IMPROVE THE WIND ENERGY EFFICIENCY THROUGH THE USE OF SMART ROTORS: FRENCH NATIONAL PROJECT SMARTEOLE

PO.086

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Objectives

The present consortium, composed of four complementary research labs and two industrial partners, has teamed-up to evaluate innovative control strategies at different scales of the wind farm: 1. the turbine blades aerodynamics, 2. the turbine pitch and yaw control system and 3. the wind farm global production. The project is called SMARTEOLE and will contribute to develop the concept of "smart rotor" in order to improve the operating conditions of wind turbines. It will consist in integrating new sensors (as LiDAR technology) in order to detect in advance the wind speed and direction at very-short term timescale. This anticipated wind measurement enables to implement real-time control strategies to drive the nacelle and blade orientation of turbines in an optimal way. Additional flow control strategies acting at shorter time scales and directly on the blades are also studied.

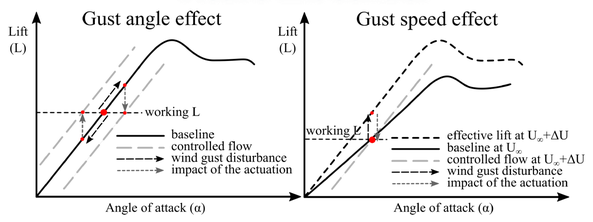
Approach

The control technologies developed in the present project are applied at three different scales (blade, rotor and farm scales) and are tested from the lab to the full scale for the most mature ones.
Two types of experiments are performed:
- Testing at full scale in a wind farm owned by Maia Eolis on the basis of control strategies developed by IFPEN and Maia Eolis with the use of LiDAR sensors manufactured by Avent Lidar technology.
- Wind tunnel testing in LHEEA and PRISME facilities, on active flow control on blades with control strategies developed by LAAS-CNRS and PRISME.
These developments are based on the partners' expertise on wind energy, LiDAR technology, metrology, control sciences and fluid mechanics.

