PROGETTO PER LA REALIZZAZIONE DI UN IMPIANTO PER LA PRODUZIONE DI ENERGIA MEDIANTE LO SFRUTTAMENTO DEL VENTO NEL MARE ADRIATICO MERIDIONALE - BARIUM BAY

74 WTG – 1.110 MW

PROGETTO DEFINITIVO - SIA

Progettazione e SIA

Indagini ambientali e studi specialistici

Studio misure di mitigazione e compensazione

supervisione scientifica

5. OPERE DI CONNESSIONE ALLA RETE

R.5.2 Relazione tecnica sui cavidotti sottomarini

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REVISION HISTORY

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01	14/09/2023	for Review	First version	BL	FP	AC
02	25/01/2024	for Approval	Revised version	BL	FP	AC

CONFIDENTIALITY : Level B

Level A: Public

Level B: Confidential

CONTENT

FIGURES

TABLES

1 REFERENCES

1.1 Standards and Rules

Ref. Number	Document Title	Doc Number	Doc. Rev.
[1]	Calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects	IEC 60949	1988
[2]	Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um=36 kV) up to 150 kV (Um=170 kV)- Test methods and requirements	IEC 60840	2020
[3]	Submarine power cables with extruded insulation and their accessories for rated voltages from 6 kV (Um = 7,2 kV) up to 60 kV (Um = 72,5 kV) - Test methods and requirements	IEC 63026	2019
[4]	Electric cables - Calculation of the current rating	IEC 60287 series	-
[5]	Conductors of insulated cables	IEC 60228	2004
[6]	IEC standard voltages	IEC 60038	2009
[7]	Recommendations for Mechanical Testing of Submarine Cables	CIGRE TB 623	2015
[8]	Recommendations for Testing of long AC Submarine Cables with Extruded Insulation 30 (36) to 500 (550) kV	CIGRE TB 490	2012
[9]	Recommendations for additional testing for submarine cables from 6 kV up to 60 kV	CIGRE TB 722	2018
[10]	Recommendations for mechanical testing of submarine cables for dynamic applications	CIGRE TB 862	2022
[11]	Power cable rating examples for calculation tool verification	CIGRE TB 880	2022
[12]	G. Anders, “Rating of cables on riser poles”, Jicable	NA	1995
[13]	W. B. R. Hartlein, “Ampacity of Electric Power Cables in Vertical Protective Risers”, IEEE	NA	1983

2 INTRODUCTION

2.1 Project overview

Barium Bay is an offshore wind farm development project located in the Adriatic Sea, 40km off the Apulian coastline between Barletta and Bari. The project is being developed by Barium Bay Srl, a Joint Venture between Galileo, a pan-European platform for renewable energy development, and Gruppo Hope, a holding company active in designing renewable energy and green hydrogen plants.
The park includes 74 floating wind turbines of 15MW, for a total capacity of 1110MW. Two offshore substations 66/380kV collect and transform the power from the turbines. Two HVAC export cables (EXP1 and EXP2) connect the first substation to the shore following a 57km long corridor. The landing point is approximately 3 kilometers south of Barletta. One HVAC cable (EXP3) connect the second substation to the first one.

IRON SOLAR SRL has requested Aventa to perform the following preliminary studies relative to the submarine cables:

- EXP and IAC: Electrical and mechanical preliminary design
- EXP: Preliminary cable burial and risk assessment study
- EXP: Review of the export cable landfall configuration
- IAC: Preliminary dynamic cable configuration
- EXP and IAC: Installation philosophy of the export cables
- EXP and IAC: Cost evaluation

2.2 Purpose of the document

The purpose of this document is to present the cable designs proposed for the scope of work including a design description, design data and ampacity results for the scenarios described in the Basis of Design (BOD) document [29].

2.3 Abbreviations

The following abbreviations are used in the present document:

AC	Alternating Current
BOD	Basis of Design
CAPEX	Capital Expenditure
CIGRE	Conseil International de Grands Réseaux électriques (International Council on Large Electric Systems)
DC	Direct Current
HDD	Horizontal Directional Drilling
HVAC	High Voltage Alternating Current
IAC	Inter-array cable
IEC	International Electrotechnical Commission
IFR	Issued for Review

LIWL	Lightning Impulse Withstand Level
MBR	Minimum Bending Radius
OD	Outer diameter
PE	Polyethylene
PP	Polypropylene
RFP	Request for Proposal
TB	Technical Brochure
TBC	To Be Confirmed
TBV	To Be Validated
WTG	Wind Turbine Generator
U_0/U	Rated voltage
U_m	Highest system voltage
XLPE	Cross-linked polyethylene

3 PROJECT LAYOUT

The wind farm layout is presented in Figure 1. The farm is divided in two clusters of 37 turbines, distributed on 8 strings of 4 or 5 turbines. The strings are not looped. The two OSS are located on the western side (shore side) of their own cluster. Cluster n°1 is the northern part of the park and Cluster n°2 the southern part. OSS1 is installed in 130m water depth. OSS2 is positioned in 150m water depth. Both OSS are interconnected via an 15km HVAC link. The two export HVAC cables are connected to the OSS1 only.

Further optimization of the electrical layout might be recommended at a later design stage to consider OPEX scenario and potential LCOE optimization through redundancies.

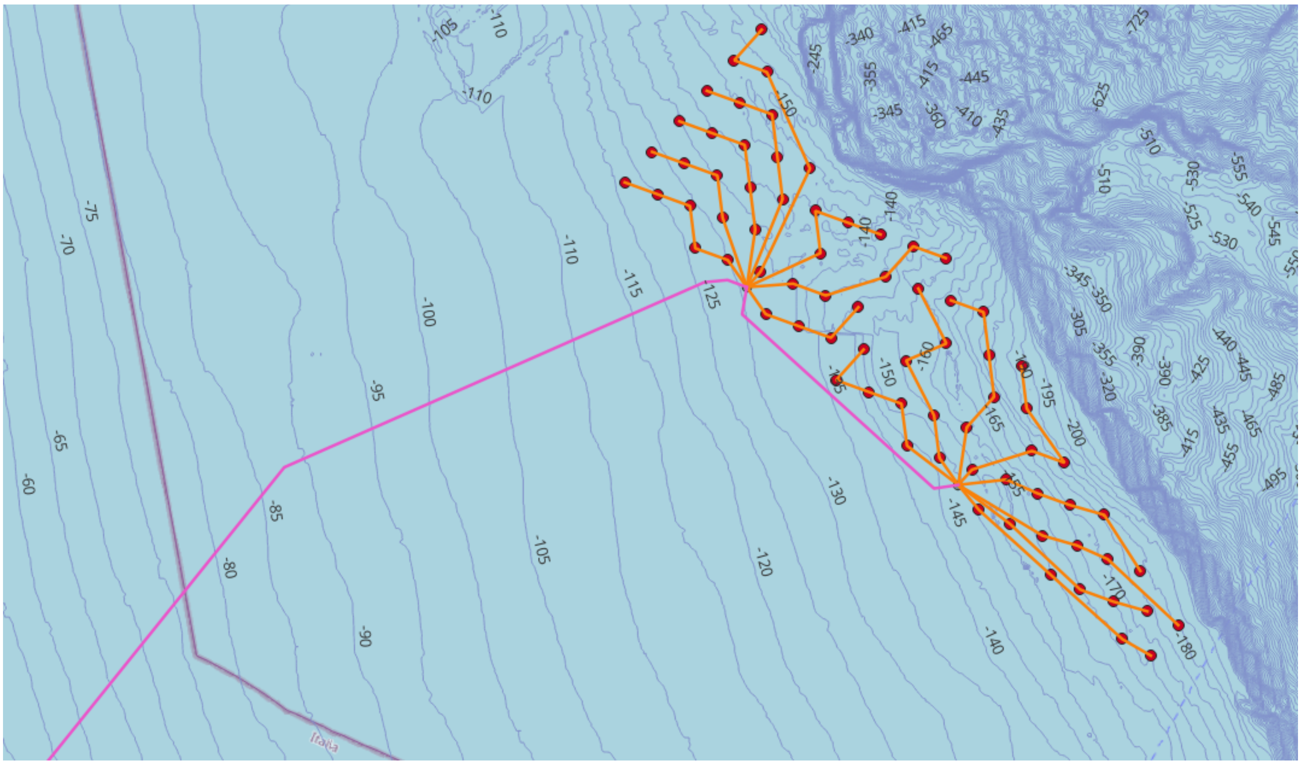


Figure 1 – Wind Farm Layout v5 with OSS, WTG, Cable schematics, 5m isobaths

4 CABLE CROSS SECTION OVERVIEW

A total of three cross sections are proposed for the project layout, according to the requirements established by HOPE:

Cable	Type	Voltage (kV)	Power (MW)	Cross section
IAC 1	Dynamic	66	30	3x120 mm² Cu
	Static			
IAC 2	Dynamic		75	3x800 mm² Cu
	Static			
Export 1	Dynamic	380	555	3x800 mm² Cu
	Static			

Table 1 – Cable cross section overview

Aventa proposes three possible configurations with the defined cross sections.

For the 2 required IAC cross sections at 66 kV, the proposed designs are:

- IAC 1 (dynamic and static), 3x120 mm^2 Cu, able to transmit the power of two WTG (30 MW).
- IAC 2 (dynamic and static), 3x800 mm^2 Cu, able to transmit the power of five WTG (75 MW).

For the required export cross section at 380 kV, the proposed design is:

- Export 1 (static), 3x800 mm^2 Cu, able to transmit a power of 555 MW.

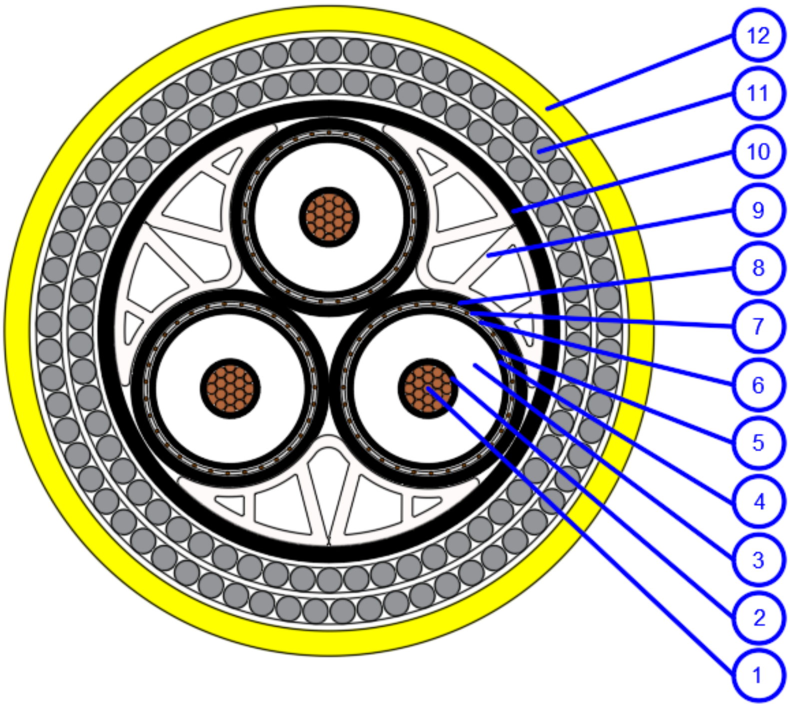
5 CABLE DESIGN

The cable designs are defined for the required parameters and application, specified in the BOD document [29], based on the applicable IEC standards [16][17][19], CIGRE recommendations [21][22][23][24][25] and market benchmark. The cable layers described in the next paragraphs are common in HVAC cross sections. Other solutions with different materials and/or dimensions could be implemented; however, based on knowledge of the submarine cable market, the proposed design provides a conservative approach in terms of linear weight and outer diameter of the cable. These parameters are determinant for the cable design and global analysis performed under the scope of this conceptual study.

The functionality of the cable design shall be demonstrated by the applicable analysis and qualification according to the applicable IEC standards [16][17] and CIGRE recommendations [21][22][23][24][25].

5.1 IAC 1 – 3x120 mm^2 Cu 66kV 30 MW dynamic

5.1.1 Cross section drawing of IAC 1 dynamic



Item	Layer	Nominal thickness (mm)	Nominal outer diameter (mm)
1	Conductor	13	13
2	Insulation	13	39
3	Metallic screen	31 wires x ϕ 0.8	41
4	Core sheath	2	47
5	Inner sheath	3	110
6	Armour	57/65 wires x ϕ 6	142
7	Outer sheath	5	152

5.1.2 Mechanical data of IAC 1 dynamic

Total weight in air: 48.2 kg/m

Total weight in water: 29.7 kg/m

Estimated MBR under tension: 3 m

Expected pulling tension during laying at max. water depth in WTG area [21]: 216 kN [1]

5.1.3 Electrical data of IAC 1 dynamic

Rated voltage, U_0/U: 38/66 kV

Highest continuous voltage, U_{max}: 72.5 kV

LIWL: 325 kV

Nominal current, I_N: 292 A

Max. design conductor temperature: 90°C

DC conductor resistance at 20°C: 0.153 Ω/km

AC conductor resistance at max. conductor temperature: 0.2 Ω/km

Inductance: 0.439 mH/km

Capacitance: 0.16 µF/km

Insulation loss factor (tan δ) = 4.10^{-3}

Thermal resistivities:

- T_1 = 0.657 K.m/W
- T_2 = 0.275 K.m/W
- T_3 = 0.038 K.m/W
- T_{4_buried} = 0.365 K.m/W

Max. short circuit current in the conductor: 17.1 kA for 1 s

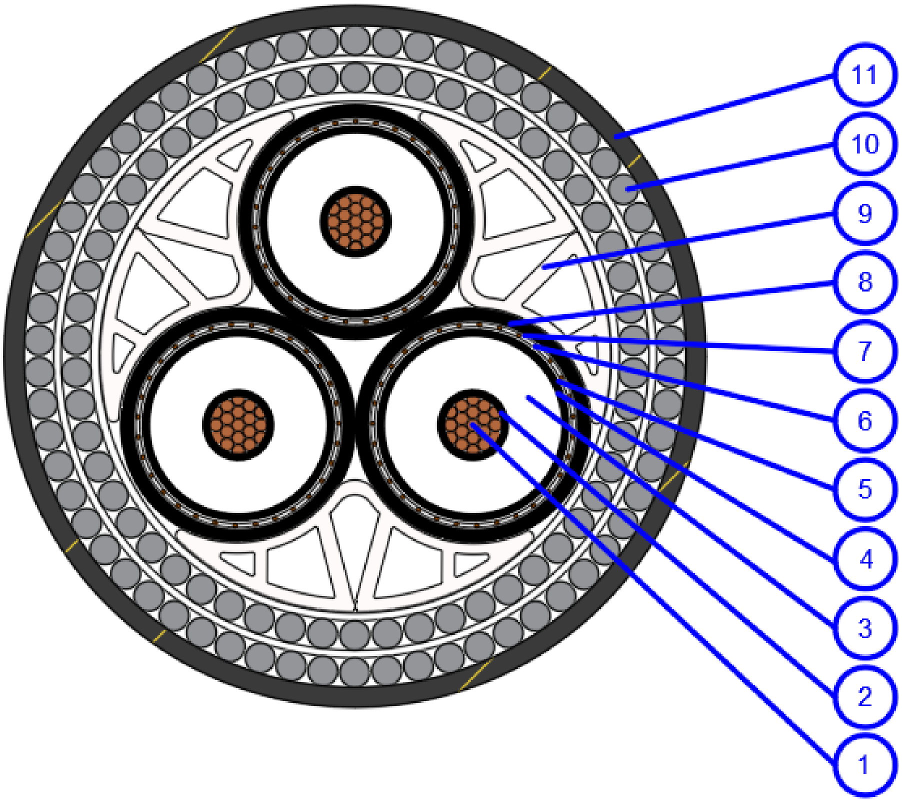
Max. short circuit current in the metallic screen: 4.6 kA for 1 s

Max. electrical stress in insulation at U_0: 5.73 kV/mm

[1] CIGRE TB 623 [7] calculation methodology of the pulling tension is considered a conservative approach. The results are verified through global analysis.

