SubOptic2019 TO THE BEACH AND BEYOND RETHINKING GLOBAL NETWORKS

GENERIC CROSSING DESIGN PROCESS BETWEEN POWER AND TELECOMMUNICATIONS CABLES IN SHALLOW WATER.

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Abstract: Large scale development of offshore wind farms to meet ambitious renewable energy targets in regions with restricted coast lines has led to constraints on seabed users. Intensive submarine power cable developments limit cable routing, cable spacing and lead to large numbers of cable crossings. In these circumstances, developers have been keen to adopt a generic approach to engineering of crossings. Analysis of generic crossing requirements and consideration of operation and maintenance of crossed telecoms cables led to reconsideration and proposed modification of custom and practice for cable crossings.
This paper considers the issues arising from power and telecoms cables crossings and is based on a study of the German sector of the North Sea.
This paper highlights the key issues and proposes a revised best practice.

1. BACKGROUND

The seas are not an open space; they are highly used areas with a constant increase of economic interests. The development of offshore wind energy is driven by political and public pressure to increase energy production from renewable sources. This pushes different seabed users to work together.

In the German North Sea, the offshore wind development goals are legally fixed for the years 2020 and 2030, by the year 2020 6.5GW offshore wind power have to be installed. This number will increase to 15GW by 2030. Intermediate development goals as listed below are optional scenarios, which leave room for even more ambitious goals or changes.

- 2020: 6.5GW
- 2025: 10.8GW
- 2030: 15GW
- 2035: 23.3GW

In order to realize these developments, numerous cables need to be installed to connect the wind turbines to each other and the wind farms substations to the grid connection point on land.

The chartlet at Figure 1 below shows the intensity and complexity of development plans in German waters.

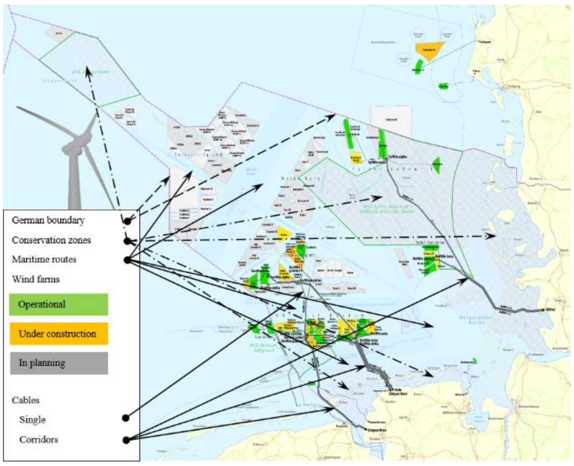


Figure 1: German waters seabed allocations. Courtesy: WikiMedia Commons

It can be seen that most areas not allocated to power generation are either marine navigation routes or environmental conservation areas.

Whilst not dealt with specifically in this paper, it is known that similar plans exist for other national waters around the Southern North Sea such as Holland and Belgium and are likely to apply to other centres around the world as the drive towards generation of renewable energy accelerates.

Rules of marine spatial planning require the minimisation of crossings when routing cables. Nevertheless, routing of cables is fixed by marine spatial planning, which enables an estimate of crossings to come. Cable routing corridors of the marine plan enable reaching the offshore development goal of 2030 and practically will mean more than 500 crossings between telecommunication, power cables, and pipelines to be installed.

This number of expected crossings trigger the need to review construction and maintenance of crossings. While a single crossing erected in the past has been considered negligible from an engineering perspective and cost wise, more than 500 will have a significant impact.

2. FOCUS ON CABLE CROSSINGS

More specific effects associated to these strategic plans for telecom cables within the zone which do not synchronise easily with the new scheme is being crossed by power cable corridors which can be seen to include up to 10 planned cables with standard separation distances of approximately 100m. The chartlet (Figure 2) shows an example of a telecom cable being crossed by 10 power cables, both planned and installed.

