Wind tunnel investigation on wake effects of a wind turbine

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ABSTRACT

The flow field in the wake of a horizontal axis wind turbine was studied through wind tunnel tests at the Mechanical Department of the Politecnico di Milano.

Aim of the research is to measure the wind flow in different points in the wake in order to characterize the flow blowing on structures that are positioned downwind a wind turbine and specifically on overhead power lines (OHL). The gathered experimental data consist in anemometric measurements and in the study of the dynamic response of an aeroelastic model of an OHL positioned in the wake of the wind turbine. The wind turbine model represents a 1:50 scaled model of a 3MW full scale wind turbine with a rotor diameter equal to 90 m. The model is equipped with an electric motor able to control the rotor angular velocity to reproduce the correct kinematics in the different wind speed operating conditions. Moreover, a mechanical system allows to change the blade pitch angle in order to have, on the blade profile, the correct velocity composition between the wind velocity and the motion velocity, as it happens in full scale.

Figure 1 reports a picture of the model in the wind tunnel test section and a rendering of the model highlighting the structural scheme inside the nacelle.

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Tests were performed both in nominal smooth flow (residual turbulence intensity less than 2 % and block vertical wind speed profile) and in turbulent flow (turbulence intensity at hub height equal to 13 % and atmospheric vertical boundary layer wind speed profile), comparing the flow field measured with and without the wind turbine.

Anemometric measurements were performed in the wake at different downstream position from the wind turbine equal to 1.5D, 2.5 D, 5 D and 8 D, where D is the rotor diameter. Different wind velocity and related wind turbine angular velocity and blade pitch angles have been considered.

Figure 2 reports the trend of the horizontal velocity profiles measured at 4 different distances downstream the wind turbine. The ratio between the measured wind speed and the incoming wind speed upwind the wind turbine $U_{ref}$ is reported versus the dimensionless transversal coordinate $y$, using the rotor diameter D as reference length. All the results are referred to the same tip speed ratio (TSR) defined as:

$$TSR = \frac{\text{tip speed}}{\text{wind speed}}$$
A 1:50 aeroelastic model of a OHL cable, reproducing the dynamic characteristics of an Araucaria full scale cable for a 400 m long span was used to measure the dynamic response of this structure when it is in the wake of a wind turbine. Tests were performed in turbulent flow condition taking into account different relative positions between the OHL model and the wind turbine (1.5 D and 2.5 D) and 3 different height of the line from the ground (distance of the minimum span height from the ground equal to 21.5 m, 31 m and 38.5 m). The motion of the cable was measured in 5 points along the line using infrared cameras.

Figure 2: Horizontal velocity profiles at different distances from the wind turbine.

Figure 3: y standard deviation of the 5 monitored points of the aeroelastic cable model.
Figure 3 shows the dependency of the standard deviation of the displacement in the wind direction of the 5 monitored points along the cable model on the distance between the wind turbine and the OHL and on the height from the ground.

REFERENCES