5.2 IAC 1 – 3x120 mm^2 Cu 66kV 30 MW static

5.2.1 Cross section drawing of IAC 1 static



Item	Layer	Nominal thickness (mm)	Nominal outer diameter (mm)
1	Conductor	13	13
2	Insulation	13	39
3	Metallic screen	31 wires x ϕ 0.8	41
4	Core sheath	2	47
5	Armour	54/63 wires x ϕ 6	136
6	Outer serving	6	148

5.2.2 Mechanical data of IAC 1 static

Total weight in air: 45.1 kg/m

Total weight in water: 29.1 kg/m

Estimated MBR under tension: 3 m

Expected pulling tension during laying at max. water depth in WTG area [21]: 216 kN [2]

5.2.3 Electrical data of IAC 1 static

Rated voltage, U_0/U: 38/66 kV

Highest continuous voltage, U_{max}: 72.5 kV

LIWL: 325 kV

Nominal current, I_N: 292 A

Max. design conductor temperature: 90°C

DC conductor resistance at 20°C: 0.153 Ω/km

AC conductor resistance at max. conductor temperature: 0.2 Ω/km

Inductance: 0.439 mH/km

Capacitance: 0.158 µF/km

Insulation loss factor (tan δ) = 4.10^{-3}

Thermal resistivities:

- T_1 = 0.657 K.m/W
- T_2 = 0.275 K.m/W
- T_3 = 0.038 K.m/W
- T_{4_buried} = 0.367 K.m/W

Max. short circuit current in the conductor: 17.5 kA for 1 s

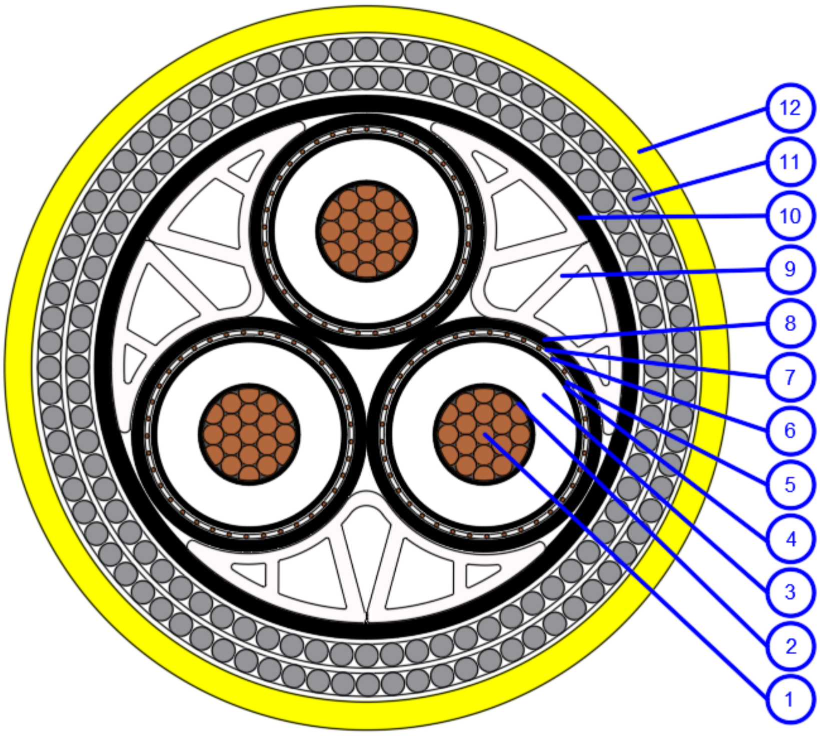
Max. short circuit current in the metallic screen: 3.6 kA for 1 s

Max. electrical stress in insulation at U_0: 5.73 kV/mm

[2] CIGRE TB 623 [7] calculation methodology of the pulling tension is considered a conservative approach. The results are verified through global analysis.

5.3 IAC 2 – 3x800 mm^2 Cu 66kV 75 MW dynamic

5.3.1 Cross section drawing of IAC 2 dynamic



Item	Layer	Nominal thickness (mm)	Nominal outer diameter (mm)
1	Conductor	34	34
2	Insulation	12	58
3	Metallic screen	37 wires x ϕ 1	61
4	Core sheath	3	67
5	Inner sheath	4	154
6	Armour	79/88 wires x ϕ 6	188
7	Outer sheath	5	198

5.3.1 Mechanical data of IAC 2 dynamic

Total weight in air: 85.4 kg/m

Total weight in water: 53.9 kg/m

Estimated MBR under tension: 3.14 m

Expected pulling tension during laying at max. water depth [21]: 1400 kN [3]

5.3.2 Electrical data of IAC 2 dynamic

Rated voltage, U_0/U: 38/66 kV

Highest continuous voltage, U_{max}: 72.5 kV

LIWL: 325 kV

Nominal current, I_N: 729 A

Max. design conductor temperature: 90°C

DC conductor resistance at 20°C: 0.022 Ω/km

AC conductor resistance at max. conductor temperature: 0.036 Ω/km

Inductance: 0.304 mH/km

Capacitance: 0.328 µF/km

Insulation loss factor (tan δ) = 4.10^{-3}

Thermal resistivities:

- T_1 = 0.334 K.m/W
- T_2 = 0.245 K.m/W
- T_3 = 0.029 K.m/W
- T_{4_buried} = 0.335 K.m/W

Max. short circuit current in the conductor: 115 kA for 1 s

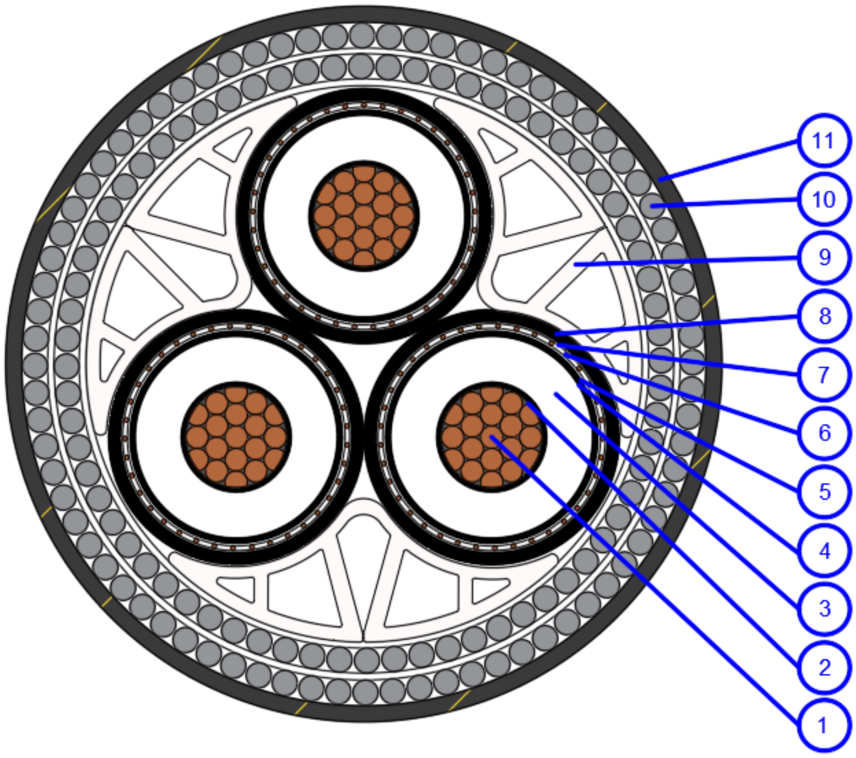
Max. short circuit current in the metallic screen: 7.6 kA for 1 s

Max. electrical stress in insulation at U_0: 5.0 kV/mm

[3] CIGRE TB 623 [7] calculation methodology of the pulling tension is considered a conservative approach. The results are verified through global analysis.

5.4 IAC 2 – 3x800 mm² Cu 66kV 70 MW static

5.4.1 Cross section drawing of IAC 2 static



Item	Layer	Nominal thickness (mm)	Nominal outer diameter (mm)
1	Conductor	34	34
2	Insulation	12	58
3	Metallic screen	37 wires x ϕ 1	61
4	Core sheath	3	67
5	Armour	76/84 wires x ϕ 6	180
6	Outer serving	6	148192

5.4.2 Mechanical data of IAC 2 static

Total weight in air: 80.7 kg/m

Total weight in water: 53.7 kg/m

Estimated MBR under tension: 3 m

Expected pulling tension during laying at max. water depth in WTG area [21]: 1400 kN [4]

5.4.3 Electrical data of IAC 2 static

Rated voltage, U_0/U: 38/66 kV

Highest continuous voltage, U_{max}: 72.5 kV

LIWL: 325 kV

Nominal current, I_N: 729 A

Max. design conductor temperature: 90°C

DC conductor resistance at 20°C: 0.022 Ω/km

AC conductor resistance at max. conductor temperature: 0.036 Ω/km

Inductance: 0.304 mH/km

Capacitance: 0.328 µF/km

Insulation loss factor (tan δ) = 4.10^{-3}

Thermal resistivities:

- T_1 = 0.334 K.m/W
- T_2 = 0.166 K.m/W
- T_3 = 0.057 K.m/W
- T_{4_buried} = 0.338 K.m/W

Max. short circuit current in the conductor: 115 kA for 1 s

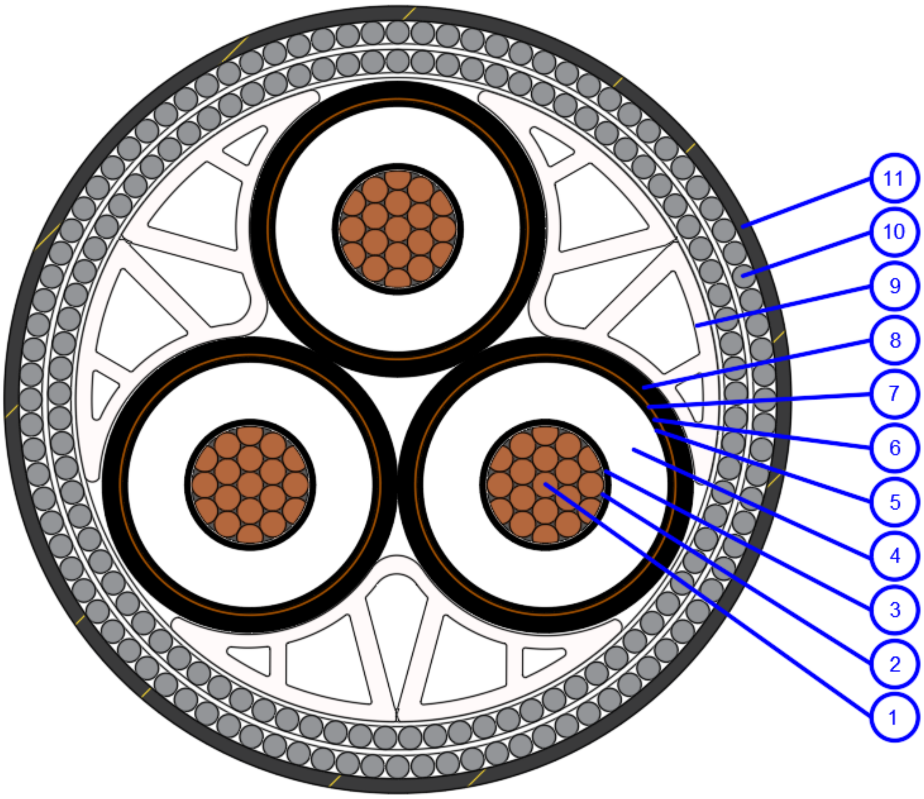
Max. short circuit current in the metallic screen: 7.6 kA for 1 s

Max. electrical stress in insulation at U_0: 5.0 kV/mm

[4] CIGRE TB 623 [7] calculation methodology of the pulling tension is considered a conservative approach. The results are verified through global analysis.

5.5 Export cable – 3x800 mm^2 Cu 380 kV 555 MW static

5.5.1 Cross section drawing of Export cable



Item	Layer	Nominal thickness (mm)	Nominal outer diameter (mm)
1	Conductor	34	34
2	Insulation	31	97
3	Metallic screen	3	103
4	Core sheath	3	110
5	Armour	59/62 wires x 12x3	256
6	Outer serving	6	268

5.5.2 Mechanical data of Export cable

Total weight in air: 113.3 kg/m

Total weight in water: 62 kg/m

Estimated MBR under tension: 3 m

Expected pulling tension during laying at max. water depth in WTG area [21]: 1400 kN [5]

[5] CIGRE TB 623 [7] calculation methodology of the pulling tension is considered a conservative approach. The results are verified through global analysis.

