Inter-island undersea cable connection

Azores

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Date: 16/04/2020

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Document Review History

Version	Date	Author/s	Summary of changes
1	06 / 04 / 2020	Emmanuel Namanya	Updated as per Client comments
0	03 / 02 / 2020	Emmanuel Namanya	First version

The Clean Energy for EU Islands Secretariat

Who we are

The launch of the Clean Energy for EU Islands Initiative in May 2017 underlines the European Union’s intent to accelerate the clean energy transition on Europe’s more than 1,400 inhabited islands. The initiative aims to reduce the dependency of European islands on energy imports by making better use of their own renewable energy sources and embracing modern and innovative energy systems. As a support to the launch of the initiative, the Clean Energy for EU Islands Secretariat was set up to act as a platform of exchange for island stakeholders and to provide dedicated capacity building and technical advisory services.

The Clean Energy for EU Islands Secretariat supports islands in their clean energy transition in the following ways:

- It provides technical and methodological support to islands to develop clean energy strategies and individual clean energy projects.

- It co-organises workshops and webinars to build capacity in island communities on financing, renewable technologies, community engagement, etc. to empower them in their transition process.

- It creates a network at a European level in which islands can share their stories, learn from each other, and build a European island movement.

The Clean Energy for EU Islands Secretariat provides a link between the clean energy transition stories of EU islands and the wider European community, in particular the European Commission.

1. Introduction

An undersea cable connection between the islands has been a long-sought grid extension for the Azores islands (hereinafter referred to as "the project"). By coupling islands, it would be possible to pool electricity demand and generation, gaining on economies of scale and reducing power-to-energy ratios which would result in economic efficiency and lower environmental impact.

An undersea cable was tested between 1977 and 1981 but recurrent breakdowns and high repair costs led to its abandonment. In the subsequent years, namely in 2002 and 2010, new studies rendered the solution uneconomical given the high probability of cable failure due to the extreme depths between the Azores islands, coupled to a rough basalt ocean floor and strong ocean currents.

Today, following the strong technological development of undersea cables and its worldwide implementation, the question stands on whether the technology is feasible and the role it could have on the ongoing energy transition of the Azores.

Objectives

As part of a Call for Proposals launched in 2019 for project support to islands, the Clean Energy for EU Islands Secretariat is providing Technical Advisory services to the Azores archipelago in Portugal. This technical note covers the trends of undersea power cabling and a high level assessment of installing undersea electric grid cables between the Azores islands of Pico and Faial and recommendations on further studies to develop this project. Undersea cables can move lower cost power to an area faced with high cost of power generation and consumption, improve energy security and reliability, and can help reduce the potential for power outages.

2. Project Description

Site Location

The Azores comprise nine islands in the state of Portugal. This report shall only cover the connection of the islands of Pico and Faial. The islands of Pico and Faial are located approximately 1,650 km from mainland Portugal and the islands have a separation of approximately 6 km. Refer to Figure 1 and Table 1 for details.

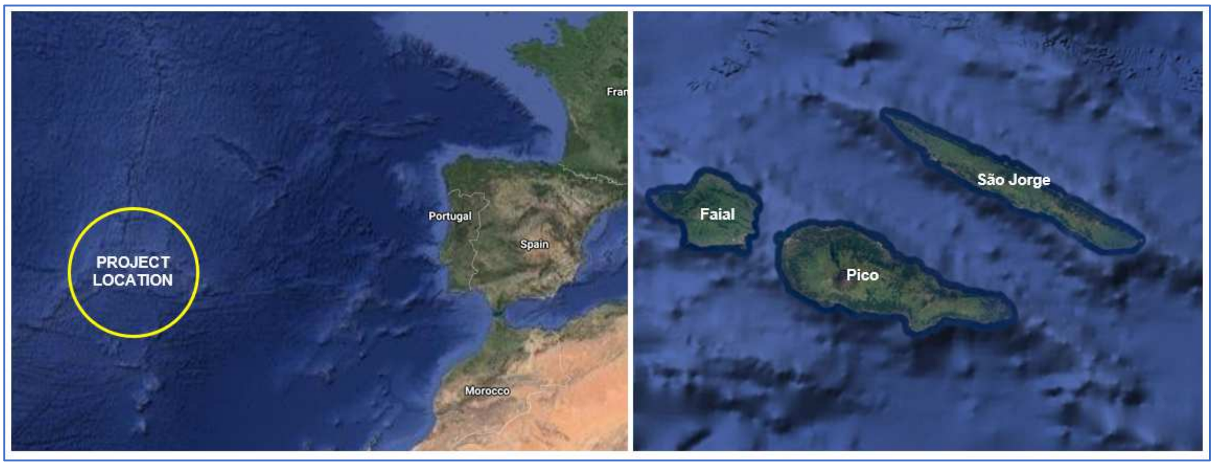

Figure 1: Project Location

Azores Project	**Value**
Pico Island	Latitude: 38.4601 °N | Longitude: -28.3205 °E Altitude: 0 m above sea level
Faial Island	Latitude: 38.5836 °N | Longitude: -28.7090 °E Altitude: 0 m above sea level

