Uncertainty analysis in a windfarm based on wind data

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The energy production is an important issue and the renewal sources of energy production have attracted a lot of attention lately. The renewal energy production systems have gained in complexity in order to optimize the production and to ensure its stability. The reliability, availability, production and efficiency of these systems are essential to guarantee a stable and acceptable production level. The efficiency and the availability of these systems require a complete analysis of the major factors impacting the operation and production. This analysis relies on different scientific fields and permits to study long term properties of these systems [1].
In the context of a wind farm, the performance and durability of the wind turbines depends primarily on the wind properties, the geographical position of the wind farm and the placement within the wind farm. A thorough study of the durability and efficiency of wind turbines can only be done after a complete analysis of the properties of the input factors of the system, i.e., the wind. In order to achieve this goal, it is essential to study the variability of the wind in a wind farm, to analyse the different parameters impacting the wind and evaluate the uncertainty related to this latter [2,3].

Indeed, the wind properties, both aerodynamic and thermo-physical, evolve spatially and temporally, in a more or less randomly. It is thus necessary to study the atmospheric boundary layer. The latter has already been the subject of numerous works, both experimental and numerical [4,7]. This problem, combining fluid mechanics and meteorology, consists in predicting the evolution of wind parameters: velocity, temperature, pressure, humidity near the ground. The latter can be more or less complex (hilly, rough...)

In the framework of wind speed modelling in a wind farm, different types and sources of uncertainty can be distinguished, uncertainty related to the random nature of the phenomenon, related to data, to the model or to the available information [6]. A first analysis of these sources, in the framework of wind speed modelling, will permit to focus on the major influencing factors. Afterward, the impact of these factors on the model will be studied through suitable mathematical tools. A sensitivity analysis will be established in order to be able to evaluate the risk of production reduction or instability [7].

The characterization of the upstream wind will be performed via a Multiphysics study of the atmospheric boundary layer. This study will be done mainly by means of hybrid RANS/LES methods, which allow the simulation of unsteady flows at a moderate computational cost. The Multiphysics (turbulence in fluid mechanics, thermodynamics, etc.) and topological (shape and roughness on the ground, in the simulated domain) aspects will be at the heart of the study. Considering the simulated wind data and the selected parameters, the analysis of the uncertainty and the modelling of this latter will be performed through statistical and numerical methods [8].

Profile of the candidate:
-Appetence in mathematical modeling and implementation of numerical methods.
-Training in applied mathematics or mechanics or statistics

Publications sur le sujet :

[1] Zakaria, A., Ismail, F. B., Lipu, M. H., & Hannan, M. A. (2020). Uncertainty models for stochastic optimization in renewable energy applications. *Renewable Energy*, *145*, 1543-1571.

[2] Pérez, J. M. P., Márquez, F. P. G., Tobias, A., & Papaelias, M. (2013). Wind turbine reliability analysis. *Renewable and Sustainable Energy Reviews*, *23*, 463-472.
[3] Damiani, R. R. (2018). *Uncertainty and Risk Assessment in the Design Process for Wind* (No. NREL/TP-5000-67499). National Renewable Energy Lab.(NREL), Golden, CO (United States).
[4]Monin, A. S. (1970). The atmospheric boundary layer. *Annual Review of Fluid Mechanics*, *2*(1), 225-250.
[5] Stevens, R. J., & Meneveau, C. (2017). Flow structure and turbulence in wind farms. *Annual review of fluid mechanics*, *49*, 311-339.
[6] Lackner, M. A., Rogers, A. L., and Manwell, J. F. (July 1, 2008). "Uncertainty Analysis in MCP-Based Wind Resource Assessment and Energy Production Estimation." ASME. *J. Sol. Energy Eng*. August 2008; 130(3): 031006.
[7] Murcia, J. P., Réthoré, P. E., Dimitrov, N., Natarajan, A., Sørensen, J. D., Graf, P., & Kim, T. (2018). Uncertainty propagation through an aeroelastic wind turbine model using polynomial surrogates. *Renewable Energy*, *119*, 910-922.
[8] Araya, D. A. (2021). *Offshore Wind Farm CFD Modelling: Uncertainty Quantification and Polynomial Chaos*. The University of Manchester (United Kingdom).