5.5.3 Electrical data of Export cable

Rated voltage, U_0/U: 230/380 kV

Highest continuous voltage, U_{max}: 420 kV

LIWL: 1425 kV

Nominal current, I_N: 750 A

Max. design conductor temperature: 90°C

DC conductor resistance at 20°C: 0.0221 Ω/km

AC conductor resistance at max. conductor temperature: 0.032 Ω/km

Inductance: 0.412 mH/km

Capacitance: 0.158 µF/km

Insulation loss factor (tan δ) = 1.10^{-3}

Thermal resistivities:

- T_1 = 0.565 K.m/W
- T_2 = 0.098 K.m/W
- T_3 = 0.04 K.m/W
- T_{4_buried} = 0.638 K.m/W

Max. short circuit current in the conductor: 115 kA for 1 s

Max. short circuit current in the metallic screen: 19 kA for 1 s

Max. electrical stress in insulation at U_0: 5.4 kV/mm

6 CURRENT RATING RESULTS

The ampacity calculations are performed for the IAC and export cables according to the IEC 60287 standards [18], in the installation and environmental conditions defined in the BOD document. The results are presented in the Table 7-1 below.

Cable cross section	Installation scenario	Conductor operating temperature at I_N (°C)	Rated current at 90°C, I_{MAX} (A)	Cable capacity utilization rate I_N/I_{MAX} (%)
IAC 1 Dynamic	Inside I-tube	86.9	302	97
	Buried	60.5	363	80
IAC 1 Static	Inside J-tube	85.5	307	95
	Buried	58.6	371	79
IAC 2 Dynamic	Inside I-tube	86.1	765	95
	Buried	71.2	838	87
IAC 2 Static	Inside J-tube	89.3	735	99
	Buried	69.3	852	85
Export 1 Static	Inside J-tube	79.1	874	86
	At landfall	87.9	761	99

Table 2 - Current rating results

The results demonstrate that the cables can operate under the specified conditions in order to transmit the required power without exceeding the maximum design conductor temperature of 90°C.

Client	**Hope**
Client Reference Number	**N/A**
Project	**Barium Bay – Preliminary Subsea Cable Engineering**
Aventa Document Title	**IAC Installation Philosophy**
Aventa Document Number	**AE-P00115-R06**
Revision Number	**02**
Date of Issue	**01/02/2024**

REVISION HISTORY

Revision	Date	Issue	Summary of Changes	Issued by	Verified by	Approved by
01	27/10/2023	for Review	First version	PCA	BLE	BLE
02	01/02/2024	for Approval	Revised version	PCA	BLE	BLE

CONFIDENTIALITY : Level B

Level A: Public

Level B: Confidential

CONTENT

FIGURES

TABLES

1 INTRODUCTION

1.1 Project description

Barium Bay is an offshore wind farm development project located in the Adriatic Sea, 40km off the Apulian coastline between Barletta and Bari. The project is being developed by Barium Bay Srl, a Joint Venture between Galileo, a pan-European platform for renewable energy development, and Hope Group, a holding company active in designing renewable energy and green hydrogen plants.

The park includes 74-off floating wind turbines of 15MW, for a total capacity of 1110MW. Two offshore substations 66/380kV collect and transform the power from the turbines. Two HVAC export cables (EXP1 and EXP2) connect the first substation to the shore following a 57km long corridor. The landing point is approximately 3 kilometers south of Barletta. One HVAC cable (EXP3) connect the second substation to the first one.

Hope Engineering SRL has requested Aventa to perform the following preliminary studies relative to the submarine cables of the Barium Bay project:

- EXP and IAC: electrical and mechanical preliminary design
- EXP: preliminary cable burial and risk assessment study
- EXP: review of the export cable landfall configuration
- IAC: Preliminary dynamic cable configuration
- EXP and IAC: Installation philosophy of the cables
- EXP and IAC: Cost evaluation

1.2 Document purpose

The purpose of this document is to establish a preliminary evaluation of cable installation methodology for the Inter-Array Cables, configured in lazy wave configurations as designed in [11].

In this perspective, an installation method statement, as well as assessments of critical loads and operational durations, are detailed for the following activities: 1st end pull-in, laying, 2nd end pull-in.

Pre-installation activities (for example, pre-lay surveys, removal of any obstacle on the route) and Post-installation activities (for example, as-built survey) are not detailed in this document.

2 ABBREVIATIONS

The following abbreviations are used in the present document:

BL	Bend Limiter
BM	Buoyancy Module
BR	Bend Restrictor
BS	Bend Stiffener
BSC	Bend Stiffener Connector
c/w	Comes with
CAPEX	Capital Expanditure
CLV	Cable Laying Vessel
CPS	Cable Protection System
CSF	Catenary Shape Factor
DAF	Dynamic Amplification Factor
DP	Dynamic Positioning
HVAC	High Voltage Alternating Current
IAC	Inter-array cable
KP	Kilometric Point
LWSF	Lazy Wave Shape Factor
Max	Maximum
MBR	Minimum Bending Radius
mT	Metric Ton
N/A	Not Applicable
OD	Outer Diameter
O&M	Operation & Maintenance
OSS	Offshore Substation
PU	Polyurethane
RDS	Reel Drive System
ROV	Remotely Operated Vehicle
SF	Safety Factor
SIMOPs	Simultaneous Operations
SWL	Safe Working Load
TBC	To Be Confirmed
TDP	Touch Down Point
UF	Utilization Factor
VLS	Vertical Laying System
WD	Water Depth
(F)WTG	(Floating) Wind Turbine Generator

3 REFERENCES

3.1 Client documents

Ref.	Document Title	Doc Number	Doc. Rev.
[1]	Progetto Preliminare - Relazione Tecnica Illustrativa	R.1	01
[2]	Progetto Preliminare - Elaborati Grafici - Schema Elettrico	EG12	01
[3]	Progetto Preliminare – Inquadramento su carta nautica	EG5	01
[4]	Relazione tecnico-illustrativa – sottostazioni offshore – ESE - Tecon	12085-PMS-001	00

3.2 Standards and rules

Ref.	Document Title	Doc Number	Doc. Rev.
[5]	Marine operations and marine warranty	DNVGL-ST-N001	2021
[6]	Subsea power cables in shallow water	DNVGL-RP-0360	2021
[7]	Installation of Submarine Power Cables	CIGRE TB 883	2022
[8]	Recommendations for Mechanical Testing of Submarine Cables	CIGRE TB 623	2015
[9]	Recommendations for mechanical testing of submarine cables for dynamic applications	CIGRE TB 862	2022

3.3 Other documents

Ref.	Document Title	Doc Number	Doc. Rev.
[10]	Barium Bay – Preliminary Subsea Cable Engineering - Design Basis	AE-P00115-R01	02
[11]	Barium Bay – Preliminary Subsea Cable Engineering – IAC Preliminary Configuration	AE-P00115-R04	01
[12]	Barium Bay – Preliminary Subsea Cable Engineering – Preliminary Subsea Cable Design	AE-P00115-R02	01
[13]	Valutazione (Preliminare) dei Rischi e della Profondità di interro	AE-P00115-R03	01
[14]	Barium Bay – Preliminary Subsea Cable Engineering – Export Cable Installation Philosophy	AE-P00115-R07	01
[15]	Barium Bay – Preliminary Subsea Cable Engineering – Cable Cost Study	AE-P00115-R08	01

4 DESCRIPTION

4.1 Site Location

The Barium Bay wind farm will be installed approximately 40 km offshore the Apulian coast between Barletta and Bari, as presented in Figure 4-1, in a water depth ranging from 120m to 190m, as per document of design basis in [10].

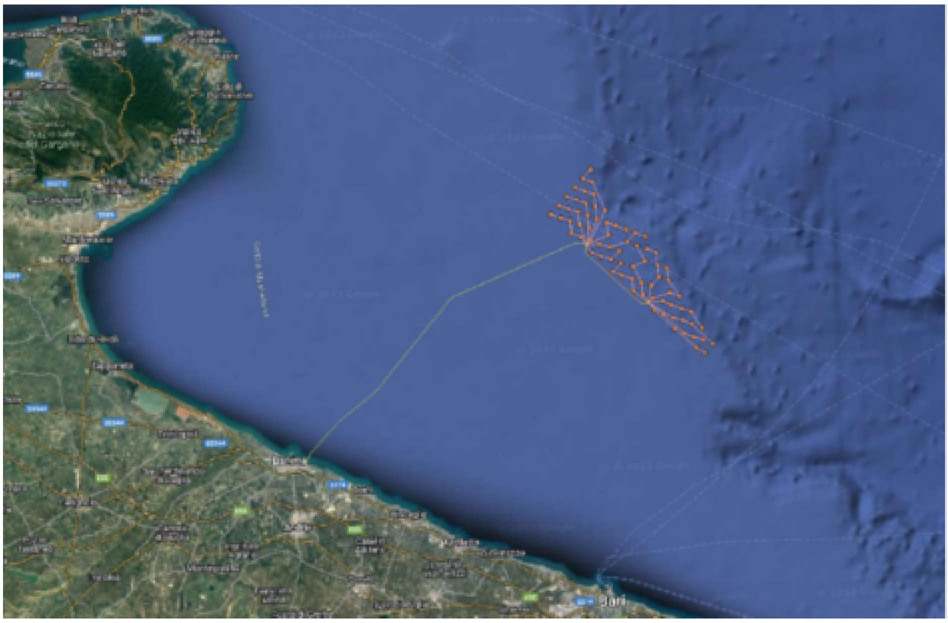


Figure 4-1 – Barium Bay - Wind Farm and Export Cable Location

4.2 Wind Farm Layout

As shown in Figure 4-2, the wind farm is divided in two clusters of 37-off WTGs, distributed on 8-off strings of 4-off or 5-off WTGs. Two offshore substations (OSS) are located on the western side (shore side) of their own cluster. Cluster n°1 is the northern part of the park and Cluster n°2 the southern part. OSS1 is installed in 130m water depth. OSS2 is positioned in 150m water depth. Both OSS are interconnected via an 15km HVAC link. The two export HVAC cables are connected to the OSS1 only.

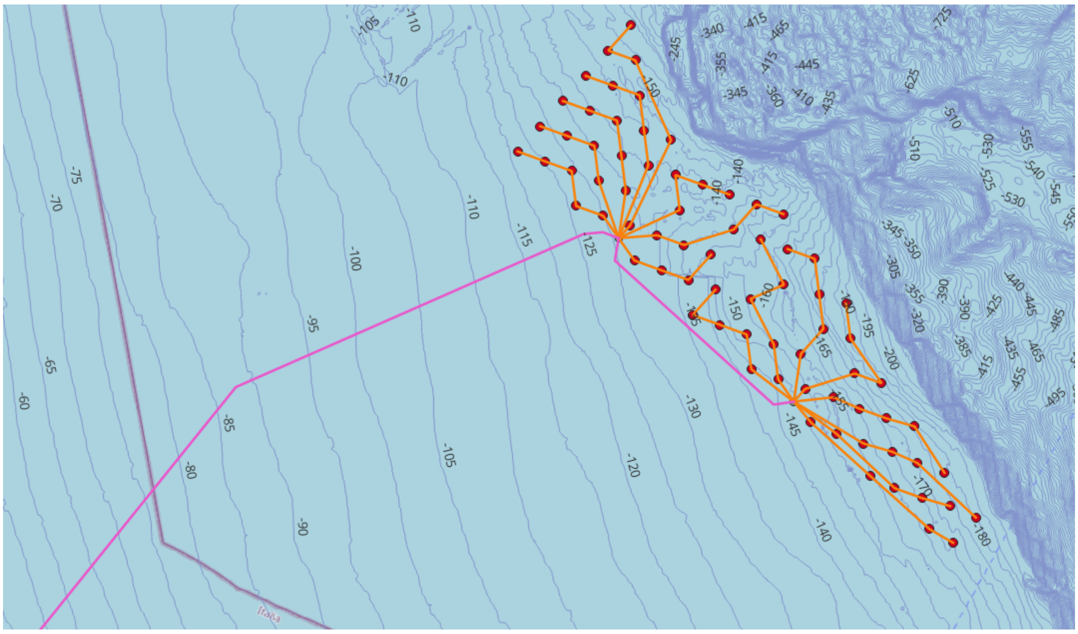


Figure 4-2 – Wind Farm Layout

4.3 WTG Floater

Semi-submersible technology has been preselected for floater of WTG as detailed in [1] and [10].

It is considered that the cable passes through an I-tube attached to the floater. I-tube entry point is assumed to be at Z=-15m elevation below mean sea level ([10]).

4.4 Offshore Substations

According to [4], the two bottom fixed substations will be supported by a jacket steel structure, equipped with standard J-tubes design, as shown in Figure 4-3. The cable deck is at +16m above sea level. As per [1], it is considered that the top flange of J-tube will arrive 0.5m above the cable deck, therefore:

- For OSS1, water depth is 130m, therefore J-tube top flange is at 146.5 m above seabed.
- For OSS2, water depth is 150m, therefore J-tube top flange is at 166.5 m above seabed.

