CABLE SIZING AND RELIABILITY OF SYSTEM FOR HDD SOLUTIONS AND HIGH SLOPES LAND SECTIONS

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FRANCE-SPAIN BISCAY GULF INTERCONNECTION

Summary :

The purpose of this study is to assess the impact of two different HDD configurations on the cable system design (for both technologies XLPE and MIND), by performing a risk analysis considering the cable system installation and its reliability during operation and maintenance.

1 Index

2 Abbreviations

FR	France
SP	Spain
HVDC	High Voltage Direct Current
TSO	Transmission System Operator
XLPE	Cross-Linked Polyethylene
MIND	Mass Impregnated Non-Draining
HDD	Horizontal directional drilling.
VSC	Voltage source converters

Table 1 – List of abbreviations

3 Project overview

3.1 Project Presentation

The "France-Spain Gulf of Biscay" Project consists of creating a new electricity interconnection between France and Spain. This project is being undertaken by the Transmission System Operator of the two countries (*Réseau de Transport d'Electricité* (RTE) and *Red Eléctrica de España* (REE)) via a joint subsidiary (INELFE). The interconnection will include two HVDC links, with converter stations, submarine and underground cables.

Cable technologies considered	- XLPE - MIND
Converter station technology	VSC
Power	2 x 1000 MW through 4 power cables
Voltage level	See below
Length (total) - **Land part** - **Submarine part**	370 km - 80 km (France) + 10 km (Spain) - 290 km
Maximum operation temperature (°C)	- 70° for XLPE - 55° for MIND
Cable system lifetime	Over 40 years

Table 2 – Project general input data

This feasibility study is focussed of XLPE and MIND technologies as they are the most common current technologies in submarine links. If the cable manufacturer would aim to offer PPLP technology, information should be provided in terms of test certifications and projects experience which should be included in §2.1 and 3.1 of the Excel file. Any specific constraint of this technology with regards to the HDD solutions described in this document should also be highlighted in the final report.

At least, two optical fibre cables will also be installed (communication between the stations and monitoring).Different voltage levels shall be considered for this study:

- **XLPE:** 320 and 400 kV
- **MIND:** 500 kV

The submarine route passes by a submarine canyon: the Capbreton canyon. One of the solutions considered for the crossing of the canyon is based on a offshore (sea to sea) horizontal directional drilling. This case is presented in §.4.1.

On the other hand, Spanish landfall area presents a quite unfavorable orography for underground cable routing. A set of routes are under study which imply different landfall points, including quite challenging HDD alternatives. This case is described in §.4.2.

3.2 Project route

Cable route is presented in Figure 1.

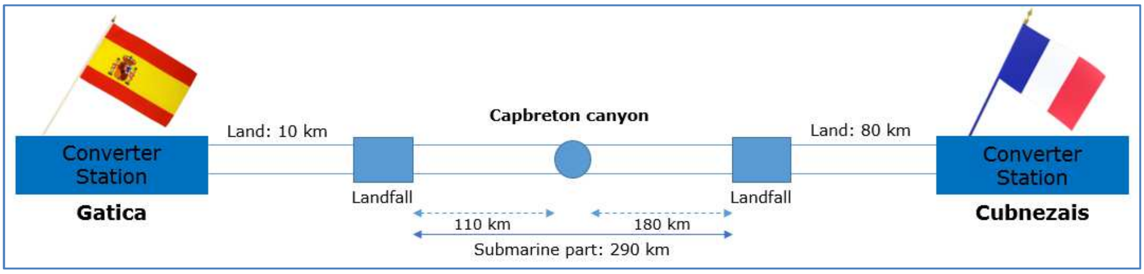


Figure 1 – cable route between France and Spain passing by the Capbreton canyon

4 Description of HDD solutions

The impact of these solutions on the cable system design, cable installation and reliability during operation and maintenance has to be studied in this Work.