Figure 2: Telecom and power cable crossings. Courtesy: TenneT

It should be noted that export power cables to windfarm sites not currently under development are not yet defined hence the density of use of the cable corridors, particularly in areas closer to shore can be expected to increase. It is also probable that the number of interconnector power cables will also increase. These extra cables will need to be accommodated within the existing plan structure and will therefore put more pressure on the utilisation of existing allocated corridor width possibly leading to reductions in cable separation and hence proximity of cable crossing points.

The seabed use allocations within German waters makes no specific consideration for telecom cables and the projected concentration of use of defined power cable areas is high. On the assumption that laying and burial of any type of cable across windfarm zones is unlikely to be acceptable either to regulatory authorities or windfarm operators, telecom cable projects will face significantly increased difficulties defining efficient and well protected routes into Northern Europe. Given this situation, with the build of the substantial new offshore power infrastructure it is a good time for telecom cable developers to commence a new cooperative approach with the offshore power developers and authorities in order to improve relationships for the future which will ultimately be in the best interests of all parties. Short term expense and disruption to telecom cables can enable simpler, less expensive and more secure crossing designs bringing lower fault rates and less environmental disturbance, therefore avoiding unplanned outages and complex, expensive repairs in the longer term.

3. CURRENT CROSSING PRACTICE

The present default practice for a power cable to cross telecom cables is to leave the telecom cable in place and all engineering work be carried out by the new power cable project. Key requirements are:

- To provide a positive vertical separation of 0.3 m between cables.
- To provide a crossing angle as close to 90˚ as feasible.
- To lay the power cable over the crossing point at the seabed surface or above and then provide protection over that.

This requires little input from the telecom cable owners but does not necessarily give a safe and durable solution for either cable.

Physical protection

As both power cable and protection are likely to be raised above the seabed surface they will be subject to the effects of sea water currents, particularly surge currents caused by wave action in the predominant shallow water. If the protection layer is formed by a standard type of concrete mattress laid over the power cable, these have been found of recent times to be susceptible to significant movement in winter storm conditions in the North Sea potentially leaving the power cable unprotected. Similarly, high profile rock berms have suffered disruption and loss of protection. With protection removed the surface laid power cable is also likely to be subject to repetitive wave related movement causing fatigue damage to the cable structure and abrasion to the outer layers. Such disruptions to the crossing cables and the effects of associated scouring of the local seabed not only represents a risk to the power cable, but is also a risk to any cable shallow buried underneath it raising the possibility of requiring repair.

Electromagnetic interaction

Calculations show that in the event of fault conditions on a power cable substantial induction can occur to the cable in proximity to it e.g. at a crossing point. These interactions are not usually evaluated and hence the potential effects are often overlooked.

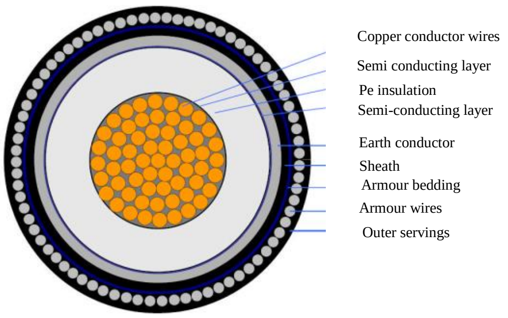
4. PROPOSED CROSSING DEVELOPMENTS

There are various aspects of cable crossing processes and design that could be addressed in order to facilitate and improve implementation.

Crossing Physical Issues

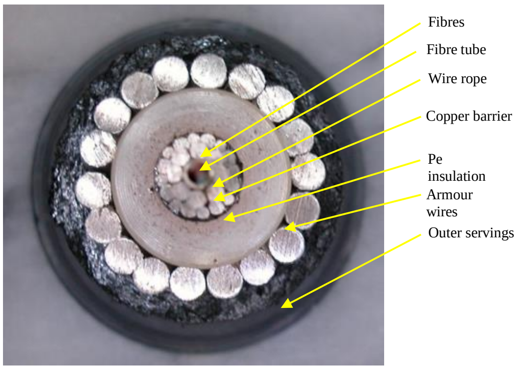
Power cables are generally large and heavy in relation to telecom types, typical examples are given below.

