Abstract - With a step out distance of 161 km and a design power of 55MW, Martin Linge offshore gas field, will be the longest AC submarine cable power supplying an entire offshore Oil and Gas platform from the shore. This field development comprises a platform with a jack up rig and a Floating Storage Offloading unit. This paper discusses the criteria which have been considered to select a power from shore concept instead of an offshore Gas Turbine power plant which is the current practice in the offshore Oil and Gas industry. Since in a first approach, for such long step-out distance, the choice of power from shore would be to select a DC transmission line, the paper discusses the design and the main technical challenges of this long step-out AC transmission development. Finally, the system approach, required for the development of the onshore and offshore part of the project, is described.

Index Terms — Power From Shore, Subsea Cable, SVC, GIS.

I. INTRODUCTION

Discovered in 1975, Martin Linge offshore gas field (formerly named Hild) and located in the North Sea will be operated by Total Norge which has chosen to base this development with a power from shore concept. The facility will be designed for remote control from Total Norge onshore base in Stavanger.

The field will be developed with a subsea installation and topside facilities. The processed gas will be exported to Total St Fergus terminal in UK via a new link to the existing Frigg UK Pipeline (FUKA). The oil, water and condensates will be processed and stored on a dedicated storage vessel where water will be separated for reinjection, and oil will be exported via shuttle tankers.

With a step out distance of 161km and a design power of 55MW, this will be the world’s longest AC submarine cable power supplying an entire offshore Oil and Gas platform from the shore.

This paper discusses the criteria which have been considered to select a power from shore concept instead of an offshore Gas Turbine power plant which is the current practice in the offshore Oil and Gas industry. Since in a first approach, for such long step-out distance, the choice of power from shore would be to select a DC transmission line, the paper discusses the design and the main technical challenges of this long step-out AC transmission development.

Finally, the paper underlines the electrical design particularities of this development and gives an operator's viewpoint as to the way forward.
programme is to drill and complete 6 Brent Gas producers, 4 Frigg Oil producers and 1 produced water injection wells. This offshore development will be supplied with electric power from shore, through a High Voltage AC submarine cable.

The maximum cable route length is considered to be 161 km. The estimated maximum power requirement is 55MW while expected load profile is 35 MW. Landfall is at Kollsnes and the system will be connected to the 300 kV Norwegian national grid.

III. SELECTION OF THE ALL ELECTRICAL SCHEME AND POWER FROM SHORE FOR MARTIN LINGE

During the conceptual and pre-project phase of Martin Linge, the base case was to consider an all electrical scheme concept where only electrical motors drive rotating equipment. To accommodate this choice, it was decided to install for the power generation of the platform 2 Gas Turbo generator in N+1 configuration. Several studies were made and several criteria were considered to finalize the choice of the all electrical scheme and the choice of the power generation.

One of the criteria was the reduction of the environmental impact of the platform. With the evolution of national and international constraints regarding CO2 and NOx emissions, the all-electrical scheme brings environmental advantage by using a reduced number of Gas Turbine which are centralized. In order to optimize energy use by the Gas Turbine, Waste Heat Recovery Units (WHRU) are fitted to the Gas Turbine exhaust in order to increase the efficiency. While these WHRUs will derate the Gas Turbine by the order of 1%, they will retrieve an equivalent thermal power in excess of 50% of the rated electric output of the Gas Turbine. With a conventional all mechanical scheme, the implementation and regulation of such a WHRU would be extremely complex to accommodate on dissimilar machines with dissimilar loadings spread over the entire facility and thus with an all electrical scheme, centralization of the power generation improves the overall efficiency of the plant.

Improvement of the availability was also one of the criteria to select the all electrical scheme. The electric motor maintenance requirements are, in most cases, less stringent than those of the driven equipment. In the case where the gas turbine is the driver, it is the opposite: the turbine will require more frequent and longer shutdowns than the driven equipment. Thus this difference in shutdown time requirements will result in loss of production, especially since for such large machines, there is no redundancy implemented. For the all electrical scheme, the power generation being implemented with redundancy (typically N-1 configuration), it can accommodate the maintenance requirement of any Gas Turbine without any impact on the production. Another availability improvement factor is the difference in the starting sequence of an electric motor and a Gas Turbine. The latter relies on a much more complex and lengthy procedure and is therefore more subject to failures originating from equipment and/or human factors. Martin Linge being designed to be unmanned the improvement of the overall availability of the platform was paramount to select this all electrical scheme.