4.1 Case A – Capbreton Canyon – offshore (sea-to-sea) HDD

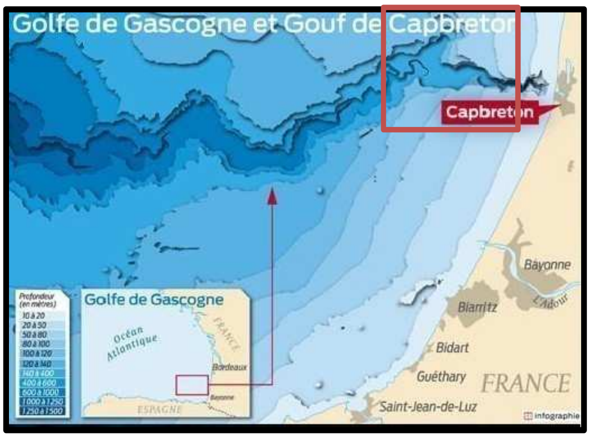


Figure 2 – Localization of the Canyon and of the crossing solution under consideration in this study

For this study, the considered solution of the Canyon consists of performing a HDD under it, from sea to sea.

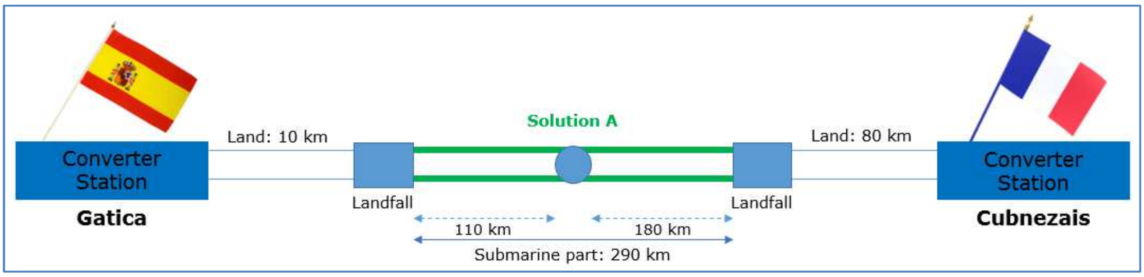


Figure 3 – Localization of Canyon crossing

More details are given in **Appendix 1**.

4.2 Case B – Spanish landfall

The landing of the cables in the Spanish coast will be made in the rugged coastline of Vizcaya.

Several alternatives for HDD landing are under evaluation.

Figure 4 - Spanish HDD landfall area

For this study, a hypothetical case based on the main constraints of the different alternative has been elaborated.

More details are given in **Appendix 2**.

4.3 Configuration of the HDD

The Figure 5 shows the configuration of the HDDs for the power cables. In this configuration there is one hole per power cable. For the purpose of this feasibility study no grout filling should be considered.

FO cables might need other HDDs or could be integrated in the same HDDs as the power cables.

The following configuration is the same for both cases A and B.

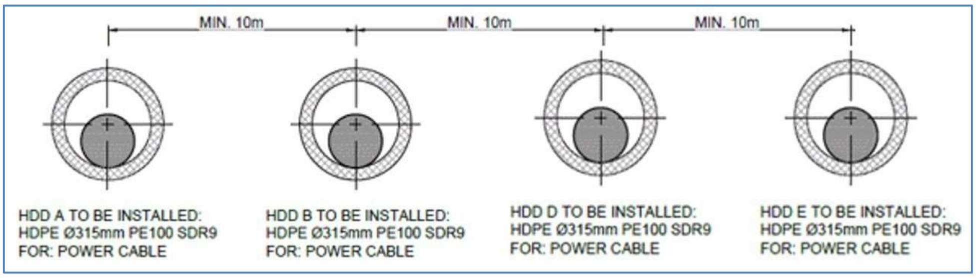


Figure 5 – Configuration of the HDD (for information).