Power Cable



Overall diameter: 128 mm
Weight: 40.6 Kg/m
Minimum bending radius: 2.5 m

Telecom Cable



Overall diameter: 28 mm
Weight: 2 Kg/m
Minimum bending radius: 1.5 m

Figure 3: Telecom cable crossing power cables. Figure 3

Power cable protection is typically provided by burial to a depth of 1.5 m whereas existing telecom cable burial is commonly to a depth of 1m.

Considering the compatibility of the cable types at a crossing it can be seen that laying power cable over telecom cable can potentially create a number of issues:

- Burial depth of the power cable is greater than that of the telecom cable requiring the power cable to be raised to a height of 0.4 m above the seabed level if a mattress is to be used for separation from an undisturbed telecom cable.
- Hence from the dimensions above protection of the power cable will require a structure of at least 1 m above the surrounding seabed which would give only 0.6 m of protection to the power cable.
- In the event that the power cable comes into contact with the telecom cable the weight of the former can easily impress a non-conforming bend into the latter.

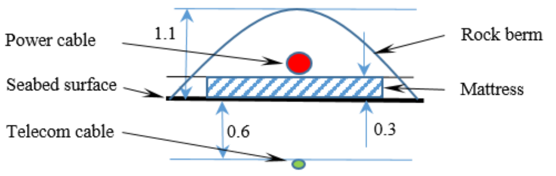
Should the crossing cables be made with existing telecom cables by reinstatement over the power cable the issues above become easier in that:

- The power cable will normally be buried to a greater depth than the telecom cable. If needed this burial depth may be able to be increased during power cable installation at the planned crossing point.
- Minimum cable separation can be provided by placement the required depth of suitable material into the open power cable trench.
- The telecom cable can be laid and jet buried over the crossing point potentially maintaining the original depth below the seabed surface.
- The telecom cable trench can then be backfilled to restore the original level of protection.
- Any future reconfiguration of the telecom cable due to close proximity new crossings or faults become far easier.

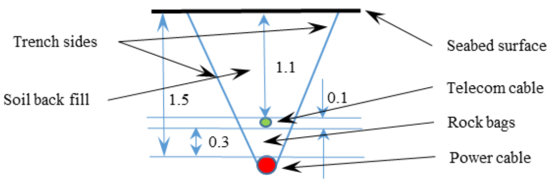
It should be noted that the telecom cable could be buried to a depth sufficient for the power cable to be installed above it. This option has some benefit in that the telecom cable would only require one interruption to service for such burial to be carried out however there are also a number of issues:

- Burial to a depth of 2m minimum will require a powerful burial machine and/or vessel, which may be problematic to obtain.
- The burial of the power cable may need to be reduced to accommodate the above issue.
- Such a solution would be difficult to carry out in 100m proximity to existing crossings.

Proposed crossing design



Typical current design



Proposed design

All dimensions in metres

Crossing cross sections Figure 4

In order to facilitate the telecom cable over the power cable, the telecom cable would need to be removed from the power cable route during power cable installation. This will require the telecom cable to be cut and recovered from the crossing zone, which will require service on the cable to be interrupted. In order to reduce the impact on the telecom service the cable should be cut and moved close in time to arrival of the power cable laying spread at the crossing and restored after the installation spread is clear of the area.

The telecom cable can be relayed with additional cable length as necessary clear of the power cable route to cross the laid power cable behind the installation spread and reconnected to the first cut end. Service can then be restored until a second operation is carried out after the power cable installation spread is clear of the designed crossing point. This operation to relay and protect the telecom cable along the final planned route is less time critical than the first operation. Thus, the crossing operation will keep the interruption to two separate short planned outages.

5. ELECTROMAGNETIC CHARACTERISTICS OF CABLE CROSSINGS

Concerns have been raised about the possibility of a fault on a power cable such as caused by anchor damage and the effect it would have on telecoms cables. The magnetic coupling between cables will cause a current to be induced into the telecom cable. Calculations were done to determine if the induced current could be significant, the key factors affecting the amplitude and examine possible mitigation methods.