Regarding the power sizing and power margins, in a conventional scheme, the compressor or pump rated power will be subject to Gas Turbine market range compatibility. This constraint is avoided with the all-electrical scheme since high voltage electric motors will be tailor-designed to fit the driven equipment requirements. In addition, due to the de-rating factors of a Gas Turbine for both ageing and fouling, the Gas turbine is selected with a significant power excess. Such power is not available for use by other loads, so although it has been designed and accounted for, it does not benefit operations. In the electrical scheme, since all turbines are connected to the grid, their power margins can be consolidated to optimize the power generation sizing.

It was then decided during the pre-project to investigate a step further the reduction of the environmental impact of this development. To accommodate this choice, the solution was then to consider a power from shore concept (Fig. 3) instead of having an offshore Gas Turbine power plant. Finally after verification of the feasibility of this concept, a power from shore solution, associated to an all electrical scheme, was selected for the project. At that time, the platform layout was already defined and the additional offshore electrical equipments required for the Power From shore concept had to fit in the existing layout.

IV. POWER FROM SHORE AC OR DC TRANSMISSION CONSIDERATION

With the power from shore concept selected, there were 2 possible technical transmissions choice either AC or DC transmission, each solution having advantages and disadvantages. Even if an AC transmission has a number of drawbacks which limit its use for long step-outs application; such as high voltage variations between no-load and full-load mode, risks of resonance and reactive power generation by the subsea cable. AC transmission was the solution allowing to not modifying the existing layout, since AC transmission minimizes the number of electrical equipment to install offshore. For AC transmission only GIS and transformers (Fig. 4) were required to be installed when for a DC transmission solution an additional DC to AC Inverter associated with harmonic filter (Fig. 4) were required to be installed offshore.
Even if an AC transmission was the first preferred choice for the project, the feasibility of an AC transmission had still to be proven for such long step-out distance. Some technical studies were then conducted confirming the feasibility of an AC transmission line for the project. It appears from the here under figure (Fig. 5) that Martin Linge is in fact at the limit of feasibility for an AC transmission at 50Hz.

![Fig. 5 AC and DC projects through the world](image)

So even if for such long step-out distance, the first choice of power from shore coming in mind would have been to select a DC transmission line, it was decided to select an AC transmission for the project.

V. MARTIN LINGE ELECTRICAL ARCHITECTURE

With the selection of the power from shore concept with an AC transmission, the challenge was now to design the system in the existing layout with a reduced number of equipment installed offshore. For this purpose it was chosen to design the system without offshore compensation reactor even if this would have improved the current distribution between both cable ends (onshore and offshore). In addition, a system without offshore compensation reactor has the advantage of having a better offshore voltage stability since in case of full offshore load rejection, the offshore reactive power variation is small compared to the reactive power consumed continuously onshore at Kollsnes. The single line diagram (Fig. 6) has been designed in order to maximize the availability of the power from shore system, on this purpose redundant equipments are integrated in the system. 2 step-down transformers (300kV/100kV, 80 MVA) equipped with On Load Tap Changer (OLTC) will be installed onshore at Kollsnes, these transformers are redundant. The OLTC is here to regulate, during normal load variation, the offshore voltage of the 100kV Martin Linge GIS. The OLTC has a wide range of tap to be able to energize the subsea cable at approximately 80 % of the rated voltage in order to limit stress, inrush current and reactive power steps when energizing the system.

Due to its compactness and availability capability, double busbar systems GIS will be installed onshore and offshore. For energizing purpose, the onshore 100 kV GIS cable outgoing feeders is intended to be designed for single pole point of wave closing. The onshore GIS normal operating voltage range will be from 90.5 kV to 106 kV with possibilities to operate at 80 kV during energizing operations.

![Fig. 6 Martin Linge Power From Shore Single Line Diagram](image)
suspended. These control strategies (Fig. 7) will contribute actively to stabilize the platform voltage, but at the same time it will ensure active voltage support to the grid in case of significant voltage dips and ensure fast regulation to be neutral towards the grid with respect to reactive power exchange.

