SUND OG BÆLT

ANALYSES OF NEW ISLAND HARBOUR TÅRS

CONCEPT CABLE CALCULATION

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INDHOLD

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1 Summary

The following calculation is provided for preliminary sizing calculation of the cables for Tårs Harbour. The conceptual electrical single line diagram for 10 kV switchgear is shown in figure 1. The scope of work is including following:

- The cable from connection point of existing 10 kV network to ferry charging station, which is split up into 3 sections:
  - Section 1: Onshore cable route that is starting from the connection point to existing 10 kV to landfall area that will be connected to offshore section with cable joints (1500 m)
  - Section 2: Offshore cable route on seabed. Submarine cable starts from landfall and ends at the ferry island (3500 m)
  - Section 3: Onshore cable route on the island (500 m) that will use the same submarine cables

The connection cables to the windfarm and cable from convertor unit to ferry are not included in the scope. All cables are sized based on capacity of transformer of ferry convertor feeder AKA04 as 14 MW.

According to calculations with 10 kV voltage and 14 MW demand power, see ref. /1/, two parallel 3 cores submarine cables with 300 mm² cupper conductor cables are required for the offshore part (each cable will carry 7 MW). For onshore part of the circuit, two parallel 3x1 single core 630 mm² aluminium conductor cable circuits are needed.

For optimizing the cable supply and pulling costs and to have a simpler and more practical installation and construction works, it is highly recommended to transmit the power from onshore to offshore at a higher voltage level such as 20 kV. According to calculations one 20 kV 3 core submarine cable 500 mm² aluminium conductor and 3x1 single core 500 mm² aluminium are sufficient to carry full power. The switchgear nominal voltage shall be updated to 20 kV and 10 kV voltage at connection point to existing network needs to be stepped up to 20 kV.

It is noticed that only one 20 kV cable connection is assumed. The redundancy and availability criteria shall be aligned with the developer, since and outage due to faults or maintenance may impose unacceptable time duration without ability to power up the load at the Ferry Island.

