MVA))	
Option-12	Replace Ardmore – Loch Carnan subsea cable with larger cable (subsea cable 300mm^2) and add a new larger size cable / OHL Ardmore – Clachan (subsea cable 300mm^2 and 150mm OHL) Additional feeder from Ardmore – Harris substations (132kV, 185mm^2 subsea cable & OHL 175mm^2 CU conductor.)	Two sources: • Ardmore, Skye • Mainland Scotland (HVDC source)
Option-14	Remove Ardmore – Loch Carnan subsea cable and replace with Dunvegan – Loch Carnan OHL/subsea cable (subsea cable 300mm^2 and 150mm OHL) and Ardmore – Clachan subsea cable / OHL Clachan (subsea cable 300mm^2 and 150mm OHL) Additional feeder from Ardmore – Harris substations (500mm^2 subsea cable & OHL (150mm CU conductor with a thermal rating of 29.8 MVA))	Three sources: ▪ Ardmore, Skye ▪ Dunvegan, Skye ▪ Mainland Scotland (HVDC source)
Option-15	Remove Ardmore – Loch Carnan subsea cable and replace with Dunvegan – Loch Carnan OHL/subsea cable (subsea cable 300mm^2 and 150mm OHL) and Ardmore – Clachan subsea cable / OHL Clachan (subsea cable 300mm^2 and 150mm OHL) Additional feeder from Ardmore – Harris substations (132kV, 185mm^2 subsea cable & OHL 175mm^2 CU conductor.)	Three sources: ▪ Ardmore, Skye ▪ Dunvegan, Skye ▪ Mainland Scotland (HVDC source)
Option-18	Feeder from Dunvegan to Loch Carnan substations (subsea cable 300mm^2 ,150mm OHL and 300mm^2 underground cable) Feeder from Harris – Clachan substations (subsea cable 300mm^2 and 150mm OHL) Additional feeder from Ardmore – Harris substations (500mm^2 subsea cable & OHL (150mm CU conductor with a thermal rating of 29.8 MVA))	Three sources: ▪ Ardmore, Skye ▪ Dunvegan, Skye ▪ Mainland Scotland (HVDC source)

Option No	Description	Number of Sources on Skye / mainland
Option-19	Feeder from Dunvegan to Loch Carnan substations (subsea cable 300mm^2 , and 300mm^2 underground cable) Feeder from Harris – Clachan substations (subsea cable 300mm^2 and 150mm OHL) Additional feeder from Ardmore – Harris substations (500mm^2 subsea cable & OHL (150mm CU conductor with a thermal rating of 29.8 MVA))	Three sources: ▪ Ardmore, Skye ▪ Dunvegan, Skye Mainland Scotland (HVDC source)
Option -20	Feeder from Dunvegan to Loch Carnan substations (subsea cable 300mm^2 and 150mm OHL) Feeder from Harris – Clachan substations (subsea cable 300mm^2 and 150mm OHL) Additional feeder from Ardmore – Harris substations (132kV, 185mm^2 subsea cable & OHL 175mm^2 CU conductor).	Three sources: ▪ Ardmore, Skye ▪ Dunvegan, Skye ▪ Mainland Scotland (HVDC source)
Option-23	New Ardmore – Loch Carnan subsea cable (Subsea cable 300mm^2) and additional Dunvegan – Loch Carnan OHL/subsea cable (subsea cable 300mm^2 and 150mm OHL) Additional feeder from Ardmore – Harris substations (500mm^2 subsea cable & OHL (150mm CU conductor with a thermal rating of 29.8 MVA))	Three sources: ▪ Ardmore, Skye ▪ Dunvegan, Skye ▪ Mainland Scotland (HVDC source)
Option-24	New Ardmore – Loch Carnan subsea cable (Subsea cable 300mm^2) and additional Dunvegan – Loch Carnan OHL/subsea cable (subsea cable 300mm^2 and 150mm OHL) Additional feeder from Ardmore – Harris substations (132kV, 185mm^2 subsea cable & OHL 175mm^2 CU conductor).	Three sources: ▪ Ardmore, Skye ▪ Dunvegan, Skye ▪ Mainland Scotland (HVDC source)
Option-26	Feeders from Ardmore – Loch Carnan substations (subsea cable 300mm^2) Additional feeder from Ardmore to Harris subsea cable (subsea cable 500mm^2 and 150mm OHL)	Two sources: ▪ Ardmore, Skye ▪ Mainland Scotland (HVDC source)

