Baltic
InteGrid

Integrated Baltic Offshore
Wind Electricity Grid Development

Baltic InteGrid

Offshore Wind Farm Electrical Design Optimization Tool

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Outputs of the Thematic Working Group on Technology and Grid Design

In the Baltic InteGrid project, the Thematic Working Group on Technology and Grid Design has produced several outputs.

Offshore Wind Power Plant Technology Catalogue

The Offshore Wind Power Plant Technology Catalogue, aims to cover most of the technical components for the offshore network, starting from wind turbines up to the onshore connecting substation. It contains brief descriptions of each of the components followed by stages of development, cost and lifetime. Building an offshore grid is a technically complex endeavour implying a significant number of components. While for AC connections the technology is mature and well known, in power electronics and HVDC technology the component development is in more incipient phases. This has prompted for the creation of a technology catalogue covering all main components needed when developing offshore wind power and grids projects. The main purpose of this publication was to serve as a common source for the techno-economic assessments done in this project and beyond.

Offshore Wind Farm Electrical Design Optimization Tool

An Offshore Wind Farm Electrical Design Optimization Tool is developed to reduce the electrical infrastructure cost of offshore wind farm. The algorithms applied in the tool cover these two areas:

- **Optimization algorithm for Export Infrastructures for Offshore Wind Farms**:

The export system optimization adds a new approach to how the export cable sizing is calculated for offshore wind farms. Currently, the sizing of the offshore export cables is done according to the CIGRE and IEC standards. However, such standards consider steady state conditions under rated operation. The limitation of the conductor temperature at this value is due to the close contact with the insulation material, which represents the most critical element in a cable. These standards' criterion may be intuitively too conservative considering that OWFs present a typical capacity factor of around 0.4-0.5. To cope with this issue, different concepts need to be combined in order to develop a methodology capable of estimating the lifetime of cables operating under real conditions, such as: time-varying cyclic power generation, thermal and electrical stress, thermal transients, capacity currents and failure probability.

The scheme of the general proposed methodology can be summarized as follows. First, input data of the site under analysis is required (time series of power produced, and seabed temperature are fundamental), then a pre-processing stage selects sequentially the cycles to run the simulations, followed by a thermal analysis done by a Thermo-Electrical Equivalent Model (TEE). Afterwards, a lifetime probabilistic estimation model known as Arrhenius-IPM model is applied, which along with the Miner's law, are worth it to estimate the lifetime of the cable for the hot-spot point under realistic time-varying conditions. Finally, a holistic performance evaluation approach is proposed as well, in order to calculate more accurately the cable's total power losses. The method can be seen in detail in [1], [2], [3].

- **Optimization algorithms for offshore wind farm collection system design**:

The collection system optimization tool finds an inter-array cable configuration between all relevant elements of a given offshore wind farm layout. The solution covers the routing sequence and the sizing of the collection system cables. The user can run several optimization methods and modify some of the inputs to obtain different solutions to the problem. The optimization methods available are the following:

- Heuristics: These provide fast and deterministic solutions but in certain situations can struggle to find feasible solutions. Methods available: Prim, Kruskal, Esau-Williams and VAM. For a detailed explanation of the method see [4].

- Meta-heuristics: It provides a higher quality solution and higher chance of finding a feasible solution compared to heuristics. The main trade off is the computational time required and that is non-deterministic. Method available: Genetic algorithm. For a detailed explanation of the method see [5].

These algorithms are used in the Baltic InteGrid project for simulating collection system design for proposed wind farms in Baltic Sea.

The results from the tool suggests possibility of substantial improvement on reduction of electrical infrastructure cost and can be used for research on future design of offshore wind farms.

[1] J.-A. Perez-Rua, K. Das, and N. A. Cutululis, “Lifetime estimation and performance evaluation for offshore wind farms transmission cables,” IET ACDC, Coventry, UK, 2019.

[2] J.-A. Perez-Rua, K. Das, and N. A. Cutululis, “Improved method for calculating power-transfer capability curves of offshore wind farms cables,” Proceedings of the CIGRE International Symposium, Aalborg, Denmark 2019.

[3] J.-A. Perez-Rua, K. Das, and N. A. Cutululis, “Optimum sizing of offshore wind farms export cables,” International Journal of Electrical Power Energy Systems, accepted for publication.

[4] J.-A. Perez-Rua, D. Hermosilla-Minguijon, K. Das, and N. A. Cutululis, “Heuristics-based design and optimization of offshore wind farms collection systems,” EERA DeepWind, Trondheim, Norway, 2019.

[5] D. Hermosilla-Minguijon, J.-A. Perez-Rua, K. Das, and N. A. Cutululis, “Metaheuristic-based design and optimization of offshore wind farms collection systems,” IEEE PowerTech, Milan, Italy, 2019.

The software is available for non-commercial purposes. To get access to it, please contact the colleagues of the Department of Wind Energy, Technical University of Denmark (DTU):

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