Determination of the Depth of Burial of Submarine Power Cables from Temperature Measurements in Real-Time

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ABSTRACT

An appropriate depth of burial (DOB) along the entire route of submarine power cables is essential for safe cable operation. Yearly surveys using remotely operated vehicles are expensive and time-consuming. They even may be not sufficient to detect fast changes of DOB in time. We have presented a solution for permanent monitoring of DOB along the entire length of submarine cables in real-time using thermal simulations based on thermal models of the power cable installation as well as distributed temperature sensing (DTS) and load data histories [1]. The performance of this new solution is now proven by comparison with finite-element method (FEM) calculations as well as by analysing field data from a submarine power cable installation.

KEYWORDS

Depth of burial, Distributed temperature sensing, Thermal model, Thermal simulation, Submarine cable, Real-time monitoring.

INTRODUCTION

Power transmission via submarine cables becomes more and more important because distributed energy generation from renewable, but strongly fluctuating sources requires large smart or super grids with interconnection between multiple countries and through seas. Furthermore, offshore wind farms are a key component in the transition to renewable energies.

Wind turbines in windfarms are connected by interconnection cables, and the whole power produced by a windfarm is transmitted by one or more export cables. Especially in installations using a single export cable, cable failures are critical and lead to enormous losses in power production. Whenever possible, submarine cables are buried in the seafloor. This, on one hand mechanically protects the cable, and on the other hand minimizes its impact on the surrounding ecosystem. Mechanical threats for cable integrity during operation are of human (e.g. anchoring) or natural origin (e.g. scraping of cable free spans on the seafloor driven by waves or tidal currents).

The depth of burial may change dynamically during operation: Sand is moved by tidal currents or waves and even the cable may slightly move by repeated thermal changes of length. Therefore, a continuous or repeated analysis of the depth of burial is highly desired or even mandatory by legal requirements. A minimum depth of burial of in general 1.5 m or 3 m inside the traffic separation scheme is required in the German exclusive economic zone (EEZ) [5]. In the North Sea, the depth of burial must be verified by operational monitoring measures after the installation of new cables and at least annually during the first five years after installation [5]. An additional requirement of German legislation (2K-criterion) ensures that the thermal impact on natural flora and fauna does not change the ecosystem. It says that the temperature rise caused by the heat dissipation of the power cable must not exceed 2 Kelvin in a depth of 30 cm below the seafloor (20 cm in the tidal flats) [6]. A proper depth of burial is a major parameter in ensuring compliance to this requirement.

DTS is meanwhile widely used for monitoring the temperature of power cables by analysing light scattering in optical fibres. Such fibres are nowadays integrated within most new power cables. Real-time thermal rating (RTTR) software packages are used to calculate the conductor temperature, and to plan future load scenarios. Ambient parameters such as the temperature and the thermal resistivity are required for proper cable rating, but they are mostly unknown or change dynamically with the seasons. We have developed an efficient software package that has the capability to calculate in real-time the full conductor temperature profile and the local ambient parameters along the entire length of a power cable route [1].

At a certain load of a submarine power cable, the difference between the measured DTS temperature and the seafloor temperature decreases with lowering the DOB. However, static DTS temperature profiles are not sufficient to unambiguously deduct the DOB since DTS temperature also depends on ambient temperature. Ambient temperatures are not necessarily constant along a cable route and may considerably vary because of local currents or variations of water depth.

DOB calculations along the entire length of a submarine power cable take longer than typical RTTR calculations. However, they can be finished within hours or days depending on the number of locations and the performance of the computing system. Such a period fully meets the requirements given by expected timescales of transient changes in the DOB and the seafloor temperature.

In the present paper, we first shortly describe the thermal modelling for calculating DOB in real-time. We also evaluate the performance of our method by comparisons with results of FEM simulations and with field data from an export cable of a windfarm in the North Sea.

THERMAL MODEL

Convective heat transfer from the seafloor to water has a strong thermal effect on buried submarine cables that clearly depends on DOB. The permanent flow and huge heat capacity of the seawater leads to practically identical temperatures of seafloor surface and water. We presented hydrodynamic calculations showing the effect of DOB on the temperature distribution around the conductor in a previous paper [1]. There, we have defined an effective thermal resistivity, which covers effects of the convection in the low frequency limit, i.e. for a slowly varying current profile. From the effective thermal resistivity, it is possible to calculate the DOB, if the initial depth of burial and the thermal resistivity of seafloor soil are known. Typical values