Option No	Description	Number of Sources on Skye / mainland
	Feeder from Harris – Clachan substations (subsea cable 300mm^2 and 150mm OHL)	
Option-28	New Ardmore – Loch Carnan subsea cable, additional (subsea cable 300mm^2) Dunvegan – Loch Carnan OHL/subsea cable (subsea cable 300mm^2 and 150mm OHL) and additional Harris – Clachan subsea cable / OHL(subsea cable 300mm^2 and 150mm OHL). Additional feeder from Ardmore – Harris substations (500mm^2 subsea cable & OHL (150mm CU conductor with a thermal rating of 29.8 MVA))	Three sources: ▪ Ardmore, Skye ▪ Dunvegan, Skye ▪ Mainland Scotland (HVDC source)
Option-28	New Ardmore – Loch Carnan subsea cable, additional (subsea cable 300mm^2) Dunvegan – Loch Carnan OHL/subsea cable (subsea cable 300mm^2 and 150mm OHL) and additional Harris – Clachan subsea cable / OHL(subsea cable 300mm^2 and 150mm OHL). Additional feeder from Ardmore – Harris substations (132kV, 185mm^2 subsea cable & OHL 175mm^2 CU conductor).	Three sources: ▪ Ardmore, Skye ▪ Dunvegan, Skye Mainland Scotland (HVDC source)

The overall security of supply to the islands will depend on the option selected, the dependency on the Skye network arrangements and the use of the HVDC link or a new subsea cable to the mainland. It is noted that the options using two separate sources of supply (Skye and the HVDVC link) should provide inherent higher reliability to the Hebrides.

Suggested local upgrades to the distribution systems on the Islands have been identified as tabulated in Table 6-2.

Table 6-2 CBA issued Option wise local upgrades.

Option Number	Recommendations
Option-8	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 126% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install an additional 80 MVA transformer in parallel. Reinforcement option 3: Install the 132 kV circuit from Ardmore to Harris and procure a 60 MVA, 132/33 kV transformer at Harris substation.

Option Number	Recommendations
	2) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 3) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 4) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.
Option-9	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.
Option-11	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 125% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install the additional 80 MVA transformer in parallel. Reinforcement option 3: Install the 132 kV circuit from Ardmore to Harris and procure the 60 MVA, 132/33 kV transformer at Harris substation. 2) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 3)3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 4) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.
Option-12	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2)3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.
Option-14	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 113% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows:

Option Number	Recommendations
	Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install the additional 80 MVA transformer in parallel. Reinforcement option 3: Install the 132 kV circuit from Ardmore to Harris and procure the 60 MVA, 132/33 kV transformer at Harris substation. 2)The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 3)3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 4)The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.
Option-15	1)The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2)3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3)The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.
Option-18	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101% of its rating, respectively. It is recommended to increase the rating from 21 to 25 MVA. 5) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 171%; consequently, an additional transformer was considered. 6) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 110% of its rating. It is recommended to increase the rating from 6.3 to 8 MVA.
Option-19	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101% of its rating, respectively. It is recommended to increase the rating from 21 to 25 MVA. 5) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to

Option Number	Recommendations
	171%; consequently, an additional transformer was considered. 6) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 110% of its rating. It is recommended to increase the rating from 6.3 to 8 MVA.
Option-20	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 6MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101% of its rating. It is recommended to increase the rating from 21 to 25 MVA. 5) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 171%; consequently an additional transformer was considered. 6) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 110% of its rating. It is recommended to increase the rating from 6.3 to 8 MVA.
Option-23	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 113% of its rating, respectively. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install the additional 80 MVA transformer in parallel. Reinforcement option 3: Install the 132 kV circuit from Ardmore to Harris and procure the 60 MVA, 132/33 kV transformer at Harris substation. 2)The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 3)3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 4)The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.