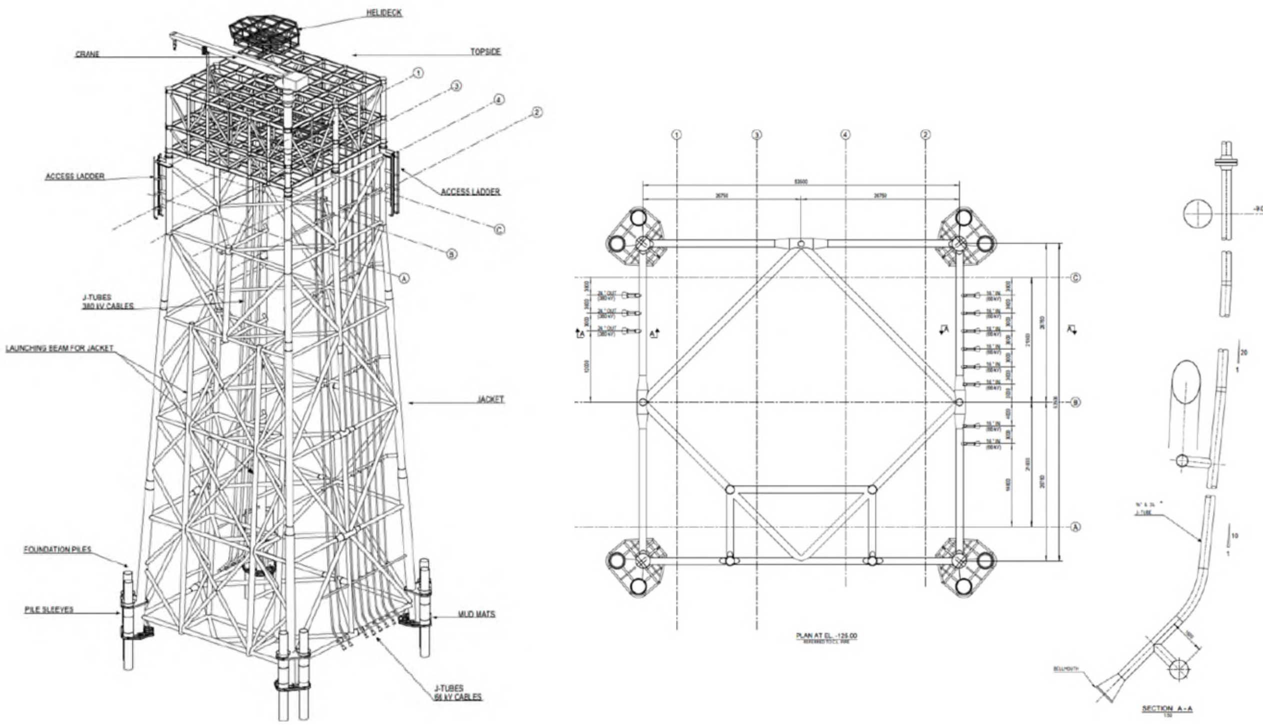


Figure 4-3 – OSS1 Isometric, J-tube and Cable Deck

4.5 Subsea Power Cables

4.5.1 Cable Cross-Sections

In accordance with [12], the different cross sections considered in this study are:

Cable	Type	Voltage (kV)	Power (MW)	Cross section
IAC 1	Dynamic	66	30	3x120 mm^2 Cu
	Static			
IAC 2	Dynamic		75	3x800 mm^2 Cu
	Static			

Table 4.1 – Cable Cross Section Overview

4.5.2 Cable Installation Parameters

In accordance with [11], IACs are pulled up to the WTG floater through a I-tube, as represented in the sketch in Figure 4-4.

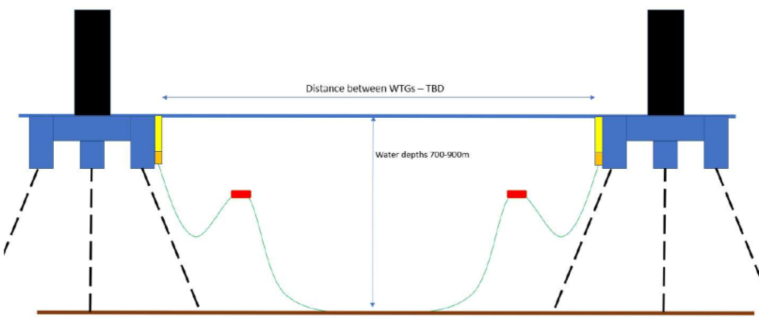


Figure 4-4 – Installation scenario - IAC connection to WTG (Lazy Wave Configuration)

IACs connected to OSS are pulled up through a J-tube, as represented by the typical sketch in Figure 4-5.

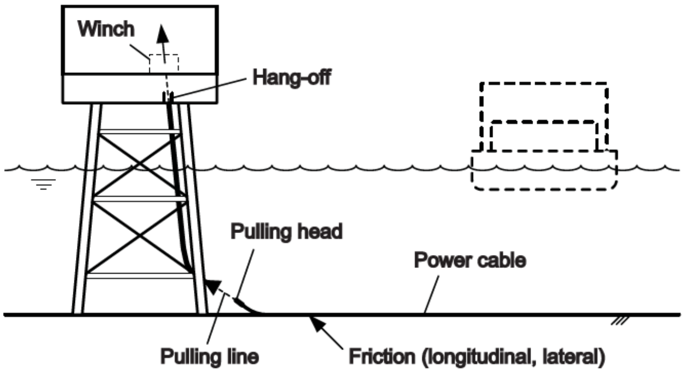


Figure 4-5 – Installation scenario - IAC Connection to OSS (typical from [6])

4.5.3 Cable Mechanical Properties

Standard properties of cables are presented in Table 4.2 (as per [12]).

Property	Unit	IAC1	IAC2
OD	mm	151.5	197.8
Weight in air	kg/m	48.2	85.4
Weight in water	kg/m	29.7	53.9
Maximum allowable tension load	mT	22,0	142,7
Minimum bending radius (MBR)	m	3	3.14

Table 4.2 – Cable Cross Section Overview

4.5.4 Cable Termination

4.5.4.1 Cable Sealing

It is assumed that cable ends are properly sealed.

Figure 4-6 below shows a picture of a typical water sealing installed onto a cable end.

Figure 4-6 – WTG/OSS Cable Connection System (Typical)

4.5.4.2 Cable Grip

Cable is fitted with a cable grip (pulling stocking) for connection to a pull-in rigging, as per [2].

As shown in Figure 4-7, a swivel may be used directly in front of the cable stocking to reduce torsion within the cable and the pulling line (pull-in winch cable).

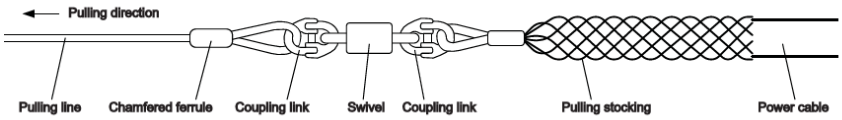


Figure 4-7 – Cable End Connection to Pull-in Rigging (typical from [6])

Note: Pull-in rigging for cable 2nd end shall be a two legs configuration rigging to allow subsea transfer from vessel to WTG floater.

As alternative to cable end fitted with cable grip, a pull-in head, mounted at cable end and fitted with a pull-in connection point (padeye) at the extremity, can be used.

According to [8], a pull-in head contains and protects the cable power cores which are sealed against water ingress. The pull-in head is temporary and is removed after the pull-in operation. The pull-in head is connected to the cable armour wires, through welding, moulding or clamping.

The choice of the design (between simple cable end or pull-in head) mainly depends on the expected loads during installation/production (based on water depth and weight of cable), on the type of WTG interface (for example I-tube with BSC system) and on the O&M strategy.

4.6 Cable Accessories

4.6.1 Buoyancy Modules

Buoyancy Modules (BM) are used to achieve the correct lazy wave configuration of dynamic cable. It is typically made of 2-off half shells with clamping system, as shown in Figure 4-8.

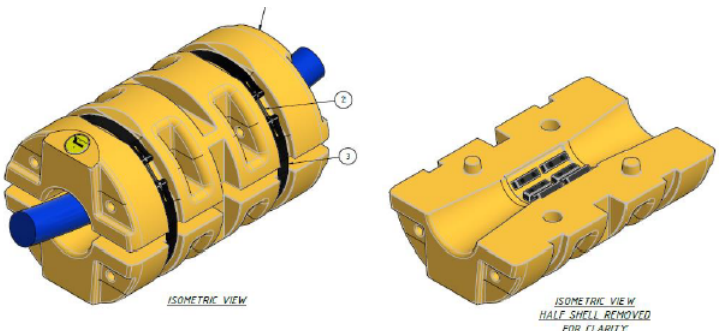


Figure 4-8 – Buoyancy Module (Typical)

BM are installed onboard vessel during cable deployment, as detailed in section 6.2.

Requirement of BM for one IAC lazy wave is defined in [11] for each type of IAC cross-sections. It is summarized in Table 4.3.

Cable	Number of BM	BM Upthrust (kg)	Total Upthrust (mT)
IAC1	24	185.3	4.4
IAC2	23	309.1	7.1

Table 4.3 – BM Distribution for each IAC Cross-Sections

Note: only maximum water depth case from [11] is considered in this document.

4.6.2 Bend Restrictor

A bend restrictor (BR), usually made of PU, aims to prevent cable overbending.
It can be either a Bend Limiter (BL) that has no effect below a certain curvature but prevents curvature from exceeding that value or a Bend Stiffener (BS) that provides increased bend stiffness in order to distribute the bending more widely.
Figure 4-9 shows a typical BS.

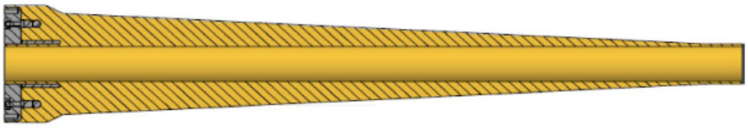


Figure 4-9 – Bend Stiffener (Typical)

4.6.3 Cable Protection System

4.6.3.1 CPS for Connection to OSS

For IAC connected to OSS (static configuration), the CPS is used to protect the cable from damage due to impact, abrasion and fatigue and from over-bending during the pull-in operations and the cable life.

CPS are installed onboard vessel during cable deployment, as detailed in section 6.

4.6.3.2 Touchdown Protection

For IAC connected to WTG (dynamic configuration), the CPS (touchdown protection) is used to protect cable against impacts and abrasion at the Touchdown Point (TDP).

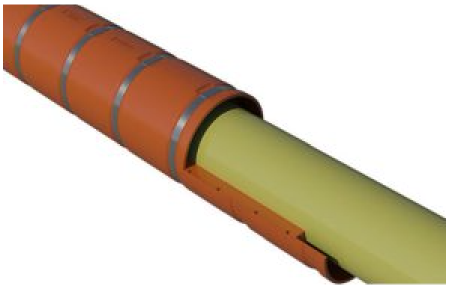


Figure 4-10 – Touchdown Protection (Typical)

CPS are installed onboard vessel during cable deployment, as detailed in section 6.

For IAC connected to WTG (dynamic configuration), touchdown protection shall be installed in accordance with length of coverage detailed in Table 4.4.

Cable	Length of coverage
IAC1	134
IAC2	104

Table 4.4 – CPS for Each Cable

Note: Length of coverage is given for one IAC lazy wave and is calculated as twice the difference between the maximum TDP arc length and the minimum TDP arc length from [11] (considering maximum WD). An extra length of 20m is added to the total length.

5 NAVAL MEANS AND EQUIPMENT

Installation of IACs shall be performed by a vessel equipped with a turntable (carousel). It is considered in this document that cable line, previously transpooled into turntable of vessel, is cut at correct length during offshore installation and sealing is fitted on deck.

As an alternative, use of reel c/w RDS could be considered. For this option, cable is transported on reel, already pre-cut at required length and fitted with sealing (in that case sealing will be done in the factory, prior to the cable loading). Reel is loaded into RDS onboard vessel for offshore installation.

Naval Means & Equipment	Characteristics
Cable Laying Vessel (CLV)	
DP Class	Minimum Recommended 2
Turntable	Suitable for IACs
Tensioners	see note 1
Overboarding Chutes	Minimum radius: >3.5m (see note 2)
Subsea Crane	see note 1 Radius range: suitable for cable overboarding
Quadrant (for 2nd end overboarding – IAC connection to OSS)	see note 1
Hold Back Winch (for 2nd end overboarding – IAC connection to WTG)	see note 1
ROV	Work class system Minimum tether length (ROV excursion): >200m
Wind Turbine Generator (WTG)	
Pull-in Winch	see note 1
Offshore Substation (OSS)	
Pull-in Winch	see note 1

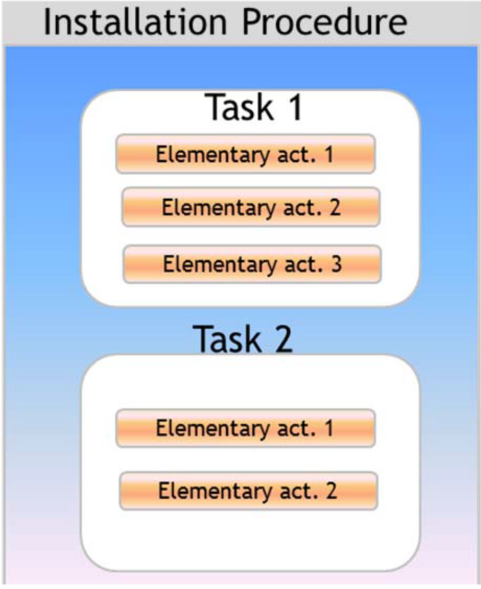
Table 5.1 –Naval means and required equipment for IACs installation activities

Notes:

1) Maximum load for the heaviest IAC to be considered to define requirement for minimum capacity of each equipment, applying a safety margin on equipment of 0.9.
2) Minimum radius of chute is based on maximum MBR (see section 4.5.3) with a safety margin of 0.9.
3) IAC installation activities might be optimized by selecting naval means specific to each configuration of cable installation (dynamic IAC for connection to WTG and static IAC for connection to OSS). For example, in case of dynamic IAC installation, alternative to the overboarding chute is the use of VLS fitted with a working platform for BM installation in vertical configuration. In case of static IAC installation, vessel shall be equipped with two overboarding chutes, two tensioners and a quadrant.

6 OUTLINE PROCEDURE

This method statement is organized in two levels of detail: the tasks and the elementary activities, providing a step by step guide to execute the installation activities.



The task is minimum measurable time unit to define/record an operational duration.

Some typical sketches are included in the step-by-step sequences to ease understanding of the operation performed.

6.1 Installation Criteria

During the installation of a IAC cable, the following criteria shall be satisfied:

- Cable integrity (max tension, MBR, max torsion, max compression)
- Laying corridor
- Cable Pull-in rigging capacity
- Cable max entrance angle
- WTG/OSS winch capacity
- Vessel laying equipment capacity
- Vessel crane capacity

These criteria shall be detailed in final installation procedures.

6.2 Step by Step

The following sections detail a typical installation of 1-off IAC connected between two WTGs and 1-off IAC connected between one WTG and one OSS. It is considered that the cable 2nd end is the one connected to OSS.

6.2.1 Offshore Preparations

Initial Status

- Pre-installation Survey (cable route and cable entry location on WTGs and OSS) has been performed

WTG Preparations:

- Hang-off device is ready
- Pull-in winch is function-tested and ready
- Pull-in winch cable c/w messenger line is inserted into I-tube and is hanging in the water column, ready for recovery.

OSS Preparations:

- Hang-off device is ready
- Pull-in winch is function-tested and ready
- Pull-in winch cable c/w messenger line is inserted into J-tube and is laying on the seabed, ready for recovery.