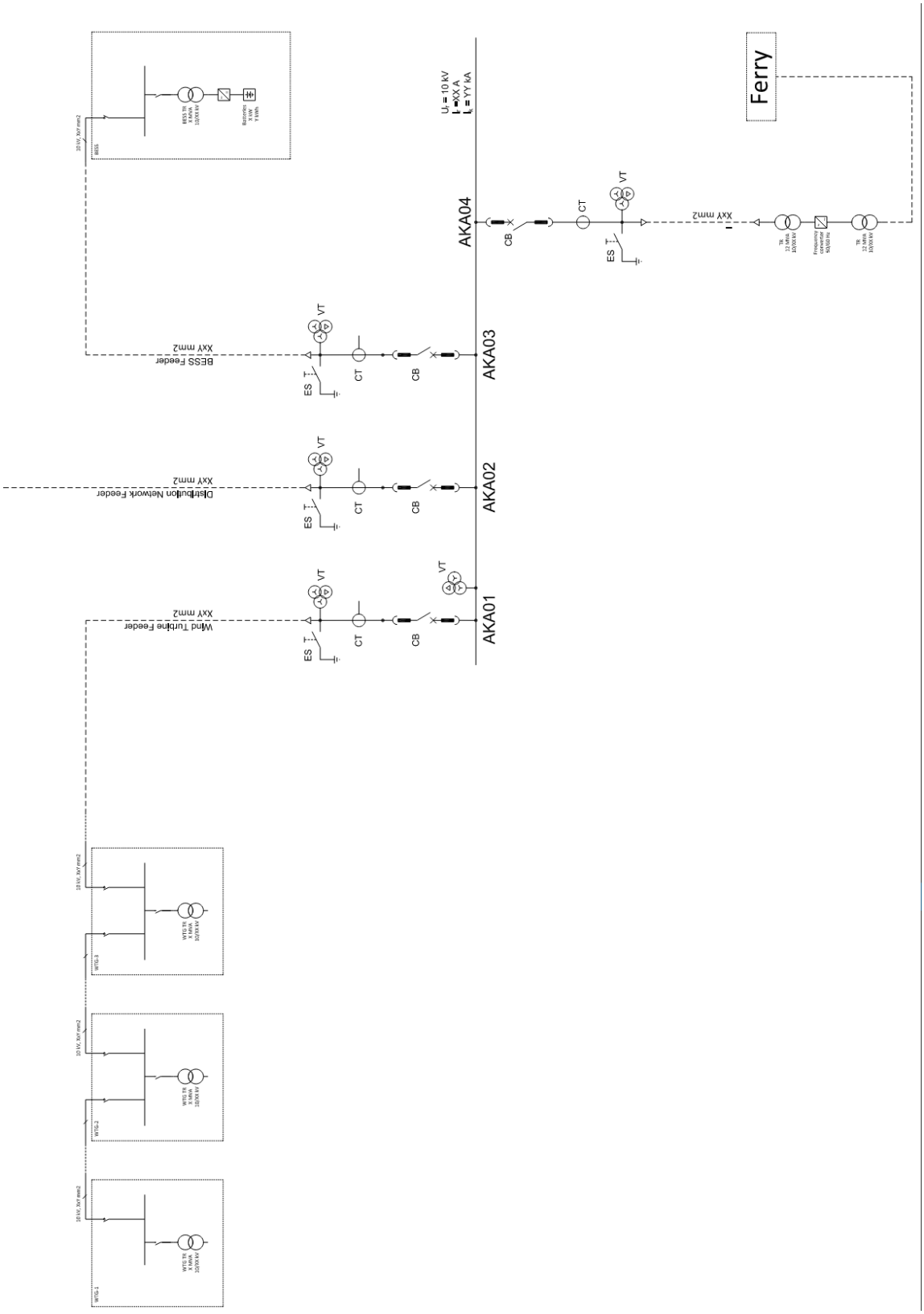


Figure 1 Preliminary Single Line Diagram (see Appendix of ref. /2/)

2 Assumptions

- For the onshore cable routing, a HDPE conduit system is installed in a trench in which the cables are pulled into placement.
- All calculations and cable selections are based on 20 kV nominal voltage for transmission system and switchgear.
- The offshore cables are laid on the seabed and no trench is considered for submarine part except for landfall areas at both ends. The offshore cables are buried in the seabed using a hydro jet cable burial machine.
- Jointing bays are needed for offshore to onshore cable connections at one end.
- The cable sheaths are connected to earth at both sides as double point bonding for the off- and onshore cable systems.
- There is no grid short circuit data available, so the cable sheath short circuit withstand is considered as 3 kA 1 sec.
- Accurate geotechnical data for soil are not available at this stage since site investigations have not been carried out. It is therefore important to emphasizing that the estimated cross sections developed in the report are indicative and will change subject to availability of more project specific site data details.
- The water temperature and seabed soil thermal resistivity are not available in this stage and the calculations are based on assumptions.
- Site conditions assumed aligns with Energinet's Kabelhåndbog 2018 and are captured in the design input list.
- Ampacity studies are done in conformity with IEC 60287 with continuous load current applied.
- There is no information about potential crossing with existing utilities. Therefore, the selected cross section will change subject any future crossing with existing utilities.
- There is no cable redundancy considered in this note.
- The BOQ is only provided for the cables and cable accessories.

3 Cable circuits summery

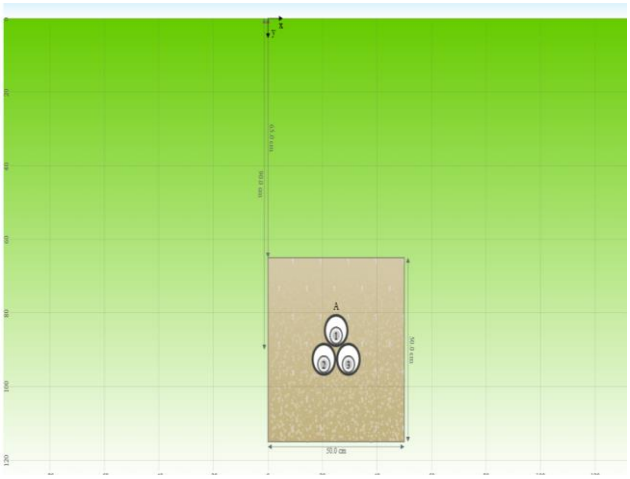
System	From	To		Capacity (MW)	Length (m)	Voltage (kV)	Current (A)	Bonding	Core	Conductor Type	Conductor Size (sqmm)
1	Distribution Feeder 1	AKA02	offshore	14	3500	20	425	Double	3 core	Aluminium	500
2	Distribution Feeder 1	AKA02	onshore	14	500	20	425	Double	3 core	Aluminium	500
3	Distribution Feeder 1	AKA02	onshore	14	1500	20	425	Double	Single	Aluminium	500
4	BESS FEEDER	AKA03	onshore	14	1500	20	425	Double	Single	Aluminium	500
5	AKA04	FERRY	onshore	14	500	20	425	Double	Single	Aluminium	500