Option Number	Recommendations
Option-24	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA.
Option-26	1) The 132/33 kV, 60 MVA transformer at Ardmore was loaded up to 123% of its rating. The proposed reinforcement options to mitigate the overloading are as follows: Reinforcement option 1: Increase the 132/33 kV transformer rating at Ardmore from 60 MVA to 80 MVA. Reinforcement option 2: Install an additional 80 MVA transformer in parallel. Reinforcement option 3: Install a 132 kV circuit from Ardmore to Harris and install a 60 MVA, 132/33 kV transformer at Harris substation. 2) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 3) 6MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 4) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 5) The 33/33 kV, 21MVA voltage regulator at Loch Carnan was overloaded up to 101% of its rating, respectively. It is recommended to increase the rating from 21 to 25 MVA.

Option Number	Recommendations
Option-28	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 175%; consequently an additional transformer was considered. 5) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 115% of its rating. It is recommended to increase the rating from 6.3 to 8 MVA.
Option-29	1) The transformer rating at COLL substation was increased from 2.5 MVA to 5 MVA. 2) 3.5MVAr, 6 MVAr, 8MVAr, and 2MVAr fixed capacitors were considered for 33 kV Clachan 3A, 33 kV Gisla 3A, 33 kV Battery Point 1A, and 33 kV Tarbert 3A substations. 3) The cable rating from Callad to Gisla substation was increased from 7 to 10 MVA. 4) The transformer at Clachan (Clachan3B to Clachan1A) substation was loaded to 175%; consequently an additional transformer was considered. 5) The transformer at Clachan (Clachan3A to Clachan1A) substation was loaded up to 115% of its rating. It is recommended to increase the rating from 6.3 to 8 MVA.

In the case of the compensation requirements, it is recommended further consideration is given to the specific running arrangements in the area and other the options to manage reactive power flows such as the availability of bus section breakers to open the system.

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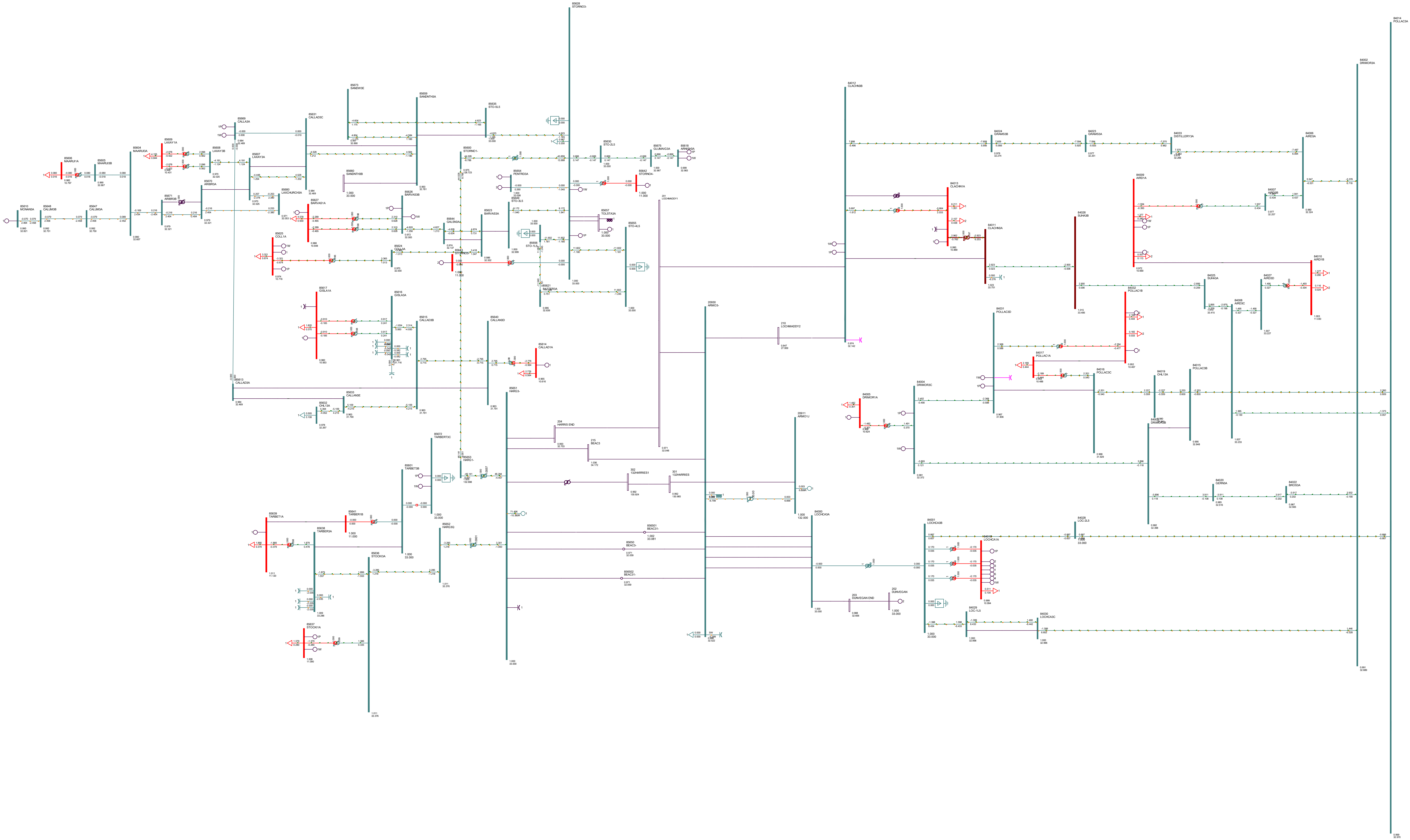
APPENDIX