Vessel Preparations:

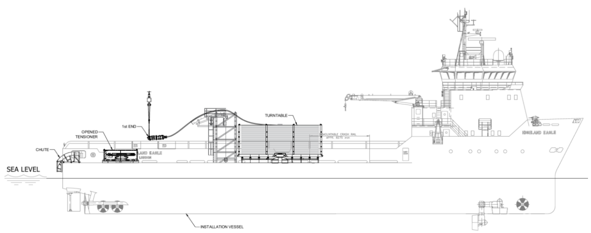
- Cable line is loaded into vessel turntable and ready for use
- Vessel Crane, hold back winch and quadrant are operational
- All required rigging for operations is ready for use on board, complete with valid certificates
- BMs and CPS are ready close to overboarding chute
- Cable route is displayed on the Navscreen

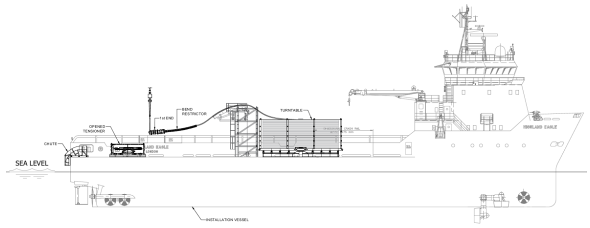
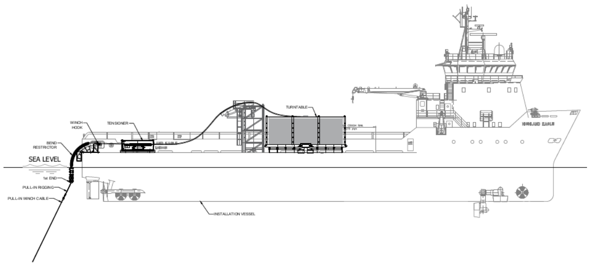
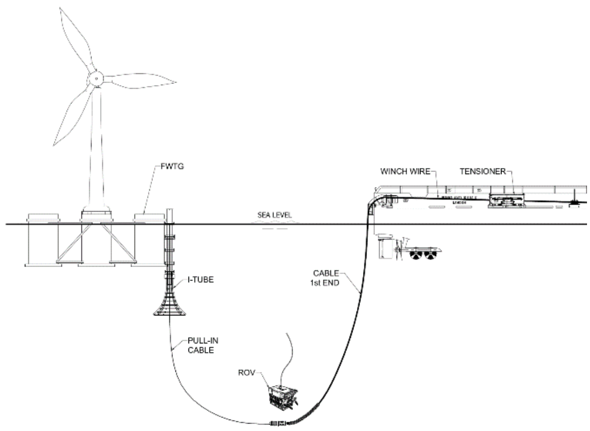
SIMOPs:

- Communication has been established between vessel and WTG/OSS winch team and check on communication networks has been performed.
- Toolbox talk completed.

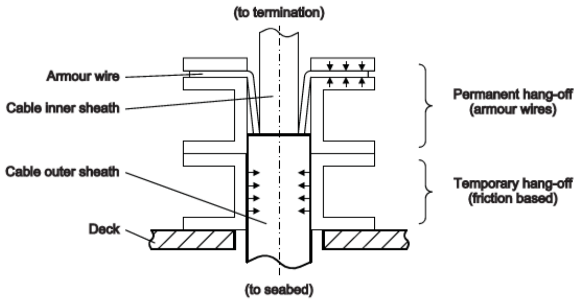
6.2.2 IAC Connection to WTG

6.2.2.1 1st End Pull-in

Elem Act	Description	Sketch
1.1.	Connect handling rigging (soft sling chocked around 1st end/cable) to cable 1st end and connect vessel crane.	
1.2.	Lift cable 1st end with vessel crane and bring it to working area. **See sketch enclosed**	
1.3.	Prepare the 1st end for overboarding: - Fit the sealing on cable end (if not already done) - Connect bend restrictors (if applicable) - Install pull-in rigging (including cable grip)	

1.4.	Connect vessel crane to the 1st end pull-in rigging.	
1.5.	Slowly lift the 1st end off deck (above tensioner) with vessel crane and move it in front of chute, paying-out cable accordingly. **See sketch enclosed**	
1.6.	When the 1st end and bend restrictors have fully passed tensioner and the cable is inserted in the opened tensioner: - Stop cable paying-out - Close tensioner on the cable ⚠ **During all the operation, it is visually checked that cable MBR is respected.**	
1.7.	Recover pull-in winch cable, fitted with messenger line, onboard vessel. Connect pull-in winch cable to cable 1st end pull-in rigging. ⚠ **The messenger line should not be considered as the pulling line.** **See sketch enclosed**	
1.8.	Overboard cable 1st end and lower it toward the seabed, in a controlled manner, by paying-in pull-in cable, while cable is paid-out from vessel. **Note:** Overboarding is achieved by using vessel crane (two legs configuration rigging is required) or directly by paying-in from WTG winch system once cable 1st end is on chute.	
1.9.	Perform pull-in operation, paying-out tensioner and paying-in pull-in winch. **Note:** The entire pull-in operation shall be continuously monitored for all parameters to be within specified limits. As a result from installation analysis, a specific sequence table can be defined. **See sketch enclosed**	

<table>
<tr><td>1.10.</td><td>Complete cable 1st end pull-in into WTG I-tube and secure it using temporary hang-off clamp.

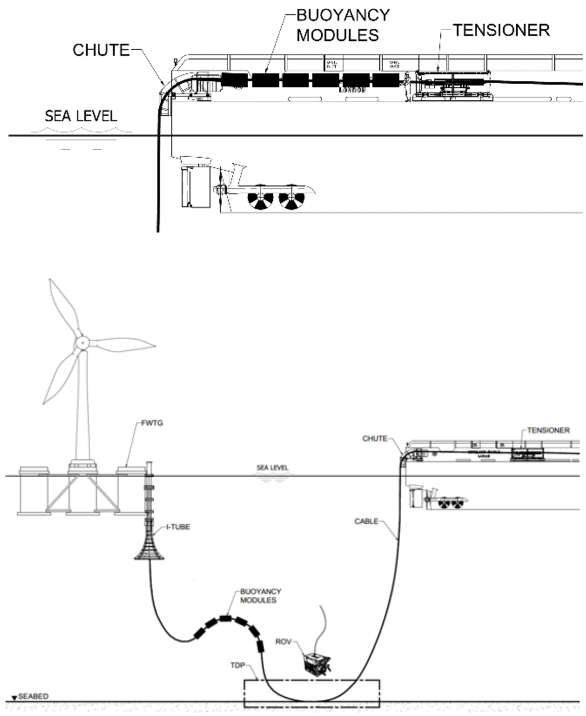
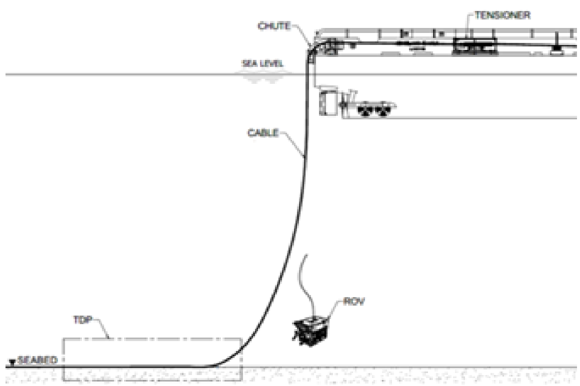
<u>Note:</u> The temporary hang-off secures the cable sufficiently for cable installation works to proceed.</td><td rowspan="2">

(Typical design of cable hang-off - [6])</td></tr>
<tr><td>1.11.</td><td>Remove tension in pull-in winch cable.

Disconnect pull-in rigging from cable 1st end.

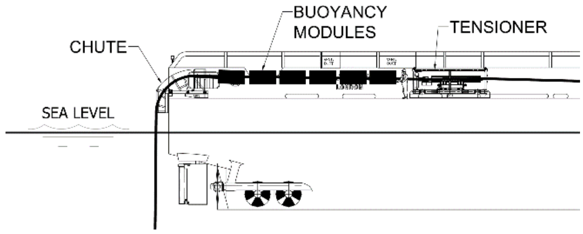
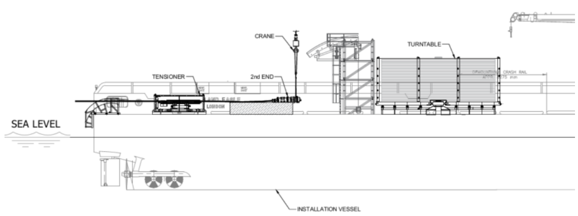
Install permanent hang-off clamp (fixing of cable armouring).</td></tr>
<tr><td>1.12.</td><td>Perform electrical connection and testing.</td><td>N/A</td></tr>
</table>

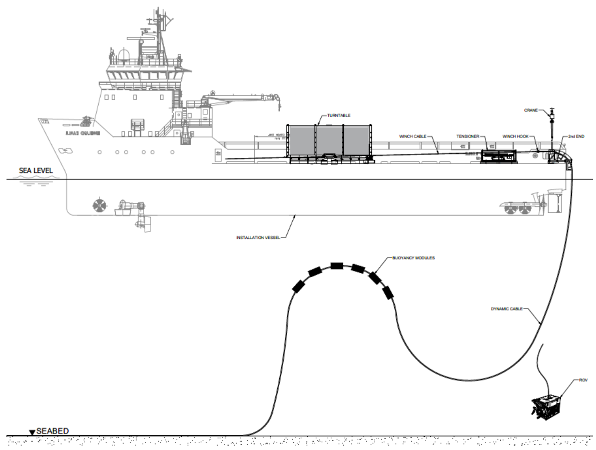
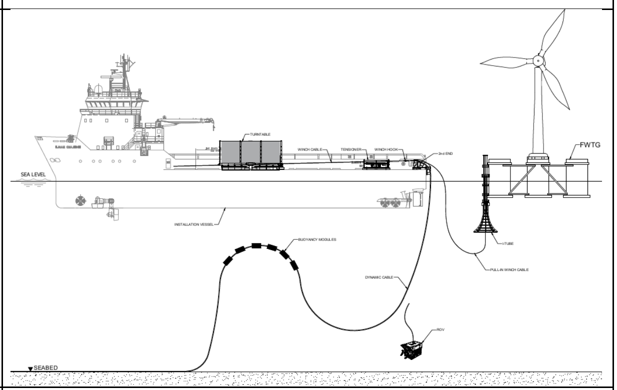
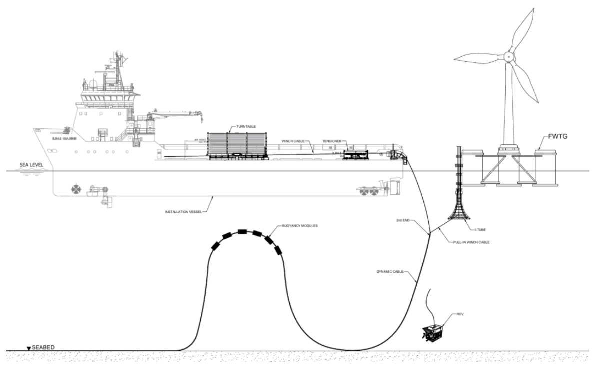
6.2.2.2 Cable Laying

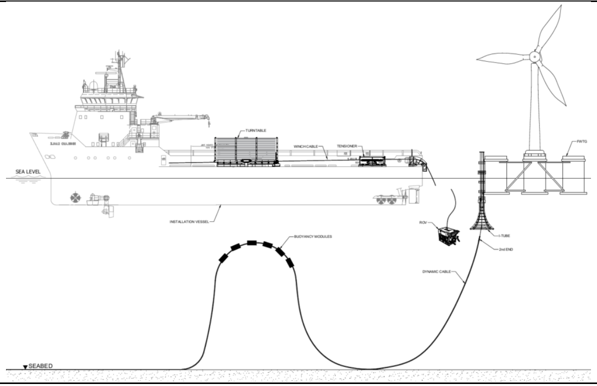
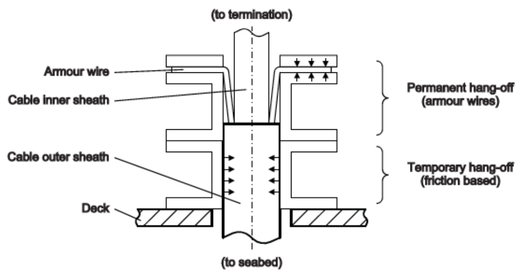
Elem Act	Description	Sketch
BM/CPS INSTALLATION		
1.1.	Start cable deployment by continuous paying-out of cable, moving vessel accordingly. When required, install BM and CPS as per installation guideline from supplier. ⚠ **In order to prevent BM/CPS from snagging when passing over chute:** **- Ensure the chute is constantly lubricated with sea water.** **- Deck crew to check entry of the BM/CPS into chute.** **- Deck crew to check the system is not sliding along the cable**. ⚠ **It is important to accurately position BM and CPS . This equipment is essential for correct lazy wave configuration related to good lifetime duration of the dynamic cable.** See sketch enclosed	
CABLE LAYING		
1.2.	Lay cable as per cable route respecting laying corridor by continuous paying-out of cable, moving vessel accordingly. Deck crew to continuously check the length of cable paid out using cable marking & tape measure. ⚠ **TDP to be continuously monitored by ROV.** ⚠ **Cable paid-out length and cable marking to be continuously monitored.** ⚠ **Laying parameter (tension, layback) to be continuously monitored (as per analysis).** See sketch enclosed	

6.2.2.3 2nd End Pull-in

<u>Note:</u> As described in section 5, cable shall be cut at required length. The cutting length calculation of the cable should take into account the required configuration of lazy wave (from global analysis), the cable path inside WTG, overlength required for electrical termination and any contingency.