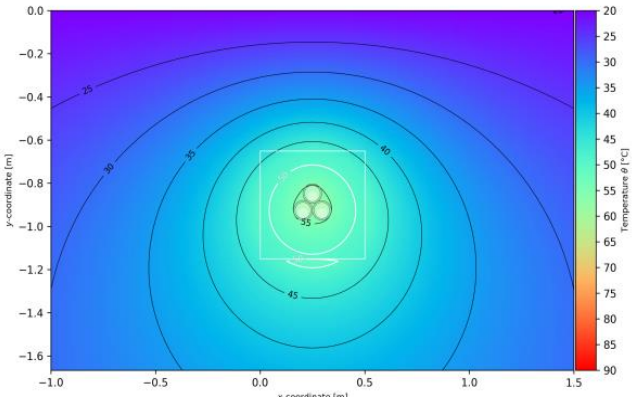
Figure 2 Suggested cable sizes.

4 Cable ampacity calculation

4.1 Onshore cable calculation

The typical calculation is provided for one cable feeder including one circuit in trefoil arrangement for onshore part.





Systems

Following systems are active in the arrangement:

System	Object	Current [A] I_c	Temp. [°C] θ_c | θ_e (θ_{de})	Losses [W/m] W_{sys}	Load LF
A	N2XS2Y 500AL/35R CU mm2 12/20kV	425.0	70.8 | 66.5 (56.6)	47.9	1.00

4.2 Technical specifications

Soil characteristics:

- Soil Temperature: 20°C
- Thermal conductivity: 0.5 W/(m.K)
- Thermal resistivity: 2.00 K.m/W
- Calculation method: IEC 60287

Trench size:

› Width / Height: 100*100 cm

Backfill areas:

› Shape: rectangular

› Material: sand

› Width / Height: 100*50 cm

› Thermal resistivity: 0.8 K.m/W

Duct:

› PE

› Size Inn/Out: 90/100 mm

4.3 Cable arrangement

› Cable Size: 3*1c500 Al

› Arrangement: trefoil

› Earthing: Double point bonding

› Minimum Depth of laying: 90cm

4.4 Cable Trench Detail

The outline of the cable trenches is illustrated in the following sketch.

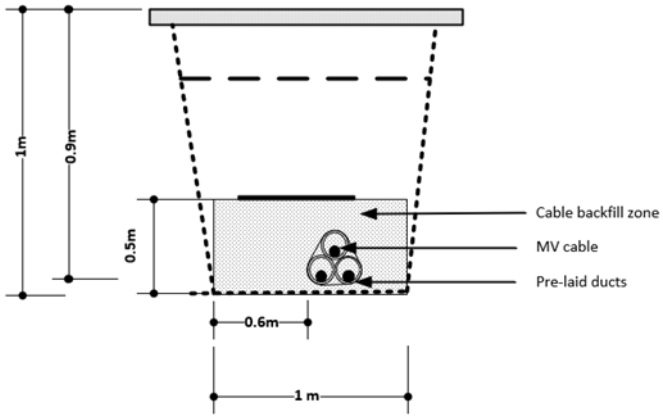


*Figure 3 Cable arrangements (3*1*500 AL)*

4.5 Cable data sheet(onshore)

NKT Cables 12 20(24) kV-XLPE AL

- 12/20 kV
- Min. bending radius: 0.6 m

AXALJ-TT EQV 24 kV

NKT

Tekniska data
Technical data

Ledarantal och area No. of cores and cross-section (mm²)	E-nummer E-number	Förpackning/ lev. längd Packaging, delivery length	Diameter nominell Nominal diameter Ledare Conductor (mm)	Isolering Insulation (mm)	Mantel (omskriven cirkel) Sheath (circumscribed circle) (mm)	Ca vikt Cable mass approx. (kg/m)	Induktans ledare plan formation Inductance conductor plan formation (mH/km)	Induktans ledare triangulär formation Inductance conductor triangular formation (mH/km)	Kapacitans Capacitance (µF/km)	Jordslutningsström Ground connection current at U_0 (A/km)
1x95/25	00 808 00		12,2	22,7	26,6	1	0,52	0,35	0,21	2,2
1x150/25	00 808 10		15	25,5	29,6	1,2	0,48	0,33	0,24	2,6
1x240/35	00 808 20		19	29,5	33,8	1,6	0,44	0,31	0,29	3,2
1x300/35	00 808 30		21,3	31,8	36,3	1,8	0,42	0,30	0,32	3,5
1x400/35	00 808 40		23,9	34,4	39,1	2,1	0,40	0,29	0,35	3,8
1x500/35	00 808 50		27,8	38,3	43,2	2,6	0,38	0,28	0,40	4,3
1x630/35	00 808 60		31,8	42,3	47,4	3,2	0,36	0,27	0,45	4,9
1x800/35	00 808 70		36,2	46,7	52,2	3,8	0,34	0,26	0,50	5,5
1x1000/35	00 808 80		40,3	50,8	56,9	4,5	0,33	0,26	0,55	6,0
1x1200/35	00 808 90		43,6	53,7	60,4	5,1	0,32	0,26	0,61	6,7