APPENDIX-A

PSS/E OVERVIEW DIAGRAM



APPENDIX-B

PSS/E OPTION RESULTS FOR SUMMER MINIMUM AND WINTER MAXIMUM

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The attached Excel workbook contains the PSS/E option results for summer minimum and winter maximum.

APPENDIX-C

Sub-Sea Cable Data Sheets

4.5.4 3-phase power cable, 18/30(36)kV

Conductor X-section [mm2]	50	70	95	120	150	185	240	300
Conductor diameter [mm]	8,2	9,9	11,5	12,9	14,3	16,0	18,4	20,5
Phase diameter [mm]	31,8	33,5	35,3	36,8	38,5	40,1	42,8	46,0
Screen cross sectional area [mm2]	21,6	23,0	24,2	25,3	26,4	27,8	29,6	31,3
Lay up diameter (3xUNIT-P) [mm]	69,4	73,0	76,9	80,1	83,8	87,3	93,1	100,0
Armour steel wires diameter [mm]	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Diameter over armour [mm]	77,8	81,4	85,3	88,6	92,2	95,7	101,5	108,4
Nominal outer diameter [mm]	83,8	87,4	91,3	94,6	98,2	101,7	107,5	114,4
Outer diameter tolerance [mm]	± 2.8	± 2.9	± 3,0	± 3.1	± 3.2	± 3.4	± 3.5	± 3.8
Conductor DC resistance [Ω/km]	0,387	0,268	0,193	0,153	0,124	0,099	0,075	0,060
Screen DC resistance [Ω/km]	0,796	0,748	0,711	0,680	0,652	0,619	0,581	0,550
Armour DC resistance [Ω/km]	0,24	0,23	0,22	0,21	0,20	0,19	0,18	0,17
Max current rating [A]	183	226	270	306	342	384	440	491
Short circuit current for 1s, conductor [kA]	7,6	10,5	14,2	17,8	22,2	27,3	35,3	44
Short circuit current for 1s, screen [kA]	3,4	3,6	3,8	4,0	4,1	4,3	4,6	4,8
Capacitance per phase [µF/km]	0,146	0,163	0,178	0,192	0,205	0,221	0,244	0,263
Dielectrical loss [W/m]	0,060	0,066	0,073	0,078	0,084	0,09	0,099	0,107
Charging current [A/km]	0,83	0,92	1,01	1,08	1,16	1,25	1,38	1,49
AC resistance [Ω/km]	0,492	0,341	0,246	0,195	0,158	0,127	0,097	0,078
Inductance per phase [mH/km]	0,460	0,432	0,413	0,398	0,387	0,372	0,357	0,350
Reactance [Ω/km]	0,144	0,136	0,130	0,125	0,121	0,117	0,112	0,110
Impedance [Ω/km]	0.507+0.144i	0.357+0.136i	0.262+0.13i	0.212+0.125i	0.176+0.121i	0.145+0.117i	0.116+0.112i	0.098+0.11i
Cable weight in air [kg/m]	10,9	12,0	13,4	14,6	16,0	17,5	20,1	22,9
Cable weight in water [kg/m]	6,0	6,7	7,5	8,2	9,1	10,1	11,8	13,4
Min bending diameter [m]	2,3	2,4	2,6	2,7	2,8	2,9	3,0	3,3
Safe handling load [kN]	204	221	245	264	289	314	357	401