Table 1: Project Location Details

Reference Documentation

3E did not receive the previously done reports or tests on the undersea cable studies, referenced in section 1. Therefore, the results of this assessment should be considered only as a concept solution which can form the basis of a detailed feasibility study going forward. For the purpose of this study, 3E shall assume an installation for the undersea cable connection between the islands of Pico and Faial, as shown in Figure 2.

Each of the Azores islands has its own electricity network, operated at a frequency of 50 Hz, without interconnections between islands. The power networks in the islands are largely characterised by 15 kV rated transmission / distribution system as shown below [1] [2]:

- Pico Island: Transmission at 30 kV and distribution at 15 kV and 0.4 kV;
- Faial Island: Distribution at 15 kV and 0.4 kV;

The closest nodes for connection between the islands of Faial and Pico are Santa Bárbara thermal power plant (Faial) and Madalena substation (Pico) [1]. In this report, it shall be assumed that the inter-island connection is characterised as follows:

- Total cable length of 12 km (8 km under sea and 4 km above land);
- Maximum sea depth of 140 m;
- Rated Voltage of 60 kV.

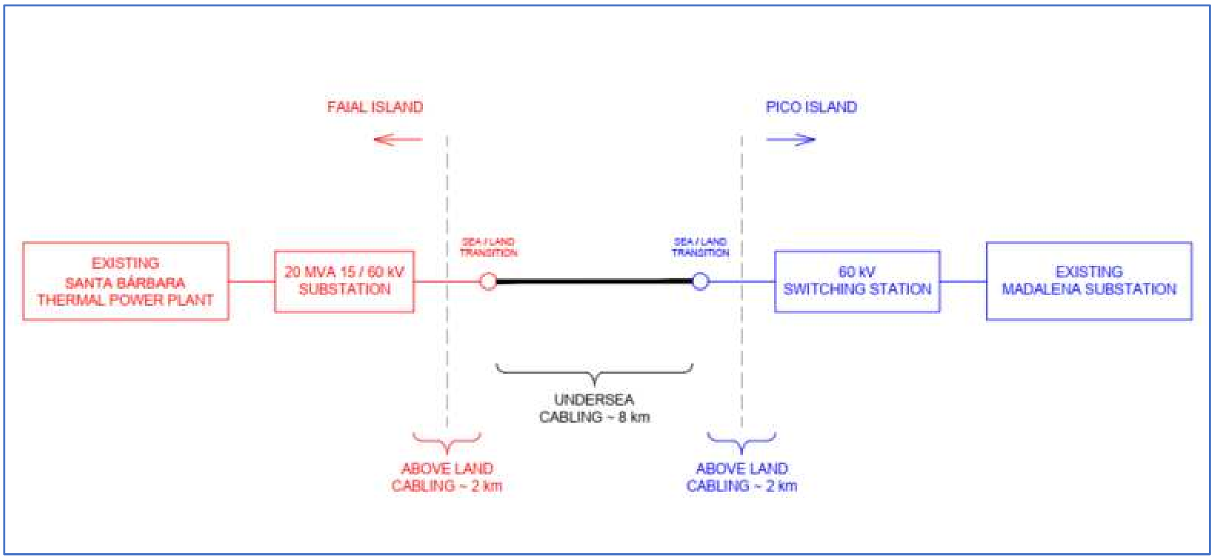

Figure 2: Illustration of undersea inter-island cable connection

To achieve the undersea connection described above, the following high level scope of works is assumed in this study:

- Faial Island:
    - Installation of a new 20 MVA 15 / 60 kV substation connecting to the existing Santa Bárbara thermal power plant. Additional bays and space can be added to accommodate additional spare capacity / connections;
    - Land – sea cable transitions or joints for the undersea cable.

- Pico Island:
    - Installation of a new 60 kV switching station connecting to the existing Madalena substation;
    - Land – sea cable transitions or joints for the undersea cable

3. Proposed System Configuration

HVDC vs. HVAC

As outlined in section 2, the undersea cable connection power transmission shall be over high voltage compared to low or medium voltage given the increased transmission efficiency and lower losses over long distances.

