SUBMARINE CABLES ROUTE SURVEY FREQUENCY OPTIMIZATION – A PROBABILISTIC APPROACH

Abbas **LOTFI;** Nexans Norway AS, (Norway), abbas.lotfi@nexans.com

ABSTRACT

This paper presents a probabilistic approach based on Markov process for optimization of submarine power cables route survey frequency. To this purpose, first, a detailed Markov model is introduced including various operational states such as the impact of adverse weather conditions. Second, a cost model is introduced to formulate an objective function consisting of three terms; route survey costs, maintenance costs and repair costs. As shown in the paper, the objective function may have a global minimum point corresponding to a specific route survey interval, which can be considered as an optimum frequency of the route survey.

KEYWORDS

Submarine cables, optimization, probabilistic approach, Markov process, cable route survey.

INTRODUCTION

Offshore windfarms and submarine interconnections are becoming key solutions for the European power system security in the wake of the energy transition [1] [2] and the objectives of the EU Green Deal; integration of 300 GW offshore wind generation capacity by 2050. Hence, failures of submarine power cables would have a large impact on system reliability mainly due to a complex, costly and time-consuming repair process affected by many different factors including logistics and preparations, availability of proper vessels, weather conditions, etc. Submarine power cables are vulnerable to various external threats that can be prevented by proper protection [3]. One of the most practiced and efficient protection methods is to bury the cables in the seabed with sufficient depth. However, cable exposure (fully or partially) occurs for different reasons (sea bottom instability, sand waves, etc) exposing the cables to a number of failure modes such as abrasion, corrosion, accelerated fatigue as a result of free spans as well as damage by falling objects, anchors and trawls [4] [5]. To maintain the design burial depth, cable route survey/burial inspection is normally performed on a time basis relying on prior knowledge of the seabed conditions [6]. Once an exposed area is identified, an appropriate remedial action (re-burial, rock dumping) is planned at a suitable time considering the overall threats of exposure, the power system operational conditions and the energy market status.

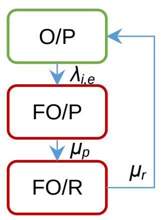
As the cable route survey is an expensive offshore operation, optimization of its frequency is of high importance, which depends on many factors such as cable system reliability and the costs related to the survey, maintenance and repair operations.

The main contribution of this paper is to present a probabilistic approach for optimizing the cable route survey frequency using a reliability model based on the continuous Markov process. In the following sections, first the reliability model is detailed, and then, an objective cost function is formulated that is minimized to obtain the optimum survey intervals. Finally, model performance is evaluated by an example considered as a base case study, which further investigates the sensitivity analysis on different influencing factors such as weather conditions, failure rate of exposed cables, and the impact of online burial depth monitoring.

MODEL DESCRIPTION

Markov process

To calculate the probability of different operational states of submarine cables, a continuous Markov process is employed to model the system state transitions [7] [8]. The basic model, as shown in Fig. 1, consists of two main modes of operations: cables are operating and the burial condition is as expected Operation/Protected (O/P), a failure occurs Forced Outage (FO). The latter is divided into two sub-modes to distinguish preparation (FO/P) and actual repair (FO/R) activities.



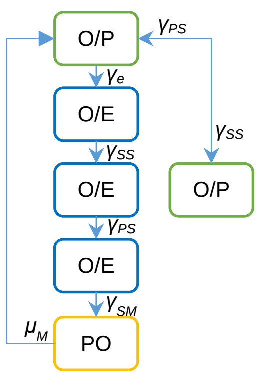
$\lambda_{i,e}$ is cable failure rate (internal and external)

μ_p is preparation rate for a repair

μ_r is actual repair rate

Fig. 1: Basic Markov model

When cables exposure occurs, a new state as Operation/Exposed (O/E) is created. Offshore survey is the only way to verify the exposure. Since the route survey is a time-based operation, it is probable that the cables are found not exposed when the survey is performed. Once the exposure is discovered, planning to perform a route maintenance commences and time-to-start the maintenance is determined. While the cables are de-energized for the route maintenance, another state as Planned Outage (PO) is created and added to the model. Fig. 2 shows how the two new states are incorporated in the existing Markov process.



γ_e is the exposure rate

γ_{SS} is survey-to-start rate (survey frequency)

γ_{PS} is the survey-to-perfom rate

γ_{SM} is the mainetenance-to-start rate

μ_M is the maintenance-to-perform rate

Fig. 2 Incorporating exposure, survey and maintenance in the Markov model