Calculation

At first examination, the calculation of induced current appears to be textbook. However, a number of factors that add complexity. The sea has a conductivity of about 0.2Ω.m, which leads to the magnetic field pulse decaying more quickly than in free space. The seabed sediment contains varying amounts of water depending on its density. Older compacted sediments are drier allowing the magnetic pulse to propagate further. Initial calculations did not consider these factors leading to results with unrealistically high induced currents. This would have led to un-necessarily expensive solutions.

After investigation, the most important factors in determining the level of induced interference were found to be the angle of the cable crossing, the thickness and properties of the steel armouring of the telecoms cable. The coupling between the cables is proportional to the field strength, to the cosine of the crossing angle and inversely proportional to the permeability (μ_r) of the telecoms cable steel armour.

The magnetic field strength is dependent on the magnitude of the fault current in the power cable. Simulations using pSpice software suggest typical fault currents are about 12kA with most of the energy being between 10Hz and 70Hz. Each frequency component was examined separately as propagation is frequency dependent.

Cable crossings angles were simulated between 45˚ and 90˚. Ideally, if crossing could be exactly 90˚ there would be no induction. However, it is not practical to lay cables at exactly 90˚ and many cables are already laid at various crossing angles.

Cable manufactures do not currently publish the magnetic properties of the steel used to amour cables. Looking at old system archives it was common for steels with a permeability (μr) of about 100 to be used. The effect of permeabilities between 100 and 1000 were calculated.

The focus of the calculation was to make realistic predictions of the induced current and to model realistic solutions.

Results

The results are presented as graphs with axis of cable crossing angle against induced current. The error bars represent the possible range of the result between surfaced laid (lower limit) and dense old sediment (upper limit), the line represents the average value. The graph is coloured with a traffic light colours. Most repeaters will not be adversely affected by current dips of 100mA, this is coloured green. Between 100mA and 150mA repeaters will probably function but they are outside the typical operating envelope. With current dips below 150mA repeaters will typically have problems although different manufactures repeaters will have differing levels of resilience.

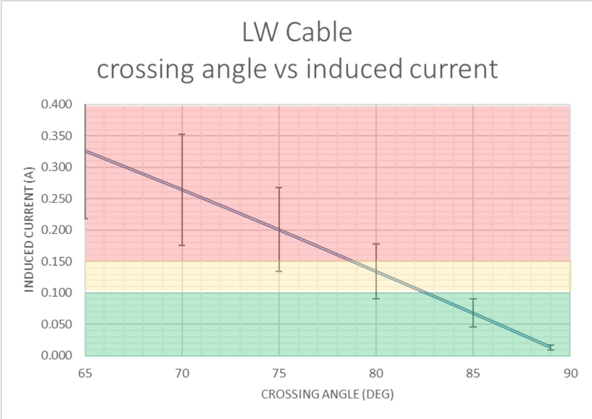


Figure 5: Light Weight cable crossing

Light Weight cable (LW) would not be used in shallow water where crossings are possible as it has no steel armour. It is a useful base line to compare other cables. The figure 5 shows that significant interference is possible at angles less than 83˚.

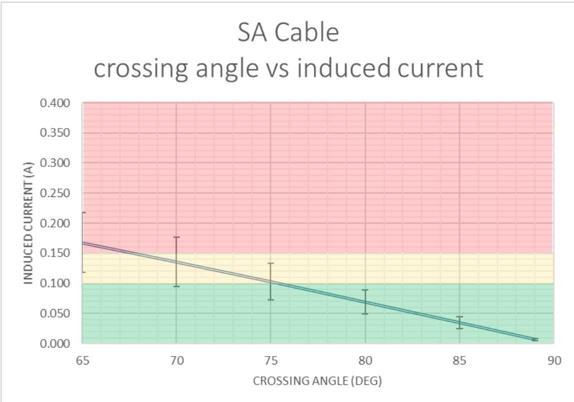


Figure 6: Single Armour cable

Single Armour cable is typically used in shallow water. It is more resilient due to the magnetic screening from the armour wires. Figure 6 shows interference could be significant with crossing angles less than 78˚.

