The challenge of choosing the right method for surveying power cables

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Key words: cable tracking, depth of burial, HVAC/HVDC, survey power cables

SUMMARY

The rising number of wind parks, and thus the demand for new survey tasks, results in continuous development for companies working in the renewable energy sector. Building a wind park requires laying inter-array and export cables. Those cables are buried or covered to protect them, bringing environmental changes to a minimum. A common depth of burial ranges from 1.5m to 3m. The challenge of surveying those buried power cables is to choose the right method.
The method involves choosing between a broad field of sensors, techniques, vehicles and software. All claiming to fulfil the task but often lacking in details. The standard equipment used by the industry to survey alternating-, or direct current or out of service cables,
consists of magnetometers, gradiometers, active pulsing, passive detection and acoustic systems. Different systems are shown that are capable of detecting different types of cables. The challenging part of choosing the right method is discussed, presenting surveys conducted by Fugro OSAE GmbH demonstrating variable survey conditions on different cable systems and the impact on results. Asymmetric EM fields, radiated by a multi core cables system may need additional care during the processing and interpretation of data, as common survey systems assume a radial symmetric field as a signal source. The reasons and solutions will give the audience up to date information that comprehensive metadata information is needed beforehand to conduct and deliver reliable results. Furthermore, a new approach by determining the depth of burial is shown using seabed difference calculations that result in inverse depth of burial information. The new
inversed depth of burial approach is faster and can reduce costs if planned in advance.

1. Subsea Power cables

There are many offshore constructions that need power cables to either supply energy or, more common, deliver produced energy to the beach. The ever-growing renewables industry is building many wind farms. In the vicinity of windfarms many cables are laid. There are two kind of cables, inter-array and export cables. The inter-array cables connect the single windmills with the transformer station. The export cable transports the energy to shore.
Other field where subsea power cables are used are islands like Norderney or Helgoland that connect the islands to the mainland's power grid. Furthermore, countries are linked by power cables to level load and overproduction like Norway and Germany.

Subsea power cables can be anything from 70mm to, exceeding, 210mm in diameter and come in two flavours, High Voltage AC (Alternating Current) and High Voltage DC (Direct Current). The selection criteria for which type of cable to use is heavily dependent on the route length, voltage and transmission capacity. When offshore wind developers decide between HVAC and HVDC cabling, the overall system must be taken into consideration - including cables and transformers/converters. There is a break-even distance between HVAC and HVDC, generally considered between 40 and 80km where economic reasons outweigh to build a HVDC connection. AC cables are three phase cables, and are laid either as a bundle in a three core formation, or as three separate cables. The configuration of DC cables is dependent on the DC system. There are two main types: Mono-polar and Bi-polar. Generally speaking, they consist of two conductors, either laid separately, bundled together or in a co-axial arrangement.

In 1954 the world's first subsea HVDC Cable, Gotland 1, was installed. This was 98km long from Gotland Island to the Swedish Mainland and had a capacity of 20MW. This changed how the world thought about submarine electricity transmission as it was realized that it was now possible to connect to other countries overseas that were previously thought unreachable.
Currently the longest inter-connector is the NorNed cable between Norway and the Netherlands. At 580km, it is the longest subsea power cable in the world, with a capacity of 700MW. However, the very latest cable technology has the potential capability of reaching up to 1.500km.

2. Burial of cables

Subsea cable damage most often arises from two areas. First area are faults caused in the open sea by anchor strikes, dragging fishing nets and erosion. Second area is poor planning and building at the start of the project, coupled with inadequate risk identification, sub-standard design, and deficiencies in how procedures are applied. Around 70% of insurance pay-outs for wind farms relate to cable damage. Around 80% of these incidents occurred in shallow water depths of less than 50 meters. Internal faults are relatively rare, external damage is the key reason for repairs: 41 reported failures were the result of external impact by third parties namely anchor dragging and fishing nets. Shifting sediment or rock account for around 5% of all external cable faults.
As result the burial of cables decreases the risk of external damage and furthermore fixes the cable to its projected position. Additionally, the heating and electromagnetic field of cables are less effective to the environment.

3. Tracking systems

Submarine power cables need to be located and surveyed for several reasons. Cables need to be inspected after lay to ensure the laying (and burial) specification has been met. It may be necessary to routinely inspect the cable in order to certify its suitability for continued service. It will be necessary to positively locate existing cables prior to carrying out works such as installation of structures, dredging and similar projects before commencing work or to locate them for repairs.