CURRENT RATING FOR XLPE SUBMARINE CABLE SYSTEMS

The XLPE cable should at least have a conductor cross section adequate to meet the system requirements for power transmission capacity. The cost of energy losses can be reduced by using larger conductor.

Load losses in XLPE cables are primarily due to the ohmic losses in the conductor and the metallic screen. XLPE cables can be loaded continuously to a conductor temperature of 90°C.

The dielectric losses of XLPE insulation are present also at no load. Those losses depend on the operation voltage applied and shall be considered above 100 kV.

Dielectric losses in XLPE cables are lower than for EPR and fluid-filled cables.

The current rating of submarine cables follows the same rules as for land cables. However there are some differences:

- Three-core submarine cables usually have steel wire armour. Single-core cables have non-magnetic armour.
- Single-core cables can be laid separated or close. Close laying gives lower losses. Separation eliminates mutual heating but means higher losses in the armour. The induced current in the armour can be high, up to the same value as in the conductor.

Single-core cable with lead sheath and wire armour

Three-core cable with optic fibers, lead sheath and wire armour

Continuous current ratings for three-core submarine cables are given in Tables 33-34 and for single-core cables in Tables 35-36. The continuous current ratings are calculated according to IEC 60287 series of standards and with the following conditions:

- One three-core cable or one three-phase group of single-core cables
- Temperature in sea bed 20°C
- Laying depth in sea bed 1.0 m
- Sea bed thermal resistivity 1.0 K x m/W

Rating factors for sea bed temperature - see Tables 7-11 in the brochure “XLPE Land Cable Systems - User’s guide”.

Current rating for three-core submarine cables with steel wire armour

Table 33

10-90 kV XLPE 3-core cables		
Cross section mm²	Copper conductor A	Aluminium conductor A
95	300	235
120	340	265
150	375	300
185	420	335
240	480	385
300	530	430
400	590	485
500	655	540
630	715	600
800	775	660
1000	825	720

Table 34

100-300 kV XLPE 3-core cables		
Cross section mm²	Copper conductor A	Aluminium conductor A
300	530	430
400	590	485
500	655	540
630	715	600
800	775	660
1000	825	720

CURRENT RATING FOR XLPE SUBMARINE CABLE SYSTEMS

Current rating for single-core submarine cables

Table 35

Cross section Cu conductor	Rated voltage 10 - 90 kV	
	Wide spacing	Close spacing
mm²	A	A
95	410	315
120	465	355
150	520	395
185	585	435
240	670	495
300	750	545
400	840	610
500	940	670
630	1050	740
800	1160	805
1000	1265	870

Table 36

Cross section Cu conductor	Rated voltage 100 - 420 kV	
	Wide spacing	Close spacing
mm²	A	A
185	580	445
240	670	505
300	750	560
400	845	620
500	950	690
630	1065	760
800	1180	830
1000	1290	895

Note 1: Calculations were performed assuming single layer of 5 mm copper armour wire.
Note 2: Aluminium cables (conductor made of aluminum and armouring made of aluminium alloy) will have a rating of 75 to 80 % for the same conductor area.
Note 3: The rating data given in the above tables should be regarded as indicative only.
Note 4: Cross sections larger than 1000 mm² can be offered on request.