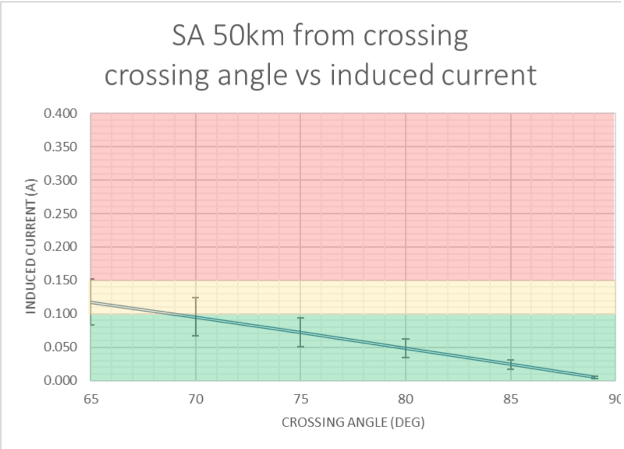


Figure 7 Repeater 50km from crossing with SA cable

The magnitude of the current pulse induced in the telecoms cable is attenuated over distance by the cable and this is frequency dependent. Figure 7 shows the effect of a repeater being 50km from the crossing. It shows that with SA cable, an acceptable level of interference can be achieved with crossings of 78˚ or greater, compared to 83˚ when a repeater is close to the crossing.

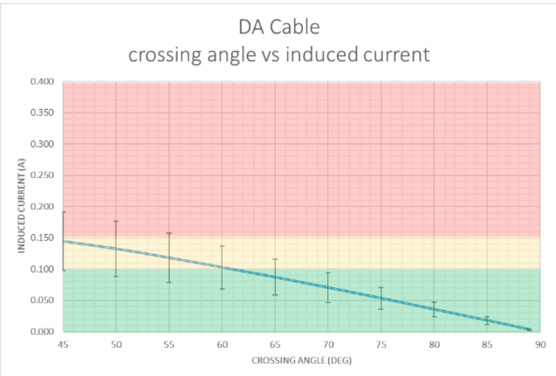


Figure 8 Double Armour cable

Double armour cable has two layers of steel armouring which gives a greater level of resilience allowing for a lower crossing angles. Figure 4 shows DA cable can have a crossing angle down to 68˚.

Further study

This study used manual calculations. This leads to compromises in particular with the interface between the sea and seabed. The seabed was considered to be homogenous and that the coupling between the crossing cables was predominately in the sea bed for buried cables. This simplification could be improved by using a Finite Elements Analysis.

The properties of the steel armour effect induced current. It is expected that there may be locations where it will not be possible to control crossing angles to within acceptable limits.

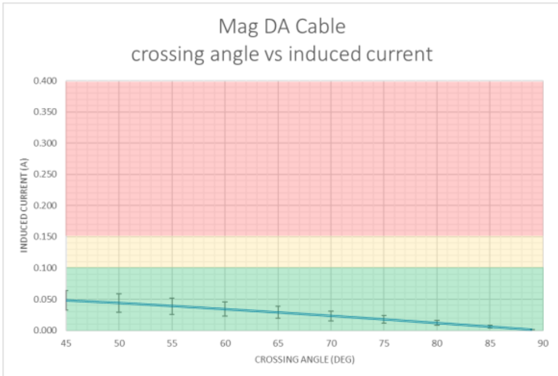


Figure 9 Mag DA cable

Cable manufacturers could consider changing the type of steel used for armouring to improve magnetic properties. If Double Armour cable were manufactured with one or both layers of steel replaced by a high μ_r steel the risk of interference would be removed for crossing angles down to 45º. Figure 9 shows the effect of replacing both layers of steel in a standard DA cable with steel with a μ_r of 400. Similar result could be obtained by replacing only the outer layer steel with one of a μ_r of 1000. These types of cable would allow greater flexibility of crossing angles.