There are several technologies which may be used for the task of surveying, all of which have advantages and disadvantages. The key task is to identify which system in which configuration is suitable to fulfil the task. The cable tracking systems can be categorized in either active or passive systems. Meant is the procedure, how the systems detect the cables.

3.1. Passive systems

Passive systems detect the location of the cable by tracking the cables own electrical frequency. It’s in the nature of AC cables that due to alternating current a sinusoidal oscillation takes place with a certain frequency. Most common is a frequency of 50Hz predominant in nearly all European cable grids. The other type of energy transmission namely direct current always flows in one direction and therefore does not emit a frequency. There are dominant harmonic frequencies called sidebands. In HVDC applications, the sideband frequency is typically around 1–2 kHz that are trackable. Another option to track DC passively is that they need to be taken out of service and an artificial frequency must be injected by a tone generator.

3.2. Active systems

Instead of tracking what is there by its own, active systems emit either electromagnetic or acoustic signals to locate cables. EM pulses are capable to induce a current flowing in the cable and emitting a magnetic field which can be measured again. By using multiple coils, a horizontal and vertical position of the target may be obtained. The system performance is dependent on the target material, the target diameter and the transmitted power. The diameter of the target is the main physical factor governing the maximum detection range. The two-way data path means high losses.
Acoustic systems work similar to sub bottom systems but visualize a 3D acoustic image of the sediment below seafloor.

System	Technology	HVAC in operation	HVAC out of service	HVDC in operation	HVDC out of service	widely tested	easy to operate
Teledyne TSS 350	tone detection **passive**	✓	✓	✗	✓	✓	✓
Optimal Ranging Field Sense	tone detection **passive**	✓	✓	✗	✓	✗	✓
Teledyne TSS 440	pulse Induction **active**	✗	✓	✗	✓	✓	✓
Innovatum Smartrak 9	gradiometer **passive**	✓	✓	✓	✓	✓	✓
Pangeo SBI	acoustic **active**	✓	✓	✓	✓	✓	✗

Figure X: System comparison matrix

4. Challenge of surveying

Passive systems use at least two or more sensors on a fixed baseline to calculate the frequencies origin by triangulation. All of these triangulated systems assume that a radial symmetric EM field is emitted.

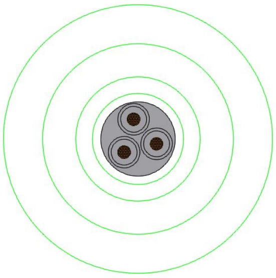

Figure X: Radial symmetric EM-field of HVAC power cable

The most common cable type of subsea 3-phase power transmission is the triaxial, or trefoil cable, where three conductors are laid up in the form of an equilateral triangle. The magnetic permeability of the seabed and seawater are approximately unity, as both are non-ferromagnetic, thus burial of the cable into the seabed will not change the magnetic field surrounding the cable. Whilst the sheaths of the cable provide good shielding to the electric field, they cannot shield the magnetic fields. As passive systems track electromagnetic fields the assumption of a radial symmetric field needs a closer look. The function of earth the sheath is to set the absolute electric potential of a conducting material to be zero – the same as the Earth. Earthing the sheath should reduce any leaked fields further down to zero (earth). Thus we should expect very little electric fields leaking to the outside of the cable. Apart from direct EM fields, one might wrongly conclude that if the cable is properly earthed, there would be no E field generated outside the cable. Dealing with an HVAC power system, Maxwell's equations for a time-harmonic case shows that the changing magnetic field B (against time) also generates an induced electric field. E and B fields exist around a typical wind power cable even when well shielded.

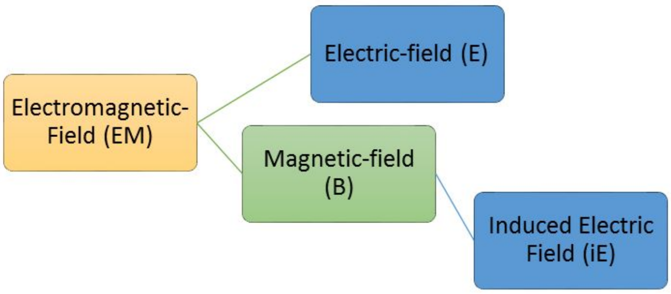

Figure X: EM fields for HVAC cables

If this magnetic field is induced in flowing seawater, then an electric field will be induced in the sea by magneto-hydrodynamic (MHD) generation.