TECHNICAL DATA FOR XLPE SUBMARINE CABLE SYSTEMS

Three-core cables with lead sheath

Cross-section of conductor	Diameter of conductor	Insulation thickness	Diameter over insulation	Lead sheath thickness	Outer diameter of cable	Cable weight (Aluminium)	Cable weight (Copper)	Capacitance	Charging current per phase at 50 Hz	Inductance
mm^2	mm	mm	mm	mm	mm	kg/m	kg/m	μF/km	A/km	mH/km

Table 47

Three-core cables, nominal voltage 132 kV (Um = 145 kV)										
185	15.8	18.0	54.2	2.1	165.0	41.4	44.9	0.13	3.0	0.47
240	18.1	17.0	54.5	2.1	166.0	41.8	46.3	0.14	3.4	0.44
300	20.4	16.0	54.8	2.1	167.0	42.4	48.0	0.16	3.8	0.42
400	23.2	15.0	55.6	2.1	168.0	43.6	51.1	0.18	4.3	0.40
500	26.2	15.0	59.0	2.3	176.0	48.6	58.0	0.20	4.6	0.38
630	29.8	15.0	62.6	2.4	185.0	53.3	65.2	0.21	5.1	0.37
800	33.7	15.0	66.5	2.5	194.0	59.0	74.0	0.23	5.6	0.36
1000	37.9	15.0	71.3	2.7	206.0	66.6	85.4	0.25	6.1	0.35

Table 48

Three-core cables, nominal voltage 150 kV (Um = 170 kV)										
240	18.1	21.0	62.5	2.4	184.0	51.1	55.5	0.13	3.4	0.47
300	20.4	20.0	62.8	2.4	185.0	51.7	57.3	0.14	3.7	0.44
400	23.2	19.0	63.6	2.4	187.0	52.9	60.5	0.15	4.1	0.42
500	26.2	18.0	65.0	2.5	190.0	55.7	65.1	0.17	4.7	0.40
630	29.8	17.0	66.6	2.5	194.0	57.8	69.7	0.19	5.3	0.38
800	33.7	17.0	70.5	2.7	204.0	64.7	79.8	0.21	5.7	0.37
1000	37.9	17.0	75.3	2.8	215.0	71.6	90.5	0.23	6.3	0.36

Table 49

Three-core cables, nominal voltage 220 kV (Um = 245 kV)										
500	26.2	24.0	77.6	2.9	219.0	71.8	81.3	0.14	5.7	0.43
630	29.8	23.0	79.2	3.0	224.0	74.9	86.7	0.16	6.4	0.41
800	33.7	23.0	83.1	3.1	234.0	80.2	95.3	0.17	6.9	0.40
1000	37.9	23.0	87.3	3.1	241.0	85.1	104.0	0.19	7.4	0.38

Table 50

Three-core cables, nominal voltage 275 kV (Um = 300 kV)										
500	26.2	26.0	81.6	2.9	229.0	75.3	84.7	0.14	6.8	0.44
630	29.8	24.0	81.2	3.0	228.0	77.0	88.9	0.16	7.7	0.42
800	33.7	24.0	85.1	3.1	237.0	82.5	97.6	0.17	8.3	0.40
1000	37.9	24.0	89.3	3.1	247.0	87.4	106.3	0.18	9.0	0.39

7. REFERENCES

[1] SSEN provided the Lochcarnan and Stornoway grid PSS/e models for both summer minimum and winter maximum scenarios in an email dated July 17, 2023..

[2] *SSEN provided Dunvegan Grid parameters for modelling in PSS/e software in an email dated September 29, 2023..*

[3] “SSEN std TG-NET-OHL-010, LOAD RATINGS OF OVERHEAD LINES – DATA SHEET”.

[4] “SSEN std TG-NET-OHL-104, ELECTRICAL CONSTANTS FOR OVERHEAD LINES – DATA SHEET”.

[5] SSEN has provided DFES load demand and generation files in SharePoint dated July 19, 2023..

[6] “SSEN provided the Clachan substation demand for modelling in PSS/e software in an email dated September 10, 2023.”.

[7] SSEN confirmed the revised load demand forcast at Clachan substation in an email dated September 17, 2023..

[8] TG-NET-NPL-002,33 kV New Demand & Generation Connections - Planning and Design Standard.

[9] SSEN provided the additional outer herbrides options in an email dated September 29, 2023..

[10] “SSEN provided the rated short circuit symmetrical and peak short circuit values for the substation located at Lochcarnan and Stornoway grids for short circuit analysis in an email dated September 30, 2023.”.

[11] *SSEN provided typical generation impedance values for generators modelling in PSS/e software in an email dated August 23, 2023..*

[12] “SSEN provided the clachan substation demand for modelling in PSS/e software in an email dated September 10, 2023.”.

[13] National Grid GRID CODE, 2023.