Noting that diameter of HDPE pipes can be modified for the calculations requested in the study depending on cable design and strain calculations.

5 Constraints on land sections in Spanish side

The first part of the land route in the Spanish side is quite rugged. Several underground cable routes are under consideration and long sections with relatively high slopes might not be avoided.

In the following figures two representative examples profiles that could be found along the study area are shown:

Figure 6 – High slope section. Example 1

Figure 7 – High slope section. Example 2

For this type of land sections, the cable manufacturer is requested to assess the installation method considering a 2500 mm² Cu conductor for XLPE cable and a 1800 mm² Cu conductor for MIND cables:

- Type of transport for cable drums delivery (on one of the extremes of the Figure 7, the highest slopes are found, with a short length of around 30% slopes). Regular transport might be considered until the beginning of the high slopes sections and special solutions beyond those points,
- Number of length of cable sections,
- Pull-in constraints,
- Joint bays basic design and position,
- Mitigation measures to avoid excessive efforts on the joints,
- Possible constraints related to the specific cable technology.

6 Deliverables

It is requested for the cable manufacturer to produce the below deliverables (1, 2 and 3).

6.1 Deliverable 1 – Cable design and sizing

The contractor has to perform a preliminary cable design and cable sizing for the two following technologies:

- XLPE – 320 and 400 kV
- MIND – 500 kV

And for the two crossing solutions:

- Case A – offshore (sea to sea) HDD
- Case B – landfall (land to sea) HDD

The cable manufacturer shall answer on either technologies (XLPE and MIND) or one (XLPE or MIND) according to its HVDC available technologies on the market.

The cable sizing shall be performed according to the information given in Appendix 1 and Appendix 2 (mechanical conditions), and Appendix 3 (thermal conditions).

The results for 400 kV can be extrapolated based on the 320 kV sizing.

6.2 Deliverable 2 – Risk analysis for HDDs

The questions regarding the technology, installation, reliability of the cable system during operation and maintenance are listed in the Excel file. The cable manufacturer shall study and give detailed responses to the questions for the case A and B vs both technologies:

- XLPE: § 2.2 of Excel file
- MIND: § 3.2 of Excel file

The answers shall be reported in to the attached Excel file and discussed deeply.

6.3 Deliverable 3 – Solutions comparison

The solution comparison shall be presented in §.0 of Excel file for the studied cases.

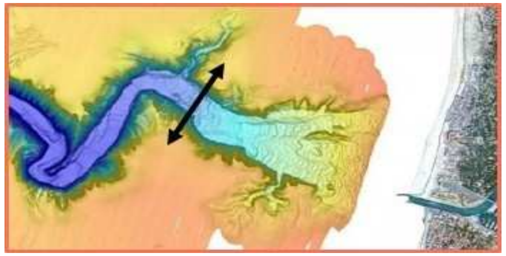
The results for the other voltage levels can be extrapolated based on the 320 kV sizing.

6.4 Final report

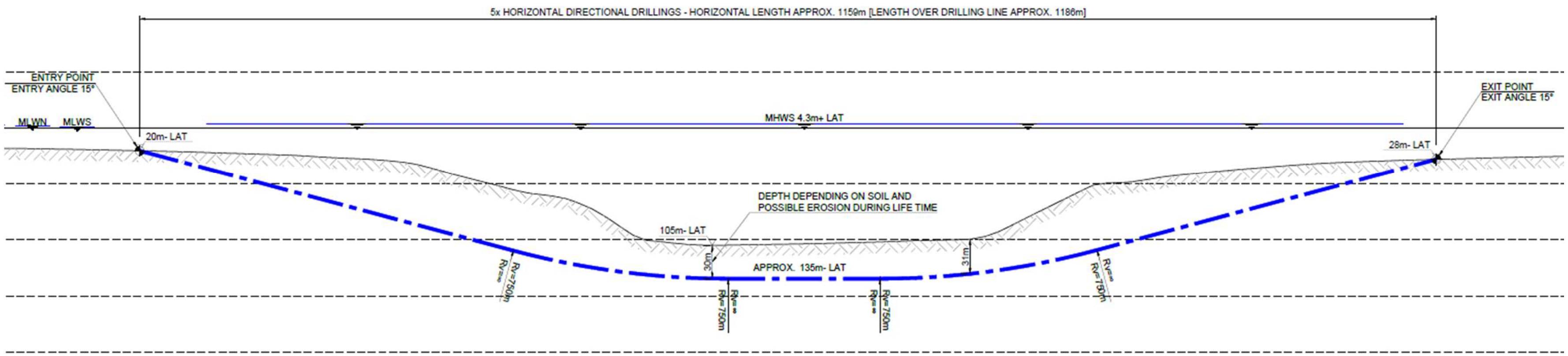
Final report shall include:

- Excel file deeply filled,
- Detailed calculations by stating all hypothesis for:
  - cable sizing,
  - tensile, compression and crush forces,
  - sidewall pressure.
- Comparison analysis report in A4 format by assessing the risk related to each technology and each case (A and B),
- Assessment of cable installation in high slope sections of the route (§.5).
- A document on the warranty possible to cover the different risks of this project. This document should address the issue of the defect notification period (5, 10, 15 years or more) and the mechanism of availability damages that could be set up.

Appendix 1. Hypothesis of HDD profile for solution A for cable mechanical sizing



- 4 HDD “sea to sea” for power cables
- Length: 1200 m
- Entrance depth of HDD: 20 m LAT
- Maximum depth of HDD: 135 m LAT
- Radius: 750 m
- Entry/exit angle: 15°



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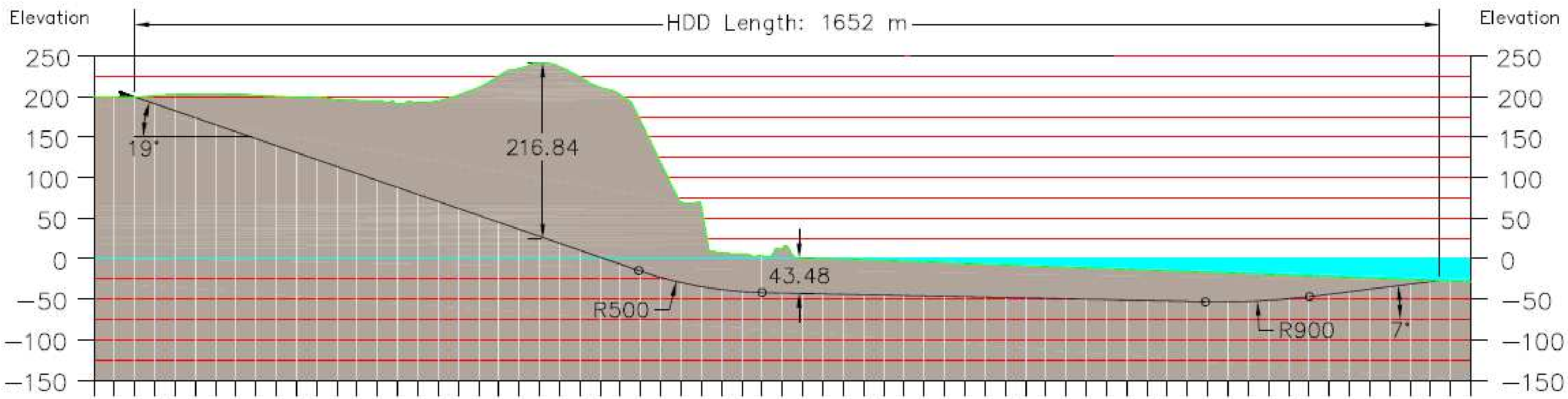
Appendix 2. Hypothesis of HDD profile for solution B for cable mechanical sizing