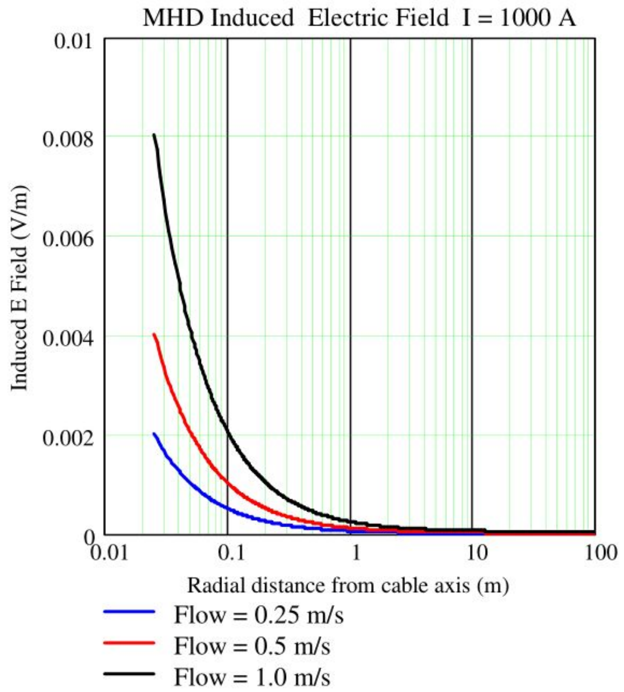

Figure X: Induced EM fields

Many researches in EM field propagation around submarine cables were conducted during the last years with a special focus on environmental or mammal effects. These studies give a good insight of EM field propagation for submarine cables. Results demonstrated that a variety of factors, such as topographic, bathymetric, and geologic conditions contribute to the natural generation and propagation of EM fields. Thus a radial symmetric field can be distorted and result in wrong depth calculations.

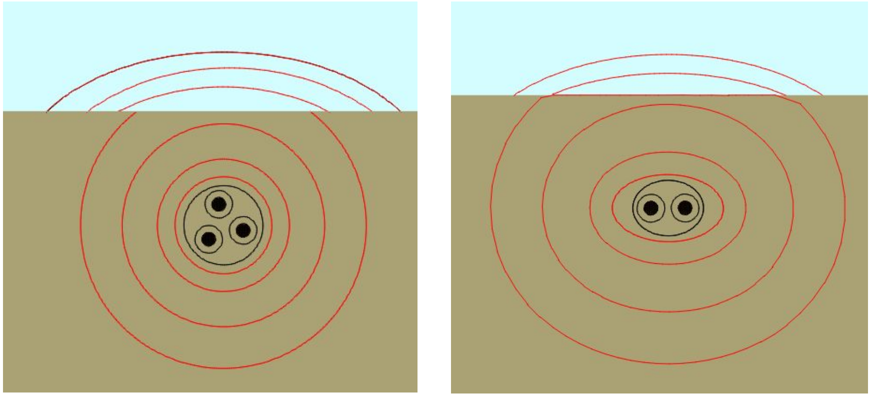

Figure X: Distorted radial symmetric EM-field trifoil and bipolar

In case of a bi-polar conductor the electromagnetic field is formed in an elliptical shape. If this is not corrected by post processing wrong depth calculations are the result.

5. Indirect Depth of burial survey by seabed difference

As-laid data gathered by the laying vessel is just valid for the epoch direct after cable lay. To ensure a constant monitoring, re-surveys are necessary at later epochs. The cable operator is interested in the change of the burial depth. Cable surveys with cable trackers require special equipment, are expensive and slow compared to multibeam measurements. Once the cable is in a stable condition (no hardening, no heating up phase) an indirect cable survey by multibeam sediment difference will give a quick and cheap depth of burial result. For a first initial primal measurement, the cable is located by one of the standard pipe and cable tracking systems. The results give a direct map of the absolute depth of the cable and its burial state. This data also contains absolute seabed height. At the stage of another survey epoch a multibeam survey provides absolute seabed heights as well. By comparing this two multibeam depth information and considering the cable as stable a change of the burial state can be derived. The aim is to provide quicker and cheaper information about the burial state of the cable. This combined cable tracking — multibeam seabed difference can be used to fulfil that aim.

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BIOGRAPHICAL NOTES

Oliver Anders started his career with an apprenticeship as qualified land surveyor. Studying at HafenCity University Hamburg a Bachelor of Science in Geomatics degree was obtained and followed by a Master of Science in Geomatics with specialization in Hydrography. Holding a CAT-A certification Oliver is now working as Hydrographic surveyor at Fugro OSAE GmbH, Germany.

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