Robust optimization study of wind farm layout by Monte Carlo simulation method

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Abstract

In the Chinese 13th Five Year Plan in respect of the energy development, the Chinese Government has set the goal of installed wind power capacity above 210 million kilowatts, with the cost of wind energy to be comparable to the electrical power produced by coals in 2020. To achieve this objective, it is imperative to improve the wind power exploitation efficiency and its market competitiveness by reducing the wake power losses. Among all approaches, the optimization of wind farm layout is one of the most effective tools to reduce the wake effect and hence increase the performance of wind power generation. However, due to the existence of uncertain factors for the wind farm design (e.g., the unpredictability and randomness of wind conditions), the optimized wind farm layouts obtained under the fixed condition are likely to result in an intensive wake interaction because of a lack of the robustness of optimization results, which consequently leads to the failure of wind farm design. Therefore, in this work we aim to study the robust wind farm layout optimization by incorporating the Monte Carlo simulation for the wind condition of Weibull distribution. A real onshore wind farm, namely the Grasmere and Albany wind farm located near to the coast line of Southern Australia, is targeted for the robust optimization study. Due to the irregular boundary of this wind farm, the ray intersection method is employed while locating wind turbines to judge whether they are inside or outside the wind farm boundary. Instead of the traditionally most commonly-used penalty method which penalize the infeasible solutions during the optimization process, a repairing infeasible solution method is employed in this work which transforms the infeasible to feasible and has the pros of higher optimizing efficiency. The objective functions are the cost of energy production (calculated as the wind farm cost over total wind farm power production considering wake losses), and the variance of power production. In order to calculate the variance, the continuous Weibull distribution is approximated by conducting the Monte Carlo simulation to obtain the discrete data of various wind speeds and wind directions. Different sample sizes ranging from 1000 to 100000 are tested for the optimization study to obtain the best selection with a balance of computational cost and accuracy. A standard Single Objective Genetic Algorithm (SOGA) is applied as the optimization algorithm to optimize the wind turbine positions wisely. The above two functions (cost of energy and variance of power production) are combined into one objective function for optimization, by introducing the arbitrarily chosen weight factors which are used to alter the importance of the two functions by changing the values. The results show that the deviation between the direct calculation of Weibull distribution by discretization, and the Monte Carlo simulation is quite small (less than 1%). For the Monte Carlo simulation, 10000 sample size is fairly sufficient to obtain a satisfactory optimization result with an acceptable computational time (5 hours for 100000 evolved generations using Intel compiler). Compared with the fixed-condition layout optimization (in which, cost of energy production is the objective function), the robust optimization, which incorporates the variance of power production into the objective function, leads to a way different optimal wind farm layout which signifies the importance of considering the robustness of wind farm design results for layout optimization.

Keywords: Robust optimization; Wind farm layout; Weibull distribution; Monte Carlo simulation; Power production variance