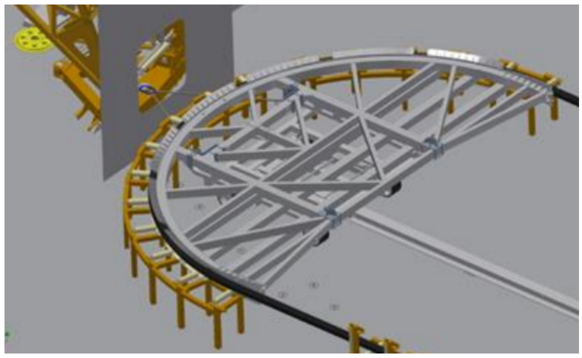
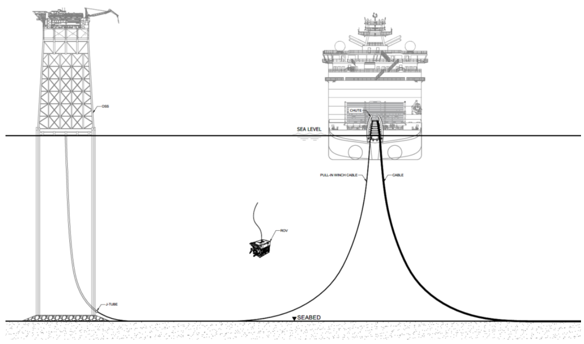
Elem Act	Description	Sketch
BM/CPS INSTALLATION		
1.1.	When required, install BM and CPS as per installation guideline from supplier. ⚠ **In order to prevent BM/CPS from snagging when passing over chute:** **- Ensure the chute is constantly lubricated with sea water.** **- Deck crew to check entry of the BM/CPS into chute.** **- Deck crew to check the system is not sliding along the cable.** ⚠ **It is important to accurately position BM and CPS . This equipment is essential for correct lazy wave configuration related to good lifetime duration of the dynamic cable.** See sketch enclosed	
2nd END DEPLOYMENT AND PULL-IN		
1.2.	**ALL STOP** on vessel arrival to final position Vessel to adapt heading for 2nd end overboarding/load transfer position	N/A
1.3.	Cut the cable at the required length and fit the sealing on cable end. **Note:** Cable is secured by tensioner or with stoppers if required.	
1.4.	Connect handling rigging (soft sling chocked around cable) to cable 2nd end and connect vessel crane. See sketch enclosed	
1.5.	Lift cable 2nd end with vessel crane and bring it to working area.	
1.6.	Prepare the 2nd end for overboarding: - Connect bend restrictors (if applicable) - Install pull-in rigging (including cable grip) **Note:** It is recommended to perform a load test of the pull-in rigging to ensure no slippage of cable grip.	

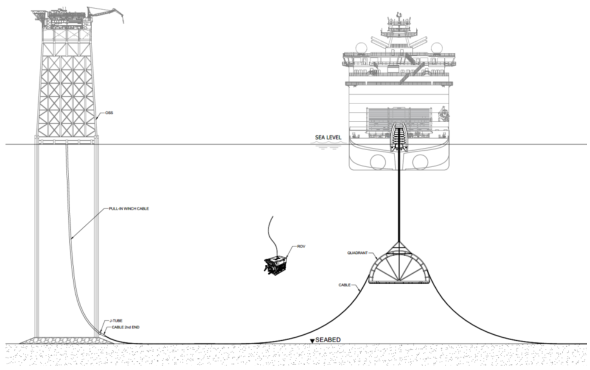
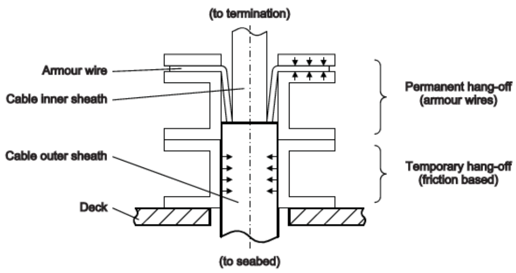
1.7.	Connect vessel crane and hold back winch to the 2nd end pull-in rigging.	
1.8.	Take tension with hold back winch until recovering cable catenary load and slowly open tensioner.	
1.9.	Slowly lift the 2nd end off deck (above tensioner) with vessel crane and move it in front of chute, paying-out hold back winch accordingly. ⚠ **During all the operation, it is visually checked that cable MBR is respected.** See sketch enclosed	
1.10.	Disconnect vessel crane from cable pull-in rigging.	
1.11.	Recover pull-in winch cable, fitted with messenger line, onboard vessel. Connect pull-in winch cable to cable 2nd end pull-in rigging. ⚠ **The messenger line should not be considered as the pulling line.** See sketch enclosed	
1.12.	Overboard cable 2nd end and lower it toward the seabed, in a controlled manner, by paying-out hold back winch while paying-in pull-in winch cable as required. **Note:** overboarding is achieved directly by paying-out from hold back winch once cable 2nd end is on chute. As an alternative, overboarding can be performed by vessel crane (having hold back winch also connected). For this configuration, pull-in winch cable will be connected subsea by ROV once all catenary load has been transferred to hold back winch. See sketch enclosed	
1.13.	Perform pull-in operation, paying-out hold back winch and paying-in pull-in winch. **Note:** The entire pull-in operation shall be continuously monitored for all parameters to be within specified limits. As a result from installation analysis, a specific sequence table can be defined.	

1.14.	ROV to disconnect hold back winch from cable 2nd end pull-in rigging. **See sketch enclosed**	
1.15.	Complete cable 2nd end pull-in into WTG I-tube and secure it using temporary hang-off clamp.	 **(Typical design of cable hang-off - [6])**
1.16.	Remove tension in pull-in winch cable. Disconnect pull-in rigging from cable 2nd end. Install permanent hang-off clamp (fixing of cable armouring).	
1.17.	Perform electrical connection and testing.	N/A
1.18.	Perform as-built survey.	

6.2.3 IAC Connection to OSS

Note: As previously defined, IAC connection to OSS is considered to be performed only for cable 2nd end. Sequence of operations for 1st End pull-in and cable laying for a cable connected between WTG and OSS will be similar to the step by step described in section 6.2.2.

Elem Act	Description	Sketch
2nd END DEPLOYMENT AND PULL-IN		
1.1.	**ALL STOP** on vessel arrival to final position Vessel to adapt heading for 2nd end overboarding/Quadrant deployment	N/A
1.2.	Cut the cable at the required length and fit the sealing on cable end. **Note:** Cable is secured by tensioner or with stoppers if required.	 **(Example of cable laying quadrant on vessel deck - [7])**
1.3.	Pass the cable around the quadrant and through a second tensioner. **See sketch enclosed**	
1.4.	Prepare the 2nd end for overboarding: - Install CPS - Install pull-in rigging (including cable grip)	
1.5.	Recover pull-in winch cable, fitted with messenger line, onboard vessel. Connect pull-in winch cable to cable 2nd end pull-in rigging. **The messenger line should not be considered as the pulling line.** **See sketch enclosed** **Note:** The vessel may have to move backwards through the route to recover the cable that was laid previously and turning it around the quadrant. The cable is brought on deck, passed through the quadrant, and gone overboard again from a second chute.	

1.6.	Quadrant to run down the deck on rails while pull-in winch cable is paid-in simultaneously. Once quadrant reaches the chutes, it is overboarded. Vessel to move along the route accordingly. **See sketch enclosed**	 **(Example of quadrant being deployed - [7])**
1.7.	Lower quadrant while pull-in winch cable is paid-in simultaneously. Vessel to move along the route accordingly ROV to monitor both the entrance of the J-tube and the configuration of the cable at the quadrant. **See sketch enclosed**	
1.8.	When the cable 2nd end is at its end point inside the OSS, the quadrant is laid down to the seabed and released by ROV	
1.9.	Once cable 2nd end pull-in into OSS J-tube is completed, lay quadrant down to the seabed and release it by ROV. Secure cable using temporary hang-off clamp.	 **(Typical design of cable hang-off - [6])**
1.10.	Remove tension in pull-in winch cable. Disconnect pull-in rigging from cable 2nd end. Install permanent hang-off clamp (fixing of cable armouring).	
1.11.	Perform electrical connection and testing.	N/A
1.12.	Perform as-built survey.	

Client	**Hope**
Client Reference Number	**N/A**
Project	**Barium Bay – Preliminary Subsea Cable Engineering**
Aventa Document Title	**Export Cable Installation Philosophy**
Aventa Document Number	**AE-P00115-R07**
Revision Number	**02**
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REVISION HISTORY

Revision	Date	Issue	Summary of Changes	Issued by	Verified by	Approved by
01	27/10/2023	for Review	First version	PCA	BLE	BLE
02	02/02/2024	for Review	Revised version	PCA	BLE	BLE

CONFIDENTIALITY : Level B

Level A: Public

Level B: Confidential

CONTENT

FIGURES

TABLES

1 INTRODUCTION

1.1 Project description

Barium Bay is an offshore wind farm development project located in the Adriatic Sea, 40km off the Apulian coastline between Barletta and Bari. The project is being developed by Barium Bay Srl, a Joint Venture between Galileo, a pan-European platform for renewable energy development, and Hope Group, a holding company active in designing renewable energy and green hydrogen plants.

The park includes 74-off floating wind turbines of 15MW, for a total capacity of 1110MW. Two offshore substations 66/380kV collect and transform the power from the turbines. Two HVAC export cables (EXP1 and EXP2) connect the first substation to the shore following a 57km long corridor. The landing point is approximately 3 kilometres south of Barletta. One HVAC cable (EXP3) connect the second substation to the first one.

Hope Engineering SRL has requested Aventa to perform the following preliminary studies relative to the submarine cables of the Barium Bay project:

- EXP and IAC: electrical and mechanical preliminary design
- EXP: preliminary cable burial and risk assessment study
- EXP: review of the export cable landfall configuration
- IAC: Preliminary dynamic cable configuration
- EXP and IAC: Installation philosophy of the cables
- EXP and IAC: Cost evaluation

1.2 Document purpose

The purpose of this document is to establish a preliminary evaluation of cable installation methodology for the Export Cables.

In this perspective, an installation method statement is detailed for the following activities: 1st end pull-in, laying, 2nd end pull-in and cable burial for export cable connected between two OSS ; 1st end shore pull and cable burial for export cable connected between landfall and OSS.

Pre-installation activities (for example, pre-lay surveys, landfall preparation or HDD works) and Post-installation activities (for example, as-built survey) are not detailed in this document.

A document giving high level review and recommendations regarding the export cable landfall configuration is available in [16].

2 ABBREVIATIONS

The following abbreviations are used in the present document:

c/w	Comes with
CAPEX	Capital Expanditure
CLV	Cable Laying Vessel
CPS	Cable Protection System
CSF	Catenary Shape Factor
DAF	Dynamic Amplification Factor
DP	Dynamic Positioning
HDD	Horizontal Directional Drilling
HVAC	High Voltage Alternating Current
IAC	Inter-array cable
KP	Kilometric Point
Max	Maximum
MBR	Minimum Bending Radius
mT	Metric Ton
N/A	Not Applicable
OD	Outer Diameter
O&M	Operation & Maintenance
OSS	Offshore Substation
RDS	Reel Drive System
ROV	Remotely Operated Vehicle
SF	Safety Factor
SIMOPs	Simultaneous Operations
SWL	Safe Working Load
TBC	To Be Confirmed
TDP	Touch Down Point
UF	Utilization Factor
WD	Water Depth
WTG	Wind Turbine Generator

3 REFERENCES

3.1 Client documents

Ref.	Document Title	Doc Number	Doc. Rev.
[1]	Progetto Preliminare - Relazione Tecnica Illustrativa	R.1	01
[2]	Progetto Preliminare - Elaborati Grafici - Schema Elettrico	EG12	01
[3]	Progetto Preliminare – Inquadramento su carta nautica	EG5	01
[4]	Relazione tecnico-illustrativa – sottostazioni offshore – ESE - Tecon	12085-PMS-001	00

3.2 Standards and rules

Ref.	Document Title	Doc Number	Doc. Rev.
[5]	Marine operations and marine warranty	DNVGL-ST-N001	2021
[6]	Subsea power cables in shallow water	DNVGL-RP-0360	2021
[7]	Installation of Submarine Power Cables	CIGRE TB 883	2022
[8]	Recommendations for Mechanical Testing of Submarine Cables	CIGRE TB 623	2015
[9]	Recommendations for mechanical testing of submarine cables for dynamic applications	CIGRE TB 862	2022

3.3 Other documents

Ref.	Document Title	Doc Number	Doc. Rev.
[10]	Barium Bay – Preliminary Subsea Cable Engineering - Design Basis	AE-P00115-R01	02
[11]	Barium Bay – Preliminary Subsea Cable Engineering – IAC Preliminary Configuration	AE-P00115-R04	01
[12]	Barium Bay – Preliminary Subsea Cable Engineering – Preliminary Subsea Cable Design	AE-P00115-R03	01
[13]	Valutazione (Preliminare) dei Rischi e della Profondità di interro	AE-P00115-R02	01
[14]	Barium Bay – Preliminary Subsea Cable Engineering – IAC Installation Philosophy	AE-P00115-R06	01
[15]	Barium Bay – Preliminary Subsea Cable Engineering – Cable Cost Study	AE-P00115-R08	01
[16]	Barium Bay – Preliminary Subsea Cable Engineering – Export Cable Landfall Review	AE-P00115-R05	01

4 DESCRIPTION

4.1 Site Location

The Barium Bay wind farm will be installed approximately 40 km offshore the Apulian coast between Barletta and Bari, as presented in Figure 4-1, in a water depth ranging from 120m to 190m, as per document of design basis in [10].

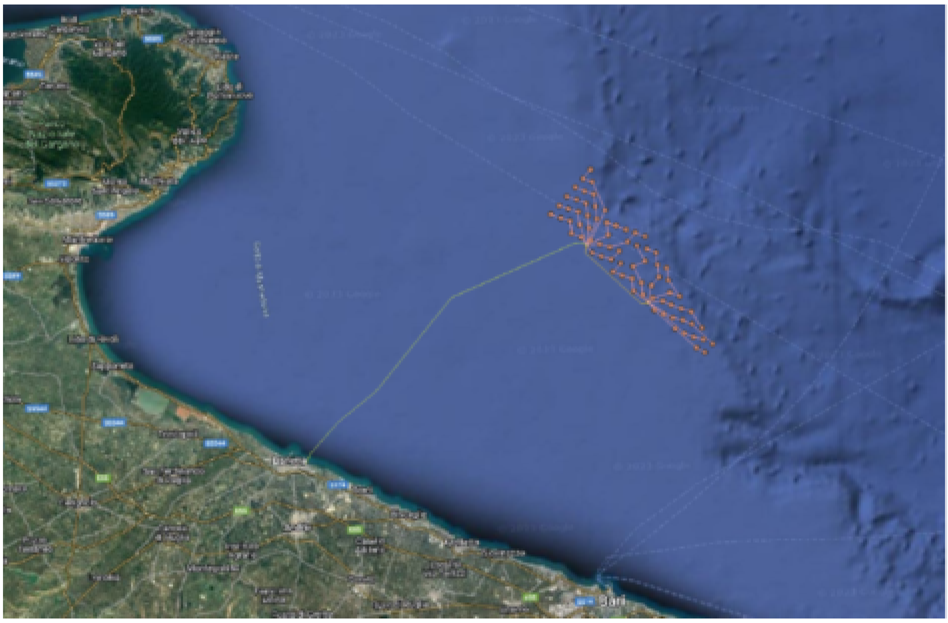


Figure 4-1 – Barium Bay - Wind Farm and Export Cable Location

4.2 Wind Farm Layout

As shown in Figure 4-2, the wind farm is divided in two clusters of 37-off WTGs, distributed on 8-off strings of 4-off or 5-off WTGs. Two offshore substations (OSS) are located on the western side (shore side) of their own cluster. Cluster n°1 is the northern part of the park and Cluster n°2 the southern part. OSS1 is installed in 130m water depth. OSS2 is positioned in 150m water depth. Both OSS are interconnected via an 15km HVAC link. The two export HVAC cables are connected to the OSS1 only.