Ledarantal och area No. of cores and cross-section (mm²)	Nominellt strömvärde mark, öppen skärmkrets (A) Nominal load current soil open screen circuit (A) Ledare 65°C triangel Conductor 65°C triangel	Ledare 90°C triangel Conductor 90°C triangel	Ledare 65°C plan Conductor 65°C plan	Ledare 90°C plan Conductor 90°C plan	Korttidsström (kA) Short time current (kA) Ledare Conductor	Skärm Screen	Resistans Resistance Ledare Conductor (Ω/km)	Skärm Screen (Ω/km)	Min. böjradie Min. bending radius Förläggning Laying (mm)	Installation Installation (mm)	Tillåten dragfraft Permissible pulling force Samtliga ledare All conductors (kN)	Dragstrumpa över mantel Tensile-sock over sheath (kN)
1x95/25	240	280	255	300	8,98	5	0,3200	0,8	266	399	2,9	3,5
1x150/25	305	360	330	390	14,2	5	0,2060	0,8	296	444	4,5	4,4
1x240/35	395	465	435	510	22,7	7	0,1250	0,6	338	507	7,2	5,7
1x300/35	445	525	485	570	28,3	7	0,1000	0,6	363	545	9,0	6,6
1x400/35	525	615	570	670	37,8	7	0,0778	0,6	391	587	12,0	7,6
1x500/35	590	685	645	760	47,2	7	0,0605	0,6	432	648	15,0	9,3
1x630/35	665	780	720	850	59,5	7	0,0469	0,6	474	711	18,9	11,2
1x800/35	750	885	780	920	75,6	7	0,0367	0,6	522	783	24,0	13,6

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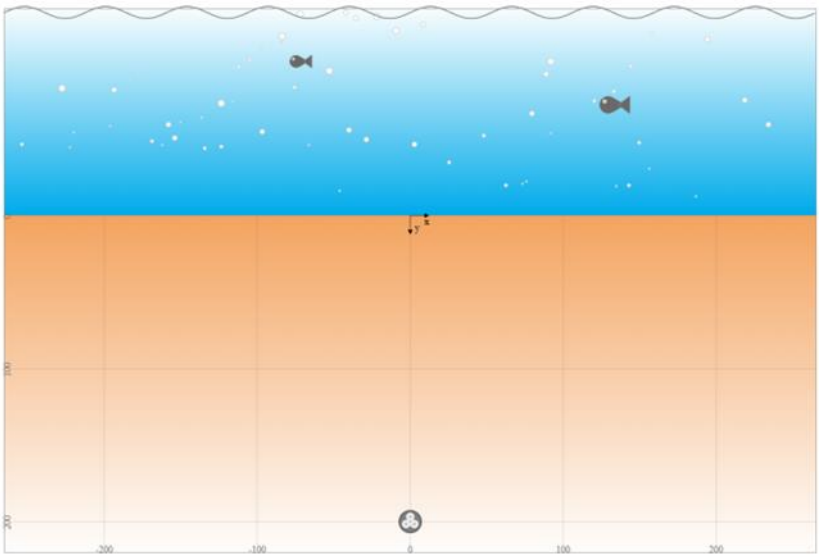
5 Offshore Cable calculation

The typical calculation is provided for one cable feeder including one circuit as base case.