- 4 HDD "land to sea" for power cables
- Length: 1652 m
- Exit depth of HDD: 27 m LAT
- Maximum depth of HDD: 217 m
- Minimum radius: 500 m
- Slope in straight part at entry side: 34.4%
- Entry angle: 19°
- Exit angle: 7°



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Appendix 3. Hypothesis for Cable thermal sizing in HDD

A complementary calculation must be done for the thermal design of the cable. Taking into account the high depth of the HDD the calculation is requested to be made by applying a transient calculation using a finite element method. The following conditions should be considered:

- Calculation should be made for case B, considering the maximum depth under the surface is 215 m. 10m between axis should be considered for first approach,
- All four cables starting with 0 amps at t0 and running at their maximum capacity during 80 years,
- At the end of the 80 years, cable should not exceed the maximum temperature,
- One cable per HDPE duct, 315 mm SDR 9. Pipe diameter could be modified,
- Pipes unfilled (no grout should be considered for the calculation),
- Temperature of soil : 18°C,
- Thermal resistivity : 1 K.m/W,
- 2,14 MJ/(m^3K)for the thermal capacity of soil.

If the result exceeds the maximum allowable temperature, it is possible to enlarge the distance between ducts (in accordance with the first calculation). Due to the high depth of the HDD, calculation can be made considering the cables won’t heat the soil beyond a sphere of a radius R, and checking that at an increased radius R+r the result doesn’t change.

Note that due to the limitation indicated in the IEC 60853 (no more than x2.5 amps variation) it is requested to run a finite elements calculation.

Appendix 4. Others inputs

- Approximate geographical coordinates of HDD entry/exit points for case A:

Entry point – UTM 30N		Exit point – UTM 30N	
X (m)	Y (m)	X (m)	Y (m)
623493	4834977	624007	4835839

HDD alternatives from which the theoretical case B has been made are located between the Nuclear power plant of Lemóniz and the beach of Bakio, in Vizcaya.

- Kmz files showing the foreseen cable routes around the canyon
- Geophysical & geotechnical data:
  - Alignment charts indicating the bathymetry, isopatches, sediment nature, seabed features, longitudinal profiles. and vibro cores and cone penetrometer tests results around the canyon.
- Meteocean conditions:
  - Summary of waves and winds conditions at points located at the proximities of entry and exit points of case A and close to the case B area

Appendix 5. Data sheet

1	**Constructional data**	**Unit**
1.1	Conductor - cross section - Material - Type: - Approximate diameter	 mm² mm
1.2	Conductor screen - Material - Nominal thickness	 mm
1.3	Insulation - Material: - Nominal thickness:	 mm
1.4	Insulation screen - Material: - Nominal thickness:	 mm
1.5	Longitudinal water barrier - Material:	
1.6	Metallic sheath - Material: - Nominal thickness:	 mm
1.7	Plastic sheath - Material: - Nominal thickness	 mm
1.8	Bedding - Material - Indicative thickness:	 mm
1.9	Armour - Material: - Number of layers: - Nominal diameter of each bare wire (including galvanisation):	 mm
1.10	Serving - Material: - Indicative thickness:	 mm
1.11	Overall cable dimensions - Diameter: - Weight in air: - Weight in sea water:	 mm Kg Kg
2	**Mechanical data**	
2.1	Bending - Minimum bending during storage and operation - Minimum bending radius under tension (MBR)	m
2.2	Mechanical forces - Maximum straight pull tension (with FJ) - Maximum straight pull tension (without FJ) - Maximum sidewall pressure during installation - Maximum tensile during installation for solution A - Maximum tensile during installation for solution B	kN
2.3	Maximum allowable impact Energy (For Rock Dumping)	kJ
3	**Delivery length**	
3.1	Maximum deliverable length (with factory-made joints) Maximum production length (without factory-made joints)	km km

Appendix 6. Soil erosion at HDD pipe exit