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MULTIOBJECTIVE WIND FARM DESIGN: EXPLORING TRADE-OFFS BETWEEN ENGINEERING, ECONOMIC, AND ENVIRONMENTAL OBJECTIVES

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Abstract

The performance of a wind farm (or the quality of a wind energy project) is given by three important criteria: (i) capacity of energy production, (ii) lifetime costs, and (iii) net impact on surroundings. The factors affecting the performance of a wind farm can be classified into two categories: the natural factors and the design factors. A majority of these factors influence all three performance criteria. Hence, the planning of a wind farm requires a clear quantitative understanding of the ***balance*** between the socio-economic, engineering, and environmental objectives – this understanding is lacking in the current state of the art in wind farm design. This paper proposes a new multi-objective optimization framework to plan effective wind energy projects. Three important performance objectives are considered in this case, which are: (i) wind farm energy production, (ii) wind farm cost, and (iii) noise impact on nearby residents. Turbine locations, turbine types, land area, land aspect ratio, and nameplate capacity are treated as design variables. The consideration of such a comprehensive set of design parameters is also unique in the wind energy literature.

The wind farm energy production is computed using the model from the *Unrestricted Wind Farm Layout Optimization* (UWFLO) framework (Chowdhury et al. 2012). The use of different wake models within the UWFLO energy production model is also explored. The *Wind Turbine Design Cost and Scaling Model* (by NREL) is used to evaluate the wind farm cost (Fingersh et al. 2006). The standard ISO 9613 (ISO 9613-2 1996) is implemented to quantify the noise pressure levels caused by the wind turbines.

Wind farm optimization is a complex *mixed-discrete constrained multi-objective* optimization problem. The Non-dominated Sorting Genetic Algorithm-II is used to solve this problem. The farm-land configuration influences the co-ordinate system of the farm layout (turbine locations); and the nameplate capacity controls the number of turbines to be installed. Based on the preliminary sensitivity analysis of the optimized wind farm output to a series of key design factors, we found the farm-land configuration and the nameplate capacity have a strong impact on the optimized farm output, and this impact varies significantly with the choice of different wake models. In this work, a bi-level optimization process is adopted, where typical layout optimization (optimal placement and selection of turbines) is performed at the lower level. The optimal planning of the land configuration and nameplate capacity is performed at the upper level. The Pareto frontier obtained from this multiobjective optimization will provide important insights into the trade-offs between the performance objectives. Such insights can significantly streamline the decision-making process (in wind farm development). The component models of the new wind farm design framework have already been developed and independently validated. The effectiveness of the entire framework is currently being tested by applying it to design a wind farm at a site with known resource information. Detailed results will be included in the final manuscript.