![Fig. 7 SVC control strategy](image)

The overall reactive power compensation requirement at steady state is at a maximum of 75 MVAR with a dynamic requirement of approximately 50 MVAR maximum. The concept is to design the SVC for 50 MVAR and to combine it with an oil filled 3 phase reactor. In combination with the SVC, it is considered that the reactor provides base compensation while the SVC provides a dynamic reserve. This is also the best solution from a loss point of view as the reactor losses are smaller than SVC losses. The SVC will be of power electronics type with fast response and high frequency switched semiconductor devices so as to minimize harmonic rejection on the network. For availability purpose, 2 redundant reactors will be installed. These onshore reactors have tap changer allowing reactive power adjustment between 20MVAR to 40MVAR each to accommodate design uncertainties mainly regarding the capacitance of the cable which is main the reactive power producer.

![Fig. 8 Load rejection with SVC operation during transient](image)

The subsea cable itself is selected with a cross section of 300 mm² (copper) and an insulation class of 145 kV. Onshore, the cable is a standard underground cable, single core 1000 mm² (Aluminium) and 145 kV insulation class. The onshore cable is spliced to the subsea cable at the landfall. From an operator point of view, we recommend to have the same company responsible to provide and install the onshore and offshore cables. For the last 1 km close to landfall an increased cross section to 500 mm² has been considered due to uncertainties of the thermal conditions for the cable in the landfall area.

Regarding the thermal condition it is recommended to have, from the cable manufacturer, the temperature time constant (from ambient to final operating temperature) of the cable at different location such as: landfall, J tube and seabed, since it is not necessary to size the cable for an operating mode where it will never reach its operating temperature.

For instance for Martin Linge, the current seen at landfall is maximum for the no load condition, but the cable will be operated in such condition for a limited period of time, therefore there is no need to size the cable for such condition since the cable final maximum temperature will not be reached due to the loading of the cable by the offshore load.

VI. MARTIN LINGE DESIGN CONSIDERATIONS

For the selection of the subsea cable and system operating voltage of the transmission line, different cables and transmission voltages (90kV, 100kV and 110 kV) have been evaluated and compared through an iterative process. The main studies made are:

- Load flow analysis with current and voltage distribution along the cable
- Cable losses
- Voltage transient studies (harmonics, inrush, load impact and rejections...)
- Fault level studies
- Site conditions and installation
- Induced voltage studies

Regarding the operating transmission voltage, 100kV has been finally chosen as being the best trade-off between several criteria which are listed and described here under:

During normal operation, from no load to full load, the OLTC of the step-down transformers (300kV/100kV) shall operate between +/- 10% of the rated voltage. With 100kV as a selected transmission voltage, there is a voltage variation at onshore end between 90.5kV (no load, Fig. 10) and 106 kV (full load, Fig. 9) that is to say a voltage variation between 90% and 106% which is fully in line with this here above requirement.

![Fig. 9 Voltage profile at full load with OLTC set at 106kV](image)
During transient mode (e.g. load rejection or load impact) the voltage variation offshore shall not exceed +/- 20%. With 100kV as a selected transmission voltage, this criterion is always fulfilled except when there is a load rejection higher than 50MW, in this case the transient is of 22% (Fig. 11) instead of 20%. With a power design of 55MW, this is not an issue since it considered that in this case the Martin Linge platform sustains a full trip such as an Emergency Shutdown. Anyway, as explained previously, for such trip the SVC is used in voltage control mode to reduce quickly the voltage.

Regarding the design of the cable, there is a different behavior between a subsea cable and an overhead line; for instance, the cable cross section for an overhead line is mainly inductive; when you increase the voltage you reduce the current and the cross section of the line; this is not the case for a long subsea cable transmission line since the capacitance of the subsea cable generates a large amount of reactive power (Fig. 13) which contributes to increase the transmission current and the cable cross section when you increase the voltage.

\[ Q = 2\pi f C U^2 \]

Where 
- \( Q \): reactive power
- \( C \): capacitance
- \( f \): frequency
- \( U \): line to line voltage

This phenomenon is shown on the here under table (Fig. 14) where for the same power required on Martin Linge (55MW, PF=0.9), there is a higher current transferred through a dedicated cable at 110kV than at 90kV and 100kV.

### Operating current at full load

<table>
<thead>
<tr>
<th>Voltage of 90kV</th>
<th>Operating voltage of 100kV</th>
<th>Operating voltage of 110kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>300mm² cable</td>
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</tr>
<tr>
<td>400mm² cable</td>
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<td>503 A</td>
</tr>
</tbody>
</table>

An increase of the cable cross section has been also investigated, but as shown (Fig. 14) at 100kV of operating voltage, by increasing the cable cross section (from 300mm² to 400mm²), the current transferred by the cable is higher (from 455 A to 503 A); this is due to the capacitance of the cable which increases along with the cable cross section.