Systems

Following systems are active in the arrangement:

System	Object	Current [A]	Temp. [°C]	Losses [W/m]	Load
		I_c	θ_c | θ_e	W_{sys}	LF
A	3*500 Al12/20(24)kV subsea k	425.0	61.2 | 39.5	55.4	1.00

5.1 Technical specifications

Soil and water characteristics (offshore part):

Soil characteristics:

- Soil Temperature: 15°C
- Thermal conductivity: 0.5 W/(m.K)
- Thermal resistivity: 2.00 K.m/W
- Calculation method: IEC 60287

Water characteristics:

- Seabed Temperature: 15°C
- Thermal conductivity: 1.4 W/(m.K)
- Thermal resistivity: 0.7 K.m/W
- Calculation method: IEC 60287

- Sea water depth: 7 m
- Water temperature: 13.5 °C

Cable buried Trench size (onshore part):

- Width / Height: 100*100 cm

Backfill areas:

- Shape: rectangular
- Material: sand
- Width / Height: 100*50 cm
- Thermal resistivity: 0.8 K.m/W

Duct:

- without duct

5.2 Buried cable arrangement (onshore part)

- Cable Size: 3*1c500 Al
- Earthing: Double point bonding
- Minimum Depth of laying: 90 cm

5.3 Seabed cable arrangement (offshore part)

- Cable size: 3c*500 Al
- Earthing: Double point bonding
- Depth of burial: 200 cm

5.4 Ls Cable data sheet

Note

01. Calculations are performed assuming galvanized steel wire armor of 4~6mm diameter.
02. The rating given in the tables should be regarded as indicative only.
03. Three-core cables with cross-sections larger than 630mm^2 can be offered on request.
04. Aluminum conductor cables will have a rating of 75~80% for the same size of copper conductor.

Cross Section of the Cable

1. **Conductor :** copper, circular stranded compacted
2. **Conductor screen :** extruded semi-conductive layer
3. **XLPE insulation**
4. **Insulation screen :** extruded semi-conductive layer
5. **Swelling tape**
6. **Screen :** copper wires and copper helix(or copper tape)
7. **Swelling tape**
8. **Laminated Aluminum tape**
9. **Outer sheath :** PE or semi-conductive PE
10. **Fillers :** polypropylene strings(or shaped fillers)
11. **Fiber optic cable (optional)**
12. **Binding tape**
13. **Bedding layer :** polypropylene strings
14. **Armour :** Galvanized steel wires filled with bitumen compound
15. **Serving :** polypropylene strings with coloured stripe

Data Sheet for 12/20(24) kV Cables

Constructional Data

Cross-section of conductor	Diameter of conductor	Insulation thickness	Cross-section of screen	Diameter of core sheath	Armor steel wires diameter	Outer diameter of cable	Cable weight (in Air)
(mm^2)	(mm)	(mm)	(mm^2)	(mm)	(mm)	(mm)	(kg/m)
20kV (Um = 24kV)							
70	9.7	5.5	23	36	4	102	16
95	11.4	5.5	31	38	4	106	18
120	12.8	5.5	40	39	4	109	19
150	14.2	5.5	50	42	4	116	21
185	15.8	5.5	61	44	4	119	23
240	18.1	5.5	80	46	5	127	28
300	20.4	5.5	100	50	5	134	32
400	23.2	5.5	133	53	6	142	39
500	26.3	5.5	166	56	6	149	44
630	30.2	5.5	210	60	6	158	52

Electrical & Mechanical Data

Cross-section of conductor	Conductor resistance DC 20°C	Conductor resistance AC 90°C	Capacitance	Charging current per phase at 50Hz	Losses	Current rating	Min. bending radius : when laying
(mm^2)	(Ω/km)	(Ω/km)	(μF/km)	(A/km)	(W/m)	(A)	(m)
20kV (Um = 24kV)							
70	0.2680	0.3417	0.244	0.85	62.85	244	1.6
95	0.1930	0.2461	0.268	0.94	65.09	290	1.6
120	0.1530	0.1951	0.287	1.00	66.99	327	1.7
150	0.1240	0.1581	0.307	1.07	69.57	365	1.8
185	0.0991	0.1264	0.329	1.15	71.63	407	1.8
240	0.0754	0.0961	0.361	1.26	74.86	461	2.0
300	0.0601	0.0766	0.393	1.37	77.96	506	2.1
400	0.0470	0.0599	0.431	1.51	81.56	552	2.2
500	0.0366	0.0467	0.474	1.66	84.78	594	2.3
630	0.0283	0.0361	0.528	1.84	88.30	631	2.4

6 References

/1/ **COWI**
A258774-HAV-RAP-03 Tårs-Konceptdesign af havn og dæmninger 2025.

/2/ **COWI**
A258774-HAV-TEK-03 Wind Turbines - electrical infrastructure 2024.