Optimizing the Power Rating of Substation Transformers for an Offshore Wind Farm

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ABSTRACT

One of the main challenges of the offshore wind energy industry is to reduce the cost of electricity. Among the crucial components of a wind farm are the substation transformers because of their high cost, size and vital role in the power transmission chain. Therefore the objective of this master project is to create a procedure and software tool to select and optimize the offshore and onshore substation transformers' power rating for a given offshore wind farm. The scope of this work will be the UK market since it is leading the offshore wind policies and practices nowadays.

The objective function of the optimization is the cost of capital investment (CAPEX) of the transformers and substation plus the power losses of the wind farm due to planned and unplanned unavailability of the system, electrical losses and power self-consumption. The CAPEX depends on the power rating of the transformer and on the required size of the substation to house the transformers. On the other hand, the power losses are highly dependent on stochastic variables such as wind speed, equipment reliability and maintenance accessibility due to weather conditions. In order to tackle the high complexity and variability of the system, Discrete Event Simulation (DES) is used. This will give the required flexibility to test different combinations of unknown parameters in order to perform a sensitivity analysis for a more informed selection of transformer rating.

Using DES allows simulating the output of the system during events that change its operation. For example, random failures or scheduled outages can be assigned to the equipment over the life time of the project. This, along with the variation of the wind speed, gives different power outputs. By performing several iterations it is possible to narrow down the average cost of losses for a specific transformer rating configuration, but also to attain a probability distribution to derive confidence intervals. There are different software options for DES; in this project it was decided to use Matlab/Simulink because of its vast functionality, availability and the flexibility of programing blocks.

The result of the project is a robust, generic and flexible methodology that allows the user to evaluate the optimum rating size of substation transformers for an offshore wind farm. The input of the model is a wind speed time series, reliability parameters of the equipment and wind farm equipment parameters and layout. The output is the difference between the increment on substations CAPEX and the variation of power losses costs. The results of the multiple lifetime iterations are summarized with the mean value, the 90%, 95% and 99% percentile and the probability of losses equal to investment. Having confidence intervals based on the distribution function of the costs provides better information for design decision making and the possibility to reduce the lifetime costs of future offshore wind farm developments.