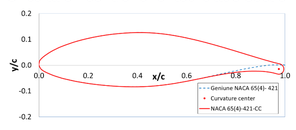
Results

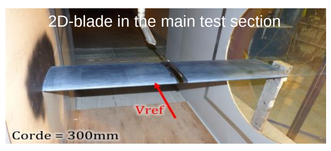
Blade scale

Active Lift control

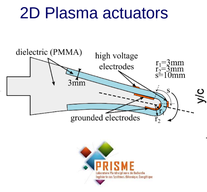


Circulation control-oriented blade section

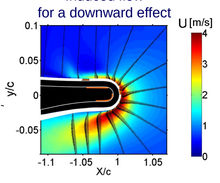




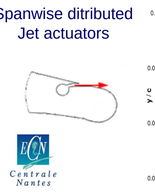
2D Plasma actuators



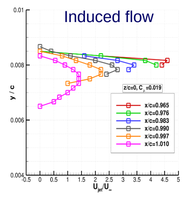
Induced flow for a downward effect



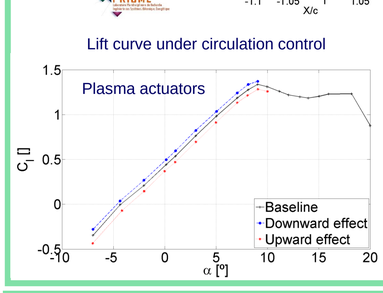
Spanwise ditributed Jet actuators



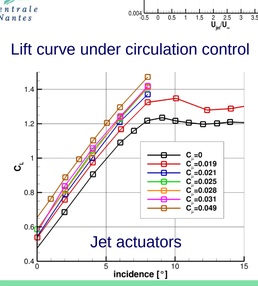
Induced flow



Lift curve under circulation control



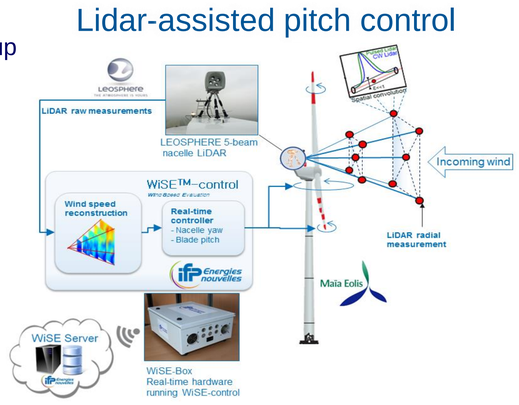
Lift curve under circulation control



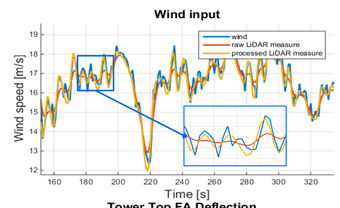
Rotor scale

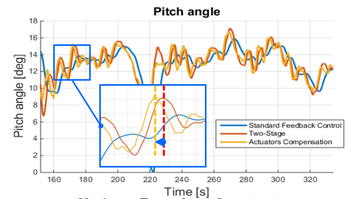
Lidar-assisted pitch control

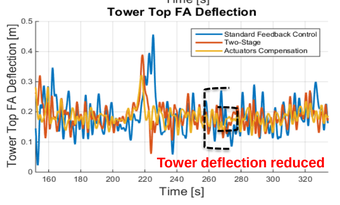
Set-up

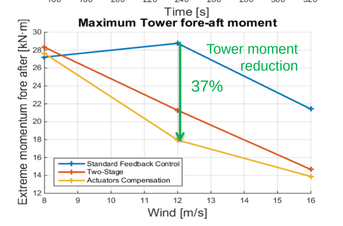


Simulation results







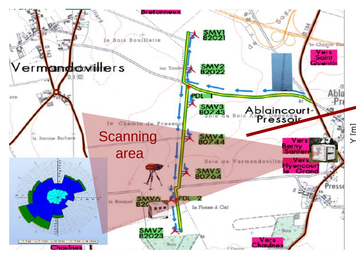


Farm scale

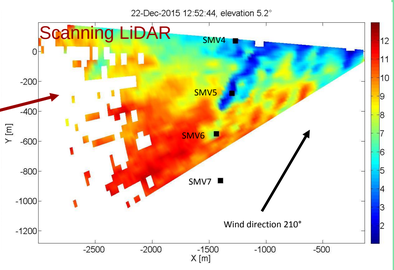
Wind turbine wake interactions

Field testing

Field site
Wind turbines of interest : SMV5 and SMV6

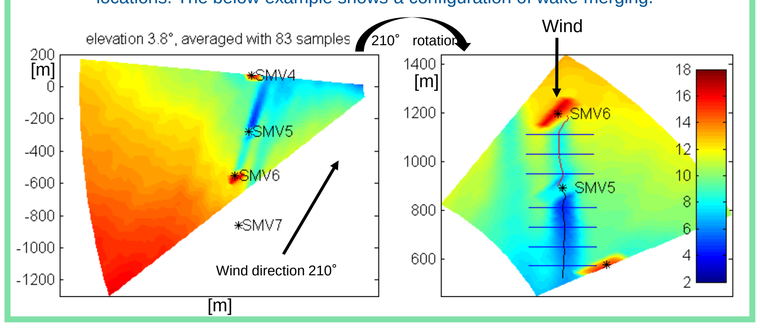


Instantaneous velocity field downstream of a wind turbine



Wake tracking

A wake tracking algorithm can be applied to the time-averaged and to the instantaneous velocity fields in order to determine the SMV5 and SMV6 wake locations. The below example shows a configuration of wake merging.



Conclusions

One year after the project launch, first outcomes are very promising regarding the efficiency of pulsed-jets and plasma actuators located at the rounded trailing edge of an airfoil to modulate the lift coefficient of a wind turbine blade tested in wind tunnel (PRISME and LHEEA) [1-3]. The development of more efficient actuators, as well as the appropriate closed-loop control tools are under process (LAAS, LHEEA and PRISME).

A 10-month measurement campaign has been set-up in the north of France (November 2015 - September 2016) to study the wake behavior of 2 wind turbines, with an original set-up using one scanning Lidar, 2 nacelle-mounted Lidars and a nacelle-embedded 2-axis inclinometer (Maia Eolis, Avent Lidar Technology and IFPEN). The great challenge of this part of the study will be to perform correlation analysis between the wind turbine wake behavior and the wind turbine monitoring sensors, characterized by signals having different dynamic responses and being polluted by variable meteorological conditions, by the broadband turbulent scales and by the wind turbine structural response [4]. Some scenarii of curtailments of the upstream wind turbine have been tested in order to quantify the influence on the overall power production. Additional scenario will be tested in order to improve the statistics.

The connection between the nacelle-mounted Lidar and the control unit developed by IFPEN is now operational on site. The "WiSEBox" control unit embeds an innovative real-time processing of the nacelle-mounted LiDAR raw data, designed to anticipate the incoming wind, and integrated into specific nacelle yaw and blade pitch control strategies, with the objective to mitigate loads and optimize the power [5]. Control strategies have been developed and tested in simulation with a modeled 2MW wind turbine representative of the instrumented wind turbines. Real-time wind reconstruction strategies are validated in simulation and on the experimental data acquired during the measurement campaign.

References

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3. Circulation active flow control on a rounded trailing-edge wind turbine airfoil using plasma actuators. Baleriola, et al. TORQUE 2016, Munich, Germany
4. Wind turbine wake tracking and its correlations with wind turbine monitoring sensors. Aubrun et al. TORQUE 2016, Munich, Germany
5. Real-time processing for incoming wind anticipation based on Nacelle LiDAR, integrated in control strategies for power optimization and loads mitigation. Guillemin et al. TORQUE 2016, Munich, Germany

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