6. CUT AND PEEL BACK PROS AND CONS

Advantages of the cut and peel back approach to a crossing operation are:

- Installation of the power cable is, at worst only minimally affected, possibly by application of increased burial depth at the crossing point.

- Security of both cables is maintained or improved at the crossing point by both cables being below seabed level minimising the risk of faults.
- Minimises effects from water current induced instability of cables or protection.
- Selection of appropriate trench backfill materials reduces environmental effects to a very low level.
- Absence of physical structures above the seabed level will avoid cumulative environmental effects of a large number of crossings on flora, fauna and current flow disruption. Reduction in water depths within navigation routes are also avoided.
- Maintenance access to the telecom cable remains simple after completion of the crossing.
- Facilitation of subsequent power cable crossings in close proximity to existing crossings within power cable corridors is straightforward even if the new crossing is between others.

Disadvantages of the cut and peel back approach to a crossing are:

- Interruption of service to the telecom cable during power cable installation.
- Requirement to coordinate telecom cable work with the power cable installation.

7. POTENTIAL WAY FORWARD

It is clear from the German economic zone chart shown at the beginning of this paper (Figure 1) that permitted allocation of routes and areas for offshore wind power and power interconnector cables is very extensive and far greater than any previous seabed development.

The initial phase of this potential far reaching change is that power cable and windfarm developers have to recognise the rights of existing permitted cables and therefore are compelled to seek agreement of crossing terms from their owners/operators. In general, telecom operators have taken minimal action to such crossings leaving their cable in place and requiring the power cable installation to provide minimum separation, facilitate crossing angles and specific protection required at the crossing point. This approach has worked but does leave the power cables vulnerable to damage from environmental conditions and third parties due to their elevated position. This is clearly not an ideal solution for the power cable operators as it has increased risk and implementation is expensive. The cut and peel back alternative for the telecom cable is both more secure and simpler overall but will cost the telecom operators more use of resources to manage the telecom element of the crossing operation and the reconfiguration of the network. There is also the possibility of loss of revenue if services cannot be re-routed. Telecom owners should seek to manage such costs in the crossing agreement.

Given the rate at which the power cable network and wind farm power generation is being built, specifically in this analysis in the German economic zone, the telecom industry is progressively going to become the second party to arrive at crossing points with existing power cables. The number of crossings required to achieve reasonable routes to German landings will be high. Such crossings may require many variations of engineering solutions to obtain crossing agreements. Since crossing structures will be the same for new telecom cables, extension of these standard recommendations for both crossing agreements and associated crossing engineering would expedite and simplify the achievement of new cable installations. Such industry standards when accepted by both the power and telecom sectors could then be taken to the relevant regulatory bodies for the national waters of countries affected to assist in the expedition of the various aspects of the acceptance process.

8. CONCLUSIONS

Adoption of the cut and peel back process in place of laying over the telecom cable at new power cable crossings has the benefit of reduced environmental impact, improved durability and simpler power cable installation.

A standard crossing design and procedure should be established for cable crossings by organisations such as ESCA and/or ICPC which can be called up by either or both crossing parties which will reduce the amount of bespoke design work and expedite the crossing implementation process.

Operation on telecom cables is best carried out by operators familiar with telecom equipment and handling methods, hence re-routing operations should be carried out by telecom cable ships and crews. Since timing is sensitive for such work a reliable source for such resources will need to be identified. The telecom industry has repair agreements for work of this type to repair faults on cables at short notice by vessels held on standby. However, such repair agreements do not necessarily allow systems to use the service for such crossing work. Hence, clarification would need to be sought that agreements can be adapted as necessary to provide support under the terms required. It is possible to use alternative resources if needed.

Careful consideration should be given to electromagnetic properties of the crossing, in particular the crossing angle and steel used for armouring. This will allow power and telecoms cables to continue using the limited seabed available.