DEPARTMENT OF ENERGY TECHNOLOGY
AALBORG UNIVERSITY

PhD Public Defence

Title: Optimization of Large-Scale Offshore Wind Farm

Location: Pontoppidanstræde 111, room 1.177

Time: Friday 5 May 2017 at 13.00

PhD defendant: Peng Hou

Supervisor: Professor Zhe Chen

Moderator: Associate Professor Xiongfei Wang

Opponents: Associate Professor Jayakrishnan R. Pillai, Dept. of Energy Technology, Aalborg University (Chairman)
Professor Constantine (Costas) D. Vournas, National Technical University of Athens, Greece
Professor Surya Santoso, Electrical and Computer Engineering, The University of Texas at Austin, USA

All are welcome. The defence will be in English.

After the defence there will be an informal reception in Pontoppidanstræde 111 (coffee room).

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Abstract:

As one of the renewable resources, wind energy has drawn more and more attention worldwide. Compared with onshore case, there is always more wind with less turbulence exists offshore which promote the development of offshore wind farm. Presently, the capacity of offshore wind farm has been over 1 GW. In such a large scale wind farm, hundreds of wind turbines (WT) and plenty of equipment are required to be installed which highlights the significance of optimization for offshore wind farm.

The wake loss is one of the dominant factors that influence the power reached at the onshore substation. It can be described as the impacts of the upstream WTs to the downstream ones which reduce the total energy yield of the wind farm due to the wind speed drop downstream. If larger space is arranged between each pair of WTs then the wake losses can be reduced. However, this could result in a bad investment due to the increase on the cost of connection. In addition, the design of the electrical system as the selection of electrical equipment, substation design regarding location and quantity, cable connection topology design significantly contributes to the overall performance of the wind farm. Hence, it is necessary to develop a method and procedure to optimize wind farm layout as well as the system topologies to make a cost-effective wind farm.

This dissertation studies the optimization of offshore wind farm with the objective of minimizing the Levelized Production Cost (LPC) which cares three aspects: the energy yields considering the wake losses, power losses within the electrical system as well as the investment. Many works has been done on optimizing the WT positions to increase the energy production, however, the restriction zone offshore which was formulated due to existing gas pipe or oil well was not taken into consideration. In addition, the electrical system layout which is correlated to wind farm layout has not yet accounted in the WT locating work. On the other hand, the electrical system (the cost of which could take up to 30% of capital investment) optimization including voltage selection, cable connection scheme determination and offshore substation design was done in some previous work. However, no the existing works took uncrossed cable connection layout as one constraint and the proposed algorithms were applied in a simplified searching domain some potential solutions are neglected due to computational cost. A new algorithm should be proposed to find a better layout to benefit the wind farm owner. The above problems were analyzed and solved in this thesis work step by step as follows: a. Optimization of offshore wind farm layout was done either for a regular distribution strategy or irregular one to minimize the wake losses. b. The electrical system design was improved for offshore wind farm to realize the reduced cost of energy by minimizing system cost and loss, improving energy production, while meet the operational requirements of power systems. c. The optimized control strategy was investigated to further benefit the offshore wind farm owner. d. The overall optimization work which takes a and b or a and c into account so that a co-design work can be done.

This research work gives an overall optimization of offshore wind farm. It firstly proposed two methods of wake losses estimation corresponding to offshore wind farm with homogeneous and mixed types of WTs respectively. Then the wind farm layout was optimized to minimize the wake losses based on the proposed method. Afterwards, this dissertation comes up with the novel way of electrical system design which concerns the voltage selection, offshore substation locating and quantity determination as well as the cable connection layout design. At last the thesis concludes the whole research work and outlook the future development trends.

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