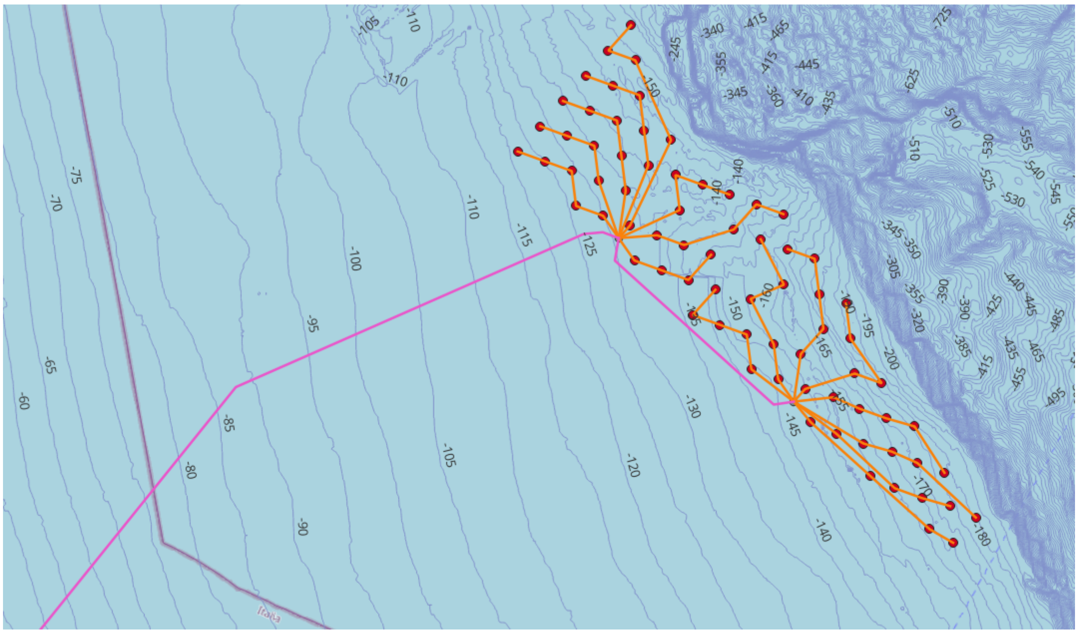


Figure 4-2 – Wind Farm Layout

4.3 Offshore Substations

According to [4], the two bottom fixed substations will be supported by a jacket steel structure, equipped with standard J-tubes design, as shown in Figure 4-3. The cable deck is at +16m above sea level. As per [1], it is considered that the top flange of J-tube will arrive 0.5m above the cable deck, therefore:

- For OSS1, water depth is 130m, therefore J-tube top flange is at 146.5 m above seabed.
- For OSS2, water depth is 150m, therefore J-tube top flange is at 166.5 m above seabed.

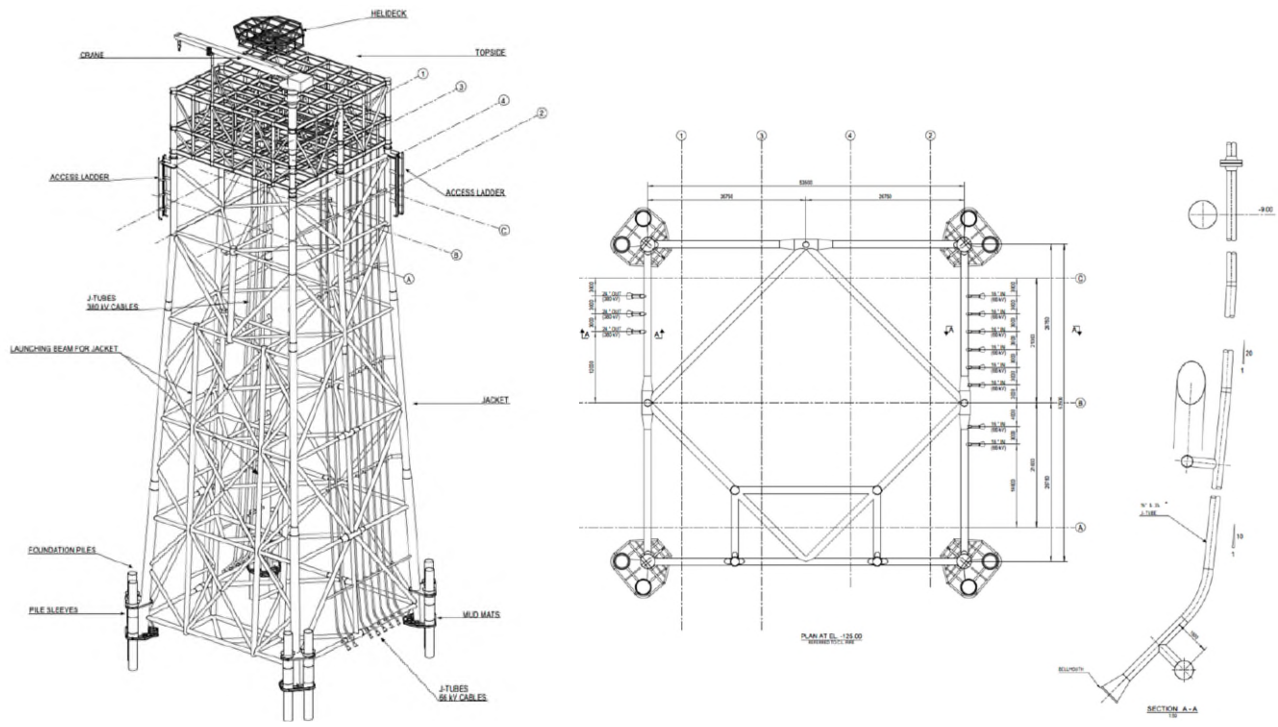


Figure 4-3 – OSS1 Isometric, J-tube and Cable Deck

4.4 Subsea Power Cables

4.4.1 Cable Cross-Section

In accordance with [12], the cross section considered in this study is:

Cable	Type	Voltage (kV)	Power (MW)	Cross section
Export	Static	380	555	3x800 mm^2 Cu

Table 4.1 – Cable Cross Section Overview

4.4.2 Cable Installation Parameters

Export cables are pulled up through the OSS J-tube, as represented by the typical sketch in Figure 4-4.

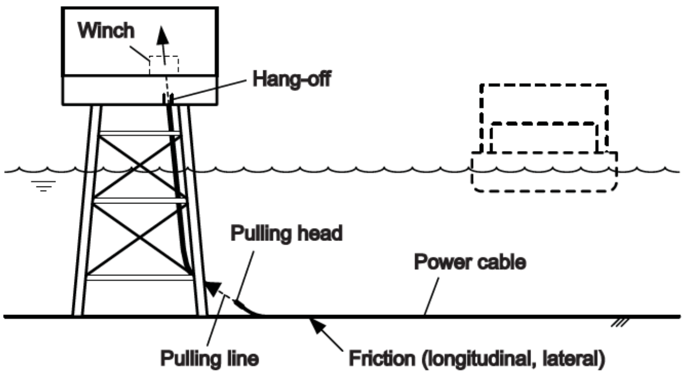


Figure 4-4 – Installation scenario – Export Cable Connection to OSS (typical from [6])

4.4.3 Cable Mechanical Properties

Standard properties of cable are presented in Table 4.2 (as per [12]).

Property	Unit	EXP
OD	mm	267.5
Weight in air	kg/m	113.3
Weight in water	kg/m	62
Maximum allowable tension load	mT	142.7
Minimum bending radius (MBR)	m	3

Table 4.2 – Cable Cross Section Overview

4.4.4 Cable Termination for Connection to OSS

4.4.4.1 Cable Sealing

It is assumed that export cable end is properly sealed.

Figure 4-5 below shows a picture of a typical water sealing installed onto a cable end.

Figure 4-5 – OSS Cable Connection System (Typical)

4.4.4.2 Cable Grip

Cable is fitted with a cable grip (pulling stocking) for connection to a pull-in rigging, as per [2].

As shown in Figure 4-6, a swivel may be used directly in front of the cable stocking to reduce torsion within the cable and the pulling line (pull-in winch cable).

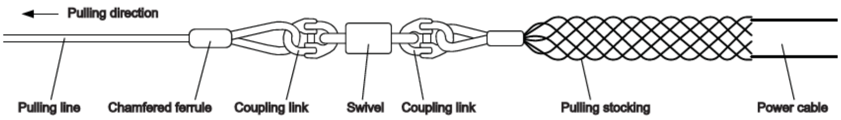


Figure 4-6 – Cable End Connection to Pull-in Rigging (typical from [6])

4.4.5 Cable Termination for Shore Pull

It is assumed that export cable end for shore-pull is fitted with a pulling head with a padeye at its extremity for connection to onshore winch pulling cable.

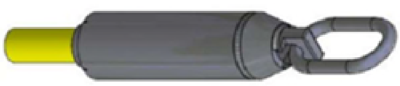


Figure 4-7 – Pulling Head for Shore Pull (Typical)

4.5 Cable Accessories

4.5.1 CPS for Connection to OSS

CPS is used to protect the export cable connected to OSS from damage due to impact, abrasion and fatigue and from over-bending during the pull-in operations and the cable life.

Note: CPS systems used along cable route are detailed in section 4.6.

4.5.2 Temporary Floats

Temporary floats are usually required on the cable as a mean to reduce friction and keep pulling tension within allowable limits.

These buoyancy aids are attached to the cable onboard the vessel and are removed before the cable comes ashore or enters the HDD duct.

4.6 Cable Protection

This section details the need for cable protection from external threats (anchors, fishing, etc). It is based on the results of the Cable Burial Risk Assessment (CBRA), as per [13].

According to [13], export cable route can be divided in 3 different sections with a specific type of requirement of cable protection to be used:

- Section from landfall to KP56
  Export cable will be routed inside a HDD.

- Section from KP56 to KP46
  Export cable will be protected by cast iron protective shells.

- Section from KP46 to OSS at KP0
  Export cable will be buried at a depth of 0,5m ([13]). It is considered in this document that burial will be performed during post-lay operations using water jet system (with or without depressor). With this method, the seabed is fluidised by injecting water into it. Then, to get the cable at the required depth, either it will sink through the fluidised soil under its own weight or the cable will be pushed down using a depressor.

Note: The soil penetration method and tool to be considered for burial of cable is related to the type of soil. In this document, a method/tool suitable for a soft clay type of soil (see [13]) is considered as a first guidance, in accordance with [7]. Final burial tool methodology must be based on burial equipment technical performance and final geotechnical assessment during detailed engineering.

5 NAVAL MEANS AND EQUIPMENT

5.1 Cable Laying Vessel

Installation of export cables shall be performed by a vessel equipped with a turntable (carousel).

Naval Means & Equipment	Characteristics
Cable Laying Vessel (CLV)	
DP Class	Minimum Recommended 2
Turntable	Suitable for Export Cable
Tensioner	see note 1
Overboarding Chute	Minimum radius: >3.3m (see note 2)
Subsea Crane	see note 1 Radius range: suitable for cable overboarding
Deck winch	Minimum capacity: 10mT
Quadrant (for 2nd end overboarding – EXP3 connection to OSS)	see note 1
ROV	Work class system Minimum tether length (ROV excursion): >200m
Offshore Substation (OSS)	
Pull-in Winch	see note 1
Landfall (Shore Pull)	
Onshore Winch	see note 1

Table 5.1 –Naval means and required equipment for export cables installation activities

Notes:

1) Maximum load to be calculated to define requirement for minimum capacity of each equipment, applying a safety margin on equipment of 0.9..
2) Minimum radius of chute is based on maximum MBR (see section 4.4.3) with a safety margin of 0.9.

5.2 Support Vessels

Several vessels are required during the shore pull activities in addition to the CLV.

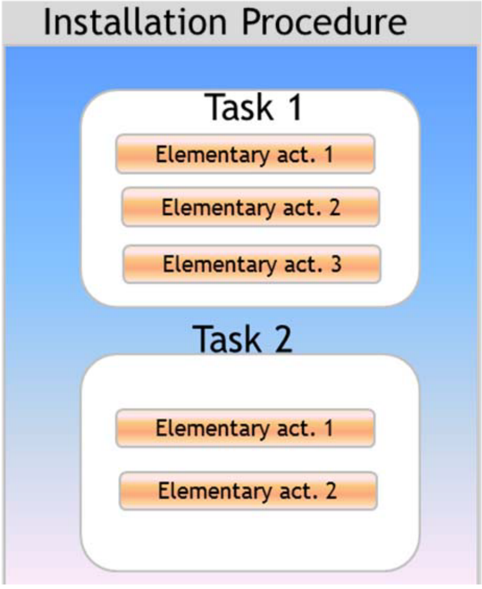
Multicat and workboat are used, as required, to pull the onshore winch pulling cable (fitted with a messenger line as required) through the HDD duct until the end socket exits the HDD duct for future recovery by CLV, as part of landfall preparation activities.

Support boats are used, as required, to assist the CLV by pulling the cable bight up current to reduce the cable catenary as necessary to conform to the design route.

Diving support vessel is used during temporary floats removal activities.

6 OUTLINE PROCEDURE

This method statement is organized in two levels of detail: the tasks and the elementary activities, providing a step by step guide to execute the installation activities.



The task is minimum measurable time unit to define/record an operational duration.

Some typical sketches are included in the step-by-step sequences to ease understanding of the operation performed.

6.1 Installation Criteria

During the installation of a export cable, the following criteria shall be satisfied:

- Cable integrity (max tension, MBR, max torsion, max compression)
- Laying corridor
- Cable Pull-in rigging capacity
- Cable max entrance angle
- OSS winch capacity
- Onshore winch capacity
- Vessel laying equipment capacity
- Vessel crane capacity
- Vessel minimum draught

These criteria shall be detailed in final installation procedures.

