Evaluation of Nested Extremum Seeking Wind Farm Control with SWiFT Facility

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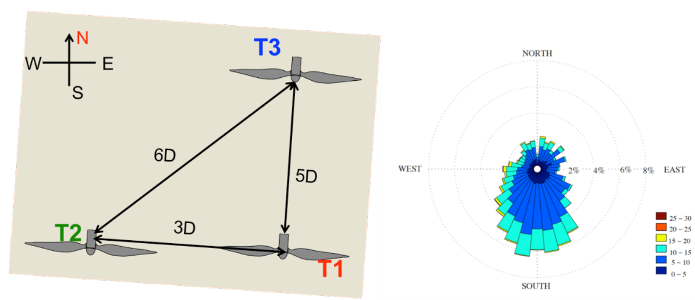
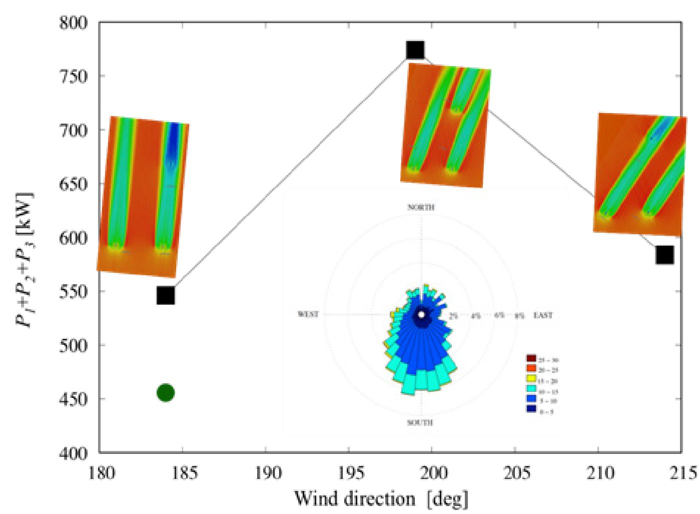
Control systems are critical for reducing the levelized cost of energy (LCOE) of wind energy. Axial-based and wake-steering controls using the generator torque, the pitch actuator and/or the yaw actuator can be deployed to maximize energy capture. Model-based control and optimization techniques have limited applicability due to the prohibitive cost for model calibration and wind field characterization. Therefore, model-free control and optimization strategies are highly desirable for wind power operators. From 2014 to 2016, WindSTAR IAB has supported two projects on model-free region-2 controls for wind turbine and wind farm based on extremum seeking control (ESC). In Project E2-14, ESC based region-2 controllers were tested on the CART3 facility at the National Renewable Energy Laboratory (NREL), and the testing results reveal a significant improvement of energy capture over NREL's baseline control strategy. In E3-14, large-eddy simulation (LES) study of the Nested ESC (NESC) reveals the effectiveness of NESC for model-free wind farm real-time optimization. The objective of Project D1-16 is to conduct initial stage work for experimental evaluation of NESC based wind farm control strategy on Sandia's Scaled Wind Farm Technology (SWiFT) facility.

During Project D1-16, the following research activities have been conducted: 1) acquisition of the FAST models of SWiFT wind turbines and wind resource information of SWiFT site; 2) ESC simulations using the SWiFT wind turbine FAST model; 3) development of NESC wind farm control testing plan based on SWiFT site wind source and IEC standard for performance evaluation; 3) development of LES simulation model of SWiFT wind farm on UTD-WF, with the capability of torque, blade pitch and yaw control; 4) LES based NESC simulations for UTD-WF model of SWiFT wind farm with both torque gain and yaw based controls.

A test plan that conforms to the IEC standard has been developed for torque-gain, blade-pitch and yaw based NESC, respectively, for the SWiFT facility. The LES based simulation studies of the SWiFT facility confirm the capability of NESC as model-free real-time optimization strategy for maximizing the energy capture of a cluster of turbines. Also, such study confirms the benefits of using high fidelity flow solvers like UTD-WF for evaluation of wind farm control strategies like NESC. The CFD model provides a virtual environment, in which a control solution can be reliably evaluated under realistic conditions with minimum impact of modeling uncertainties. In conclusion, the studies in Project D1-16 have laid a sound foundation for performing field tests for SWiFT facility.



Sketch of the SWiFT Facility wind farm (left), and wind rose at the site (right).



Total power of the SWiFT wind farm as a function of the wind direction: uniform inflow shown in black square symbols; realistic wind (with shear at inlet) shown in green circle symbol. The wind rose is included for reference.

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