There are two options for high voltage power transmission, i.e. HVAC or HVDC, which are compared below [3]:

- HVDC technology requires fewer conductors to carry as much power as HVAC technology;
- Power transmission losses are reduced in HVDC than HVAC i.e. HVAC losses increase with distance while HVDC losses are relatively constant. However, for a distance less than 600 km, HVDC losses (including terminal losses) are higher than HVAC;
- The capital investment costs for HVDC line / cabling are less than an AC line / cabling for the same transmission capacity. However, HVDC terminal stations, which are required at both cable ends have a significant capital cost. It should be noted that over a break-even distance (as shown in Figure 3), HVDC alternative will provide a lower investment cost. For this project application, HVAC system requires less investment capital.

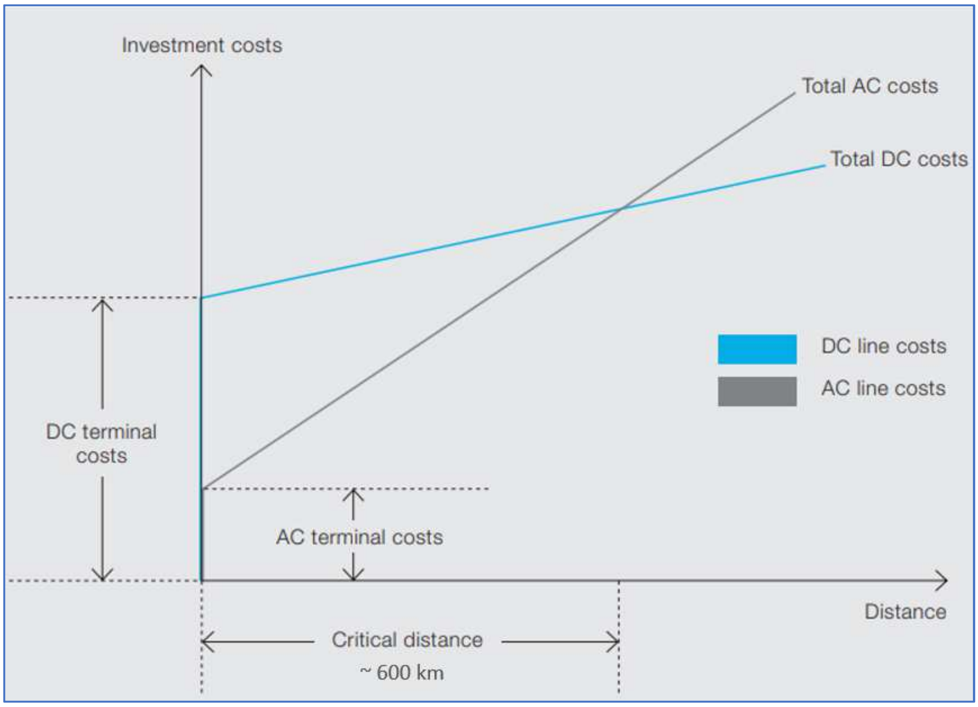

Figure 3: HVDC vs. HVAC Capital Cost Comparison [3]

Although HVDC has been widely adopted for several undersea cable connections in the world today such as off-shore wind farms, HVAC system is more suitable for this project. 3E recommend a further study is conducted to determine the financial feasibility of the HVAC solution.

Cable Technology Review

Power cables are usually categorised based on their insulation system [4], as outlined below:

- High-Pressure, Fluid-Filled (HPFF);
- High-Pressure, Gas-Filled (HPGF);
- Self-Contained, Fluid-Filled (SCFF) and Mass Impregnated cables (MI)
- Polymeric, extruded e.g. Cross-Linked Polyethylene (XLPE), Ethylene Propylene Rubber (EPR)

Table 2 provides further details on common undersea cable technologies [1][4].

Aspect	**XLPE (Three core)**	**XLPE (Single core)**	**Self-Contained Fluid Filled**	**Mass Impregnated**
Maximum Voltage	245 kV	420 kV	525 kV	500 kV
Maximum Power per circuit	400 MVA	1200 MVA	1200 MVA	1600 MW
Length Limitations	Not limited by cable technology > 500 km	Not limited by cable technology > 500 km	60 km due to hydraulic system limits	Not limited by cable technology > 500 km
Usual application	Connection of islands with small or large population, offshore wind platform	Connection of islands with large population, offshore wind platform	Crossing of rivers with large transmission capacity	Long distance connections of autonomous power grids

Table 2: Undersea Cable Technology Comparison

From the above analysis, XLPE cable technology would be suitable for this application and distance requirements. XLPE cables have good mechanical properties such as high chemical resistance to oil and solvents, excellent tensile strength and high abrasion resistance, as well as good electrical properties such as high short circuit temperature withstand ability, high AC voltage breakdown strength and have very good dimensional stability at temperatures above 90°C.