The cable selected for Martin Linge has been finally chosen with a copper cross section of 300 mm² and an insulation class of 145 kV for an operating voltage of 100kV. In the worst pessimistic thermal and installation conditions the current capability of this cable is 472A for an operation current of 452A at full load (55MW). This cable selection and operating voltage have been found as being the best trade off regarding all the criteria assessed in the different studies made.

A 145kV insulation class cable has been chosen instead of 123kV insulation class cable since the 145kV cable has a smaller capacitance which reduces the amount of reactive power and current generated by the cable. Another benefits of the 145kV cable is the reduction of the electric stress on the cable compared to a 123 kV insulation class, this has a positive effect on the long term ageing of the cable.

### VII. POWER FROM SHORE PARTICULARITIES

Here under are given some design particularities and guidelines of the Martin Linge power from shore which needs to be noticed.

Any long AC transmission system equates to a combination of many RLC circuits (Fig. 15). For a long overhead line, the mains parameters are R (Resistance) and L (Inductance), and the C (Capacitance), on its side, is small. For a power from shore system, which uses a...
long subsea cable, the capacitance is not small and the cable transmission line exhibits resonances at lower frequencies compared to a long over head line.

For Martin Linge, these resonances can be excited by the use of Variable Speed Drive (VSD) and by the inrush current of the offshore transformers. For this latter, it can be noticed (Fig. 16) that the subsea cable system exhibits resonance frequency relatively close to 2nd order which match with the harmonic 2 of transformer inrush current, therefore it has been considered for Martin Linge to implement a single pole point of wave closing and pre-magnetisation system of platform transformers connected to 100 kV offshore GIS.

Regarding the resonances which can be excited by the use of export compressor VSD (8MW), an harmonic study shall be carried out in cooperation with VSD vendor in order to define the VSD rectifier configuration and in the worst case the possible implementation of an harmonic filter.

To keep under control the power from shore design and performances such as cable losses, resonance frequencies, voltage variation and reactive power generated by the cable, it is recommended to have from the cable manufacturer guaranteed value on the cable resistance, inductance and capacitance. Tolerances on these values shall be given to all the parties involved prior to the contract award. These values shall be verified during the factory cable tests.

The target for the cable capacitance is to have a tolerance better than the IEC 60840 (<8%), some manufacturers are able to guarantee less than 4%. In addition, the guaranteed capacitance may also be refined and targeted while manufacturing and testing the first cable length/batch by adjusting the insulation thickness of subsequent batches should the need be.

The cable resistance shall be given at minimum ambient seabed temperature and at maximum conductor core operating temperature in order to assess the resistance damping effect on electrical resonances at start up and during operation.

Since a long subsea cable is equivalent to a large capacitor, the discharge time of cable, when it is not connected to earth or to any load, shall be determined to assess the requirements of additional equipment for discharging cable to earth (e.g. through earth resistor or directly to earth).

Due to the impedance of the subsea cable, there is a low short circuit power available offshore on the Martin Linge platform, therefore it has been chosen to connect the export compressor VSD directly on the 100kV GIS where the short circuit power is the largest in order to minimize the disturbances of the current harmonics rejection on the offshore grid. This choice has the additional benefit of having a smaller 100kV/11kV transformer which doesn’t need to be sized to feed the 2x8MW export compressors.

Another particularity of the power from shore of Martin Linge is the protection scheme of the cable. Since the current distribution between both cable end varies with the power (Fig. 17), it is not possible to set-up a differential protection to protect the cable. A distance protection relay shall be then considered to protect the cable.

Since the offshore platform fully rely on the subsea cable which is not redundant, it is paramount to monitor the electrical and thermal conditions of the cable.

For the thermal monitoring it can be done by DTS (Distributed Temperature Sensor) based on the use of optic fibers embedded into the subsea cable. There is nevertheless a distance limitation to such thermal monitoring; for instance, using single mode fibre, the distributed thermal monitoring could reach up to approximately 50 km. In this case, it is recommended to monitor the cable at each end in order to monitor at least 100km of cable distance. This should be sufficient since the worst thermal conditions for the cable are at landfall and inside the J-Tree which are located at both ends of the cable; so covered by the DTS monitoring.