6.2 Step by Step

The following sections detail a typical installation of 1-off export cable connected between two OSS and 1-off export cable connected between one OSS and onshore (in that case, only activities of 1st end shore pull are detailed in this document).

Notes:

1) For the first case, only activities of 1st end pull-in to OSS and laying are described. 2nd end pull-in is similar to the IAC 2nd end pull-in described into document [14].
2) For the second case, only activities of 1st end shore-pull are described. Other activities are already detailed in this document (export cable laying) or in document [14] (2nd end pull-in to OSS).

6.2.1 Offshore Preparations

Initial Status

- Pre-installation Survey, including shore and shallow sections of shore-pull area and cable route, has been performed

Landfall Preparations:

- Onshore winch is function-tested and ready
- Onshore pulling cable is deployed with end socket, fitted with recovery rigging, positioned at drop target location.

Note: Drop target location on shore-pull route shall be as close as possible to HDD duct entrance, suitable for vessel draught and pulling capacity of onshore winch. Alternative is to use a support vessel for recovery of pulling cable.

OSS Preparations:

- Hang-off device is ready
- Pull-in winch is function-tested and ready
- Pull-in winch cable c/w messenger line is inserted into J-tube and is laying on the seabed, ready for recovery.

Vessel Preparations:

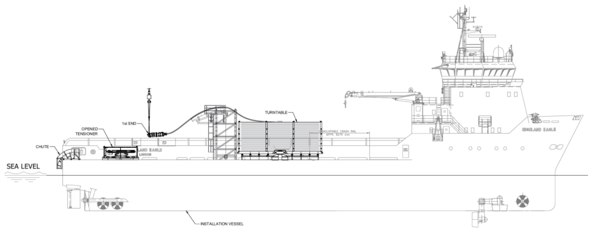
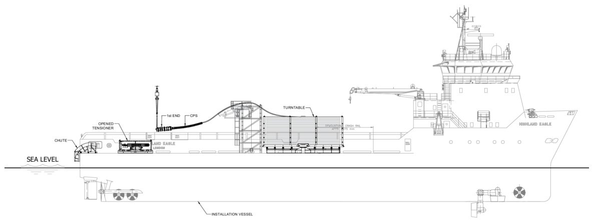
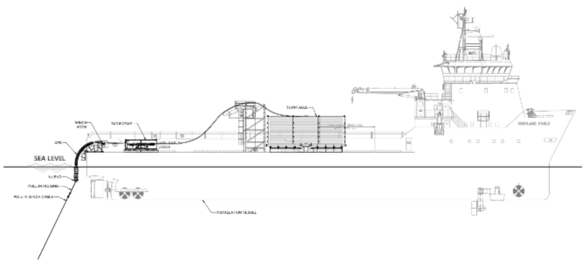
- Cable line is loaded into vessel turntable and ready for use
- Vessel Crane, quadrant and deck winch are operational
- All required rigging for operations is ready for use on board, complete with valid certificates
- Cable route is displayed on the Navscreen

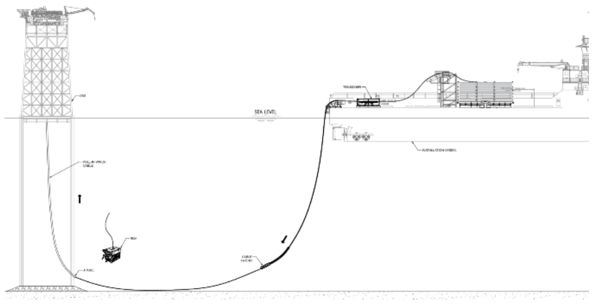
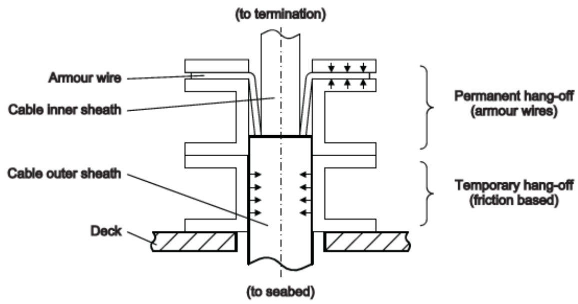
SIMOPs:

- Communication has been established between vessel and OSS winch team or between vessel and onshore winch team and check on communication networks has been performed.
- Toolbox talk completed.

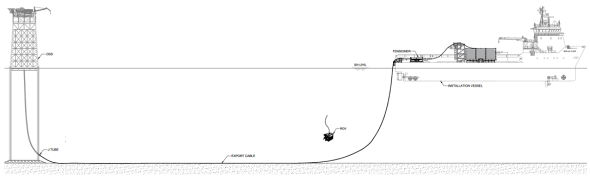
6.2.2 Export Cable Connection to OSS

6.2.2.1 1st End Pull-in

Elem Act	Description	Sketch
1.1.	Connect handling rigging (soft sling chocked around 1st end/cable) to cable 1st end and connect vessel crane.	
1.2.	Lift cable 1st end with vessel crane and bring it to working area. **See sketch enclosed**	
1.3.	Prepare the 1st end for overboarding: - Fit the sealing on cable end (if not already done) - Install CPS - Install pull-in rigging (including cable grip)	
1.4.	Connect vessel crane to the 1st end pull-in rigging.	
1.5.	Slowly lift the 1st end off deck (above tensioner) with vessel crane and move it in front of chute, paying-out cable accordingly. **See sketch enclosed**	
1.6.	When the 1st end and CPS have fully passed tensioner and the cable is inserted in the opened tensioner: - Stop cable paying-out - Close tensioner on the cable ⚠ **During all the operation, it is visually checked that cable MBR is respected.**	
1.7.	Recover pull-in winch cable, fitted with messenger line, onboard vessel. Connect pull-in winch cable to cable 1st end pull-in rigging. ⚠ **The messenger line should not be considered as the pulling line.** **See sketch enclosed**	

1.8.	Overboard cable 1st end and lower it toward the seabed, in a controlled manner, by paying-in pull-in cable, while cable is paid-out from vessel. **Note:** Overboarding is achieved by using vessel crane (two legs configuration rigging is required) or directly by paying-in from OSS winch system once cable 1st end is on chute.	
1.9.	Perform pull-in operation, paying-out tensioner and paying-in pull-in winch. **Note:** The entire pull-in operation shall be continuously monitored for all parameters to be within specified limits. As a result from installation analysis, a specific sequence table can be defined. **See sketch enclosed**	
1.10.	Complete cable 1st end pull-in into OSS J-tube and secure it using temporary hang-off clamp. **Note:** The temporary hang-off secures the cable sufficiently for cable installation works to proceed.	 **(Typical design of cable hang-off - [6])**
1.11.	Remove tension in pull-in winch cable. Disconnect pull-in rigging from cable 1st end. Install permanent hang-off clamp (fixing of cable armouring).	
1.12.	Perform electrical connection and testing.	N/A

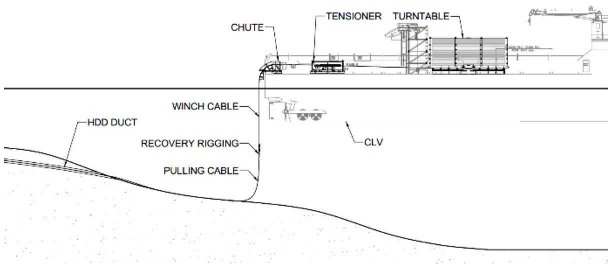
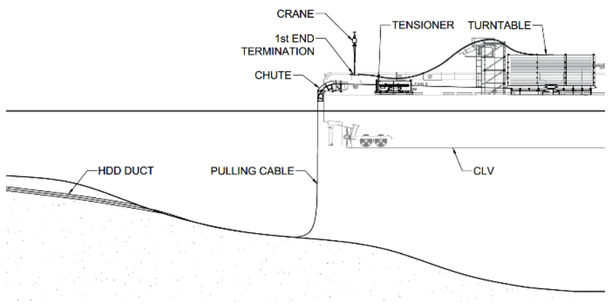
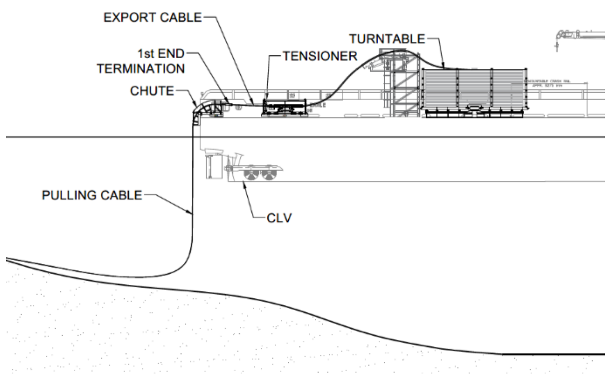
6.2.2.2 Cable Laying

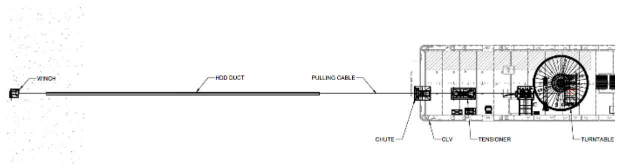
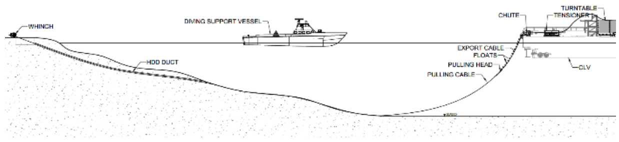
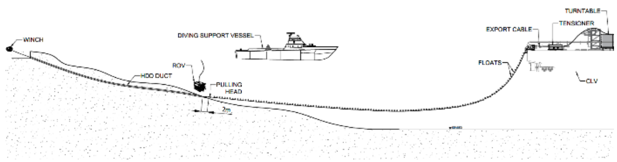
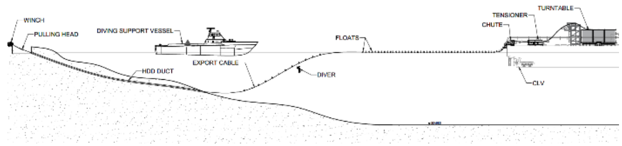
Elem Act	Description	Sketch
1.1.	Lay cable as per cable route respecting laying corridor by continuous paying-out of cable, moving vessel accordingly. Deck crew to continuously check the length of cable paid out using cable marking & tape measure. **TDP to be continuously monitored by ROV.** **Cable paid-out length and cable marking to be continuously monitored.** **Laying parameter (tension, layback) to be continuously monitored (as per analysis).** **See sketch enclosed**	

6.2.2.3 2nd End Pull-in

<u>Note:</u> As previously defined, 2nd end pull-in activities for export cable connection to OSS are similar to the ones detailed for IAC connection to OSS into document [14].

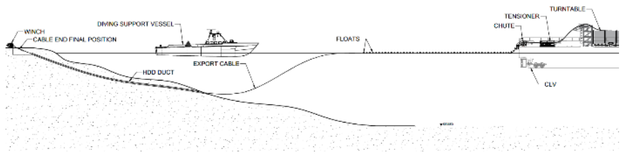
6.2.3 Shore Pull

Elem Act	Description	Sketch
1.1.	CLV is approaching pulling cable drop target location.	
1.2.	Recovery rigging is connected to subsea crane/winch hook by ROV (or Divers).	
1.3.	Onshore pulling cable is recovered onboard CLV and secured. **See sketch enclosed**	
1.4.	1st end termination (pulling head for shore pull) is brought out of the turntable: - Rotate turntable to get 1st end termination with crane - Connect crane to 1st end termination - Lift 1st end termination and rotate turntable accordingly	
1.5.	Prepare 1st end termination on deck, as required. Overboarding rigging is connected on 1st end termination. Tensioner is in open position.	
1.6.	CLV crane is connected to 1st end termination overboarding rigging.	
1.7.	1st end termination is lifted over the deck and move in front of chute, paying out cable accordingly. Export cable is centred in the tensioner: - Cable paying-out is stopped - Tensioner is closed **See sketch enclosed**	
1.8.	Onshore pulling cable is connected to 1st end termination. **See sketch enclosed**	
1.9.	Floats are installed on 1st end termination and export cable.	

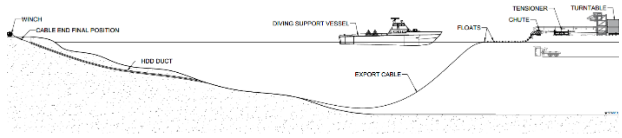
1.10.	CLV heading to be adapted for shore-pull (chute aligned with pulling cable/export cable route). **See sketch enclosed**	
1.11.	CLV to inform onshore winch team.	
1.12.	Onshore winch takes-up the slack in pulling cable and set tension as required. ⚠ A maximum tension shall be set on the onshore winch to guarantee the integrity of the cable (see section 4.4.3).	
1.13.	Once the pulling cable slack is removed, CLV informs the onshore winch team that pull-in can start.	
1.14.	Onshore pulling cable is pulled-in from onshore winch, while export cable is paying out from vessel accordingly (at same speed). CLV crew to install temporary floats onto cable as required. ROV (or Divers) to monitor 1st end termination (pulling head). Onshore winch team to monitor tension. **<u>Note:</u>** When required, CLV crew to choke strops on the cable for use by support boats. **See sketch enclosed**	
1.15.	Stop at 2m before the HDD duct entry ; ROV (or Divers) to perform a check. **See sketch enclosed**	
1.16.	1st end termination / export cable is pulled-in through the HDD duct. Divers to remove floats gradually while export cable comes inside HDD duct and to monitor cable entrance. **<u>Note:</u>** This activity can be performed during night-time using suitable sources of light. **See sketch enclosed**	

<table>
<tr><td>1.17.</td><td>Once 1st end termination is recovered at required shore location, it shall be secured.

<u>Note:</u> It can be temporarily secured to the winch frame.

See sketch enclosed</td><td>
</td></tr>
<tr><td>1.18.</td><td>Support vessel to remove floats along the route. Divers to control the correct sinking position of the cable.

Support vessel to confirm that cable is along the design route.

See sketch enclosed</td><td>
</td></tr>
<tr><td>1.19.</td><td>Once cable route is confirmed, cable can be permanently secured by anchoring the cable armour.</td><td rowspan="2">N/A</td></tr>
<tr><td>1.20.</td><td>CLV to start normal laying.

<u>Note:</u> it includes the installation of cast iron protective shells around the cable, when required, as per section 4.6.</td></tr>
</table>