Below are some of the key Original Equipment Manufacturers (OEMs) in the undersea high voltage cabling industry. Based on a review of their profiles, 3E has no specific concerns on these OEMs, who have the necessary experience to provide cable products for this project:

- Prysmian
- Nexans
- NKT High Voltage Cables
- Cable Hellenic Cables
- Southwire
- Leoni
- Sumitomo
- Fujikura
- Hitachi Cable

There have been massive steps forward and progress in the undersea cable technology and therefore the technology today is suitable for the application in this project. The cables manufactured today are able to withstand rough ocean floors, deeper installation and higher power evacuation and longer distances.

The length and depth of the cable route are a challenge for design and installation but given the extensive experience of the above mentioned OEMs, this project should be technologically feasible. Similar projects from some of the above mentioned OEMs include:

- 34.5 kV shore substation submarine cable project Mindanao, Philippines (Nexans);
- Submarine cables for Ostwind 1 Offshore Wind Farm in the Baltci Sea (Prysmian);
- 11 km, 25 kV Bell Island Interconnection (Cable Hellenic Cables).

3E recommends that the 2 - 3 of the above cable OEMs are consulted to provide solutions, detailing technical parameters, failure / fault characteristics and commercial offers, for this project.

System Costs

For the above mentioned system configuration, Table 3 outlines the supply and installation costs, from reputable suppliers and OEMs[1] as well as 3E's experience on previous projects of similar scope. For the purposes of costing, 3E selected single core cables over three core cables. 3E recommends that the Client obtains commercial offers from reputable Contractors and conduct a more detailed technical solution and financial analysis as this is only a high-level estimation based on limited data.

ID	Item Description	Unit	Qty	Rate	Total Cost
1	3 x Single Core 69 kV Al / XLPE submarine cables (with armouring and HDPE sheath with bituminous layer) including straps.	m	12000	€ 300	€ 3,600,000
2	Phase end Terminations for HV cables	each	6	€ 15,000	€ 90,000
3	20 MVA 15 / 60 kV Substation including connection to existing Santa Bárbara thermal power plant	sum	1	€ 4,000,000	€ 4,000,000
4	60 kV switching station	sum	1	€ 2,500,000	€ 2,500,000
	TOTAL				**€ 10,190,000**

Table 3: System Cost Estimates

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[1] Cable cost estimates obtained from Nexans are only for budgetary purposes.

4. Reliability

An undersea cable for this project was tested between 1977 and 1981 but recurrent breakdowns and high repair costs led to its abandonment. In the subsequent years, namely in 2002 and 2010, new studies rendered the solution uneconomical given the high probability of cable failure due to the extreme depths between the Azores islands, coupled to a rough basalt ocean floor and strong ocent currents.

The installation of undersea / submarine cables is very complex and requires specialised ships and qualified personnel to undertake. Given the rough, rock and irregular ocean floor, cable mooring through concrete blocks can be considered. Furthermore, the cable specified for this application should have a corrosion resistant high-density polyethylene (HDPE) sheath with a bituminous layer [4].

Technological advancements in cable manufacturing, cable reliability has improved from 0.264 failures / year / 100km to 0.1 failures / year / 100km [4]. Additionally, improved operation and maintenance procedures with real-time monitoring and routine inspections or preventive maintenance can detect any damages early and prompt repairs, resulting in better reliability and longer lifetime of the system. 3E recommends that a detailed analysis, addressing the reliability and fault studies for the offered cables, is provided by the cable OEMs for this project.

References

[1] — Filipe Melo. Natural zonal vegetation of the Azores Islands: Characterization and potential distribution

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[3] — ABB, "Why HVDC? Economic and Environmental Advantages", viewed 26 Feb 2020, https://new.abb.com/systems/hvdc/why-hvdc/economic-and-environmental-advantages

[4] — Svandís Hlín Karlsdóttir. (2013) Experience in transporting energy through subsea power cables: The case of Iceland.

[5] — Cablel Hellenic Cables Group, "Submarine Cables Brochure" , viewed 26 Feb 2020, https://www.cablel.com/803/en/submarine-cables/

Annex A: Submarine Cable Specification

The table below provides an example for the minimum general cable specifications, as per 3E expectations, for undersea cables [5].

Aspect	**Unit**	**Required Value**
Minimum Design Life	years	> 25
Rated Voltage U_o / U (U_{max})	kV	40 / 69 (72.5)
Standards		IEC 60840, IEC 62067
Number of cores		1 or 3
Conductor		Copper or Aluminium (Circular stranded compacted, longitudinal water-tight) with conductor screen
Insulation		XLPE or EPR
Armouring		Galvanized round steel wires, with helically applied bitumen compound coat Capable of high tensile forces, adjusted to project specific requirements
Sheath		HDPE and extruded semiconducting compound
Application		Suitable for installation in the ground and in water. They may be laid directly in the ground, in ducts or in cable troughs

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