For the electrical conditions of the cable, this is more challenging since there are currently no tools available for such long distances and voltages level. Such monitoring tools shall be developed based on instance on Time Domain Reflection (TDR) or partial discharge measurement (if feasible).

Since normal operating voltage range for the Onshore GIS busbar will be between 90.5 to 106 kV while the system must be able to operate at 80 kV during energizing operations, the selectivity studies and protection settings shall take into account these different operating conditions.

From an operator point of view, it is recommended to get only one company responsible of the engineering, procurement, installation and commissioning of the power from shore, its scope of supply shall spread from the
onshore national grid connection to the offshore point of coupling. It means that the subsea cable design, manufacturing and installation is included in this battery limit. This approach optimizes also the project execution by minimizing the number of interface. The overall system electrical performances are in the case the responsibility of one company.

When assessing the overall cable length, the total length shall include a length allowance to compensate navigation accuracy in the laying length, normally a 0.5% of the total length is considered for such allowance.

The spare cable length used to repair the subsea cable (in case of possible failure) shall be stored under cover to protect the cable from rain and prevent water soaking. If the cable is water soaked it can freeze during winter and experience has shown that the inside coils can be frozen for a significant time due to the large thermal inertia of the cable.

VIII. CONCLUSIONS

The Oil&Gas industry faces more and more the challenge of reducing its environmental impact and CO2 emissions; the power from shore development of Martin Linge is in line with this objective to curb CO2 emissions.

From a technical standpoint, Martin Linge power from shore shows the feasibility of supplying on remote location an offshore Oil and Gas platform with an AC transmission.

The final design has been the result of many studies made during the basic engineering phase which have refined and optimized the initial design. These studies are paramount to secure and ensure the success of the detail design engineering phase where it is usually too late to make major technical changes.

Fig. 18 Full subsea to shore development

With discoveries of remote fields, in sensitive environmental locations such as Arctic, the offshore industry will require power from shore solution where AC transmission won’t be possible anymore and where DC transmission will be the only possibility. The next step to these developments will be then to have "subsea to shore" concept (Fig. 18) where the full field development will be made subsea with power from shore.

IX. ABBREVIATIONS

AC: Alternating Current
CAPEX: Capital Expenditure
DC: Direct Current
DTS: Distributed Temperature Sensor
GIS: Gas Insulated Switchgear
HVDC: High-Voltage Direct Current
OLTC: On Load Tap Changer
OPEX: Operating Expenditure
PF: Power Factor
PFs: Power From Shore
SVC: Static Var Compensator
VSD: Variable Speed Drive
WHRU: Waste Heat Recovery Units

X. REFERENCES


XI. VITA

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He graduated as an electrical engineer from the Ecole Supérieure d’Ingénieurs en Electronique et Electrotechnique (ESIEE). Before joining TOTAL in 2009, he worked eleven years for ABB Power Conversion and then Converteam. He held several positions as Variable Speed Drive Systems design and commissioning engineer in several major international projects both Onshore and Offshore in France, China, USA, Caribbean, Spain and Italy. He is now electrical specialist for various projects within TOTAL Exploration & Production.

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Selection of Power From Shore for an offshore Oil and Gas development

Edouard THIBAUT  TOTAL  Exploration & Production
Bruno LEFORAGEAIS  TOTAL  Exploration & Production
Summary

- Introduction to the project
- Selection of the all electrical scheme and power from shore
- AC and DC choice for Martin Linge
- Martin Linge electrical architecture
- Power from shore design
- Power from shore particularities
- Conclusion
Introduction

• Formerly named Hild
• Gas condensate and oil field
• Norwegian continental shelf
• Operated by Total Norge (49%)
• Partners Petoro (30%), Statoil (21%)
• Discovered 30 years ago
• Expected reserves 176 Mboe
• Pressure depletion
• Basic engineering started in 2012
• Field start-up end of 2016
Project description

- Platform, Jack-up rig and FSO
- AC Power from shore transmission
- 161 km subsea cable
- 55 MW max
- Landfall at Kollsnes (Norway)
- 300 kV national grid connection onshore
Selection of the all electrical scheme

Replacement of mechanical drivers by electrical motors

Conventional

All electrical concept
• Higher availability
• Higher efficiency
• Better environmental impact
Selection of the power from shore

End of Pre-project 2011

Decision to push a step further environmental impact reduction

No more Gas Turbine and Power from shore
AC or DC choice for Martin Linge?

