Assessment of financial benefits in overplanted windfarm export cable

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ABSTRACT

A methodology was developed for the forward thermal risk estimation (TRE) applied to offshore cables based on Markov Chain (MC) transition probability matrices (TPM). The MC model analyses historical load current data and extracts probabilistic patterns of load state changes on a seasonal basis. In the present study scenarios of wind farm overplanting (for economic purposes) are induced and a 20 years online testing of the methodology is simulated considering an autonomous power curtailment when thermal risk is estimated 6h ahead.

KEYWORDS

Submarine cable; probabilistic estimation; thermal risk; overplanting; cable optimization; economic benefits.

INTRODUCTION

Offshore cables are often rated using traditional static calculations based on IEC60287 [1] standard calculations which estimate a maximum ampacity given fixed worst-case environmental parameters in order to avoid reaching the cable temperature limit. In practice, wind farm (WF) export cables face intermittent loading and have relatively long thermal time constants, which produce lower cable temperatures and cable under-utilisation.

A common practice to optimize transmission capabilities is the use of wind farm overplanting (WFO) which increase generation capacity over the static rating limits [2], [3] capturing more energy at low wind speeds while curtailment is applied when full load extends over long duration periods. In order to avoid unnecessary power curtailment, it is necessary to have knowledge of the actual and likely future temperatures that the cable could attain.

The use of real-time thermal rating (RTTR) methodologies is seen in the literature as an alternative to the static rating calculations for conventional installation on land [4]–[6]. A common approach is the use of distributed temperature sensors (DTS) for the monitoring of thermal parameters in the cable and surrounding environment in order to estimate the maximum ampacity that the cable can support in the following hours based on its actual temperature [7]–[9].

In the offshore wind farm scenario, cables face highly variable load currents due to wind speed variations, thus the knowledge of RTTR is not enough to take curtailment decisions as knowledge of the future loads in the cable and its thermal state is needed in advance in order to avoid unnecessary curtailment.

Methodologies for the estimation and forecasting of wind speed and power generation are seen in the literature based on the use of weather models and meteorological data [10] or the statistical analysis and modelling of historical data from the offshore site. Common statistical methodologies include moving average (MA), autoregressive moving average (ARMA), autoregressive integrating moving average (ARIMA) and Markov chain (MC) theory [11], [12]. The principal source of errors when forecasting load is the cubic relationship between wind and power generation. Additionally, these methodologies do not study how the thermal response of the cable is affected due to variable loads.

The development and study of cyclic rating methods for wind farm cable sizing are seen in [13] and [14]. These studies developed techniques for the capacity optimization of export cables and the results demonstrate that it is possible to optimize power transmission in systems operated under highly variable loads. Although increasing cable rating over the traditional static limits may induce the possibility of cable overheating, for projects where there is a need to reduce costs a balance between cable utilization and system margins can be achieved by the use of this techniques. An example of industrial application of alternative cable sizing techniques is seen in [15].

A methodology based on the statistical analysis of historical data was developed to estimate forward thermal risk in offshore cables [16]. The method is based on the use of Markov Chain (MC) theory which has been applied in the literature for the creation of synthetic wind speed and wind power time series [12], [17].

The work in this paper presents a financial benefits assessment for the selected cable under overplanting conditions. The results are obtained from the application of the methodology in [16] for a period of 20 years where a 6h ahead thermal risk estimation is undertaken at every time step. An automatic preventative curtailment is applied if any risk is estimated and the amount of power delivered considering the overplanting factor and curtailment action is calculated for the 20 years of simulation. An assessment of the accuracy of the thermal risk mitigation, additional energy delivery, and potential financial benefits for the reduction of the levelized cost of energy (LCoE) are calculated and compared to the traditionally conservative static ratings.

THERMAL RISK ESTIMATION METHOD

The developed technique performs a pure statistical analysis of historical data to build transition probability matrices (TPM) on a seasonal basis. The TPM's are used to estimate the most probable load current state of the system 6h ahead while a Monte Carlo Sampling (MCS) generates load current time series scenarios.

The sampled likely load scenarios are then evaluated by a dynamic rating algorithm based on a finite difference model (FDM) considering actual cable temperatures. This procedure is repeated at every time step and the obtained probability distribution functions (PDF) of cable temperatures are evaluated to derive a 6h ahead estimation of thermal risk.

Markov Chain theory (MC)

MC theory is used to model stochastic processes because