Depth of Burial State Monitoring of a 500 kV HVDC Offshore Power Cable Interconnector using Distributed Fiber-Optic Temperature Sensing

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ABSTRACT

In this work, we present a fast and accurate approach to determine exposed submarine power cable locations based on the measured load and distributed temperature traces. This method, referred to as Depth-of-Burial-Status (DoBS), involves the calculation of the local load-temperature change correlation function. This concept is applied on the 500 kV Skagerrak4 interconnector to determine the exposure locations, and the results are validated by a Remotely Operated Vehicle survey. Based on the DoBS approach, we detected all fully exposed cable sections, in addition to locations with shallow exposures and ducted cable sections in a surveyed offshore length of 22 km.

KEYWORDS

Offshore Cable Monitoring, Exposed Power Cable, Cable Survey, Distributed Temperature Sensing, Depth of Burial Status.

INTRODUCTION

In the last decade, the demand for renewable energies has grown substantially owing to the global commitment to reduce the impact of carbon dioxide emissions from fossil fuels on the environment. Furthermore, the European energy strategy is currently accelerating the transition towards more sustainable energies such as solar and wind to achieve more energy autarky, driven by the actual political impacts. According to the European Commission, offshore renewable energy has the greatest potential to scale up. Based on an actual installed offshore wind capacity of 16 GW [1], the Commission estimates to achieve an installed capacity of at least 60 GW by 2030 with a view to reach 300 GW by 2050 [2]. The increased power capacity implies the installation of more wind farms and submarine power cables, which represent the backbone for offshore energy transmission. Indeed, these cables are commonly buried during the installation process. They may, however, suffer from exposure due to waves, seabed currents, and tidal activities, particularly in the inshore areas.

To reduce the risk of cable damage, and hence eventual long power outage, monitoring of the submarine cables becomes more and more important. In fact, Third-Party Intrusion (TPI) activities such as fishing, trawling, anchoring, or sabotage are known to be real threats, especially when the cables are exposed. According to [3], in the period between 2006 and 2015, 89% of submarine power cable faults with external cause were reported on unprotected cables, where most failures were mainly due to anchor damage. The average mean outage time of the reported submarine cable failures in [3] was estimated to 105 days.

Owing to the optical fibers which are integrated within most state-of-the-art submarine three-core power cables or delivered externally and bundled to single-core cables, continuous monitoring of these assets can be implemented conveniently using distributed sensing techniques, such as Distributed Temperature Sensing (DTS) and Distributed Acoustic Sensing (DAS). The capabilities of these fiber-optics-based systems include hotspots identification [4], TPI events detection [5], cable-fault localization [6], Real-Time Thermal Rating (RTTR) [7], Depth-of-Burial (DoB) calculation [8], among others.

Conventional DoB approaches are known to provide approximate burial depths of subsea power cables based on the thermal response of the cable to load variations by using DTS measurements, load data histories, and thermal models of the power cable and its surroundings [8], [9]. Thus, such techniques require the precise knowledge of the ambient conditions and thermal parameters of the seabed, depend on the absolute measured temperature, and have limitations on the detectable burial depth.

In practice, the most important feature is often not the burial depth itself, but the state of the cable and its change. By calculating the local load-temperature change correlation function, it is possible to determine the burial state of the cable accurately and fast. The main effect behind our new DoBS approach can be understood as follows: The closer the cable to the water, the faster the dissipated heat can be transported away, and hence the lower the temperature change measured by the fiber upon a load change. Such exposure features can be identified by analyzing solely the power cable load and the temperature traces collected by a DTS instrument. Hence, the DoBS method does not require any precise knowledge of the ambient conditions and thermal parameters of the seabed and does not depend on the absolute temperature values measured along the cable. This significantly reduces the commissioning effort, avoids any uncertainties caused by measurement deviations, and is especially applicable to retrofits, where soil sample data might be outdated or not available at all.

THEORY

Various approaches to calculate the burial depth from DTS temperatures exist in literature [8], [9], [10]. They all tackle the problem by solving the corresponding diffusion equation in the vicinity of the cable, with or without convective terms. However, there are several issues with this approach: the absolute temperature of the environment must be known (or has to be estimated from the measurements), ambient parameters (like the thermal resistivity of the sea ground) might not be known precisely, material and loss parameters of the cable itself might also be unknown or inaccurate. The calculation of the heat