PossPOW: Possible Power of Downregulated Offshore Wind Power Plants

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One of the ancillary services that wind power plants can offer is reserve power which is achieved via downregulating the turbines. A verified methodology to calculate the possible or available power of downregulated offshore wind farms is the aim of the PossPOW project. While the available power calculation is straightforward and widely known for a single turbine, it gets rather complicated for the whole wind farm due to the change in the wake characteristics derived from the downregulated operational conditions. In fact, the wake losses created by the upstream turbine(s) decrease during downregulation and the downstream turbines see more wind compared to the ideal (or normal) operational case. Currently, Energinet.dk, UK National Grid and other Transmission System Operators (TSOs) have no real way to determine exactly the available power of a whole wind farm which is down-regulated. Therefore, the aim of the present project is to develop a verified and internationally accepted way to determine the possible power of a downregulated offshore wind farm using multi-disciplinary approaches. To be able to do that, the rotor effective wind speed has to be estimated and input to a wake model that simulates the normal operation of the wind farm.

**Wind Speed Estimation**

Using the general power expression:

\[ P = \frac{1}{2} C_{p} \rho \pi R^{2} \frac{v_{turb}^{3}}{\rho} \]

**Active Power**

\[ P_{\text{measured}} \]

**Rotational Speed**

\[ \Omega_{\text{measured}} \]

**Pitch Angle**

\[ \phi_{\text{measured}} \]

**Incoming Wind Speed**

\[ v_{\text{turb}} \]

The wind speed was calculated for each turbine iteratively using Horns Rev-I offshore wind farm and NREL 5 MW single turbine simulations\(^1\). Both cases have been investigated using second-wise datasets extracted during both normal operation and under curtailment.

**Conclusions**

The PossPOW project has been described and the intermediate results of the first period were presented. An aerodynamic backward calculation of wind speed methodology using active power, pitch angle and rotational speed measurements was proposed. The modelled rotor effective wind speed profile was compared to the nacelle anemometer measurements and the power curve wind speed estimations for Horns Rev case and to the simulated wind flow for NREL 5MW case. The model is verified based on the good agreements achieved during normal operation and downregulation for both turbine types which are aerodynamically different.

**Future Works**

To consider the changing wake effects for normal and down-regulated operation, the estimated rotor wind speed values of upstream turbines, which are not affected by the wake, are to be taken as inputs to the wake model to calculate the wind speed for the downstream turbines. Then the velocity deficit and therefore the possible power output of the wind farm can be calculated. However, most existing wake models have only been used to acquire long term, statistical information and verified using 10-min averaged data. Therefore, parameterization of wake models will be performed such that the parameters in the model such as wake expansion and “sweeping” speed will be calibrated for different averaging time scales using second-wise data obtained from Horns Rev.

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