1\textsuperscript{st} choice would be to consider a DC transmission

DC issues for the project
DC not feasible with existing layout \(\Rightarrow\) showstopper

AC issues for the project
High voltage variation, resonances, cable reactive power

161 km AC transmission feasible?
AC transmission validation

AC transmission studies conducted

-> Yes, we can!
Considerations:

- Availability
- Redundancy
- No offshore reactor
- Dynamic performances
Onshore Reactor

- Oil filled reactor for fixed reactive power compensation

Onshore SVC

- Dynamic reactive power compensation
- Grid power factor regulation
- Voltage control during transient

![Diagram of electrical architecture]
Power from shore design

Cable cross section and transmission voltage assessment
90kV, 100kV and 110 kV, iterative process through studies
• Load flow analysis
• Cable losses
• Voltage transient studies (harmonics, inrush, load impact and rejections...)
• Fault level studies
• Site conditions and installation

Cable choice: 145kV/ 300mm² operated at 100kV
Power from shore design

Steady state voltage criteria at 100kV
OTLC operation between 90% to 110%

Result

Steady state voltage variation: 90% to 106% Voltage
Power from shore design

Transient voltage criteria at 100kV

Voltage transient at +/- 20%

Result Ok, except for full load rejection with 22% of voltage rise
Power from shore design

Operating voltage choice

Voltage \rightarrow \text{Reactive Power} \rightarrow \text{Capacitive Current}

\[ Q = 2\pi f C U^2 \]

Where
- \( Q \): reactive power
- \( C \): capacitance
- \( f \): frequency
- \( U \): line to line voltage

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<td>455 A</td>
<td>487 A</td>
</tr>
<tr>
<td>400mm² cable</td>
<td>471 A</td>
<td>503 A</td>
<td>544 A</td>
</tr>
</tbody>
</table>

Cross section choice

Cross section \rightarrow \text{Capacitance} \rightarrow \text{Reactive Power} \rightarrow \text{Capacitive Current}

<table>
<thead>
<tr>
<th>Losses at full load 55MW, PF=0.9</th>
<th>90kV</th>
<th>100kV</th>
<th>110kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>300mm² cable</td>
<td>6.8MW</td>
<td>6.1MW</td>
<td>5.9MW</td>
</tr>
</tbody>
</table>

145kV / 300mm² cable operated at 100kV is a trade-off
Power from shore design

Cable energizing associated with a large inrush current and voltage transient

Cable $\approx 75$ MVAR capacitor

Mitigations:

- Energizing of the cable at 80% of rated voltage
- Single pole closing GIS feeder
Power from shore design

Small short circuit current fault level offshore due to subsea cable -> risks of:

- Large voltage drop
- Harmonics disturbances
- Selectivity of protections

Basic engineering studies made with Icc min

**Recommendations:**
Onshore system supplier is asked to size the onshore system to guarantee a minimum short circuit current level at the 100kV Offshore connection
Subsea cable design

Power From Shore system design and performances (e.g., voltage variation, losses, resonances, reactive power) depend on cable data.

Recommendations:

• Agreement on cable guaranteed value (R, L, C) prior to the contract award.

• Target for a capacitance tolerance better than IEC 60840 (<8%).

• Take advantage of the manufacturing of the first cable length/batch to adjust capacitance with cable insulation thickness.

• Guaranteed values shall be verified during the factory cable tests.
The system rely on a non redundant subsea cable

- **Paramount to monitor subsea cable condition**

  • Thermal condition monitoring (eg Distributed Temperature Sensor DTS)

  • Electrical monitoring tools to be developed for such large distance and voltage (eg Time Domain Reflection or partial discharge measurement if feasible)
Configuration for over voltage transient

To protect and design the system
-> Identify configurations with large over voltage

One configuration example which has lead to:
• Install surge arrestors at both cable end
• Intertripping regime between onshore and offshore circuit breaker

2.1 pu of offshore over voltage
Power from shore particularities

Cable discharge

Cable ≈ 75 MVAR capacitor

For quick restart and to not damage AC cable with DC voltage, need to know:

- Cable discharge time to assess requirements of additional equipment
  - earth resistor
  - directly to earth

- Maximum discharge current that the cable can handle

Diagram of electrical circuit with components labeled R, L, and C.
Conclusions

Martin Linge pushes a step further the limit of AC transmission on long distance

Martin Linge is in line with Total CO2 emissions reduction objective

Next step “subsea to shore” concept with power from shore or with local offshore power generation
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