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Wind Speed Estimation and Wake model Re-calibration for Downregulated Offshore Wind Farms

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In recent years, the wind farm sizes have increased tremendously and with increasing installed capacity, the wind farms are requested to downregulate from their maximum possible power more frequently, especially in the offshore environment. Determination of the possible (or available) power is crucial not only because the reserve power has considerable market value but also for wind farm developers to be properly compensated for the loss during downregulation. While the available power calculation is straightforward for a single turbine, it gets rather complicated for the whole wind farm due to the change in the wake characteristics. In fact, the wake losses generated by the upstream turbine(s) decrease during downregulation and the downstream turbines therefore see more wind compared to the normal operation case. Currently, the Transmission System Operators (TSOs) have no real way to determine exactly the available power of a whole wind farm which is downregulated. Therefore, the PossPOW project aims to develop a verified and internationally accepted way to determine the possible power of a downregulated offshore wind farm.

The first phase of the project is to estimate the rotor effective wind speed. Since the nacelle anemometers are not readily available and are known to have reliability issues, the proposed method is to use power, pitch angle and rotational speed as inputs and combine it with a generic Cp model to estimate the wind speed. The performance of the model has been evaluated for both normal operation and downregulation periods using two different case studies: Horns Rev-I wind farm and NREL 5MW single turbine.

During downregulation, the wake losses are not as severe and the velocity deficits at the downstream turbines are smaller as if also the wake is "downregulated". On the other hand, in order to calculate the available power, the wakes that would have been produced normally (if the turbines were not curtailed) are of importance, not the downregulated wake. For this reason, the proposed methodology is to use the clear wind without the wake (downregulated or not) as inputs to the wake model. Then a dynamic wake model can be directly applied to estimate the velocity deficit row by row inside the wind farm and calculate the possible power output on the wind farm scale. Most of the computationally affordable wake models have only been used to acquire long term, statistical information and verified using 10-min averaged data. However for smaller averaging bins or real-time modeling, the dynamics of the flow inside the wind farm such as wind direction variability and wake meandering is much more significant. Therefore GCLarsen wake model, which has been implemented in WindPro and shown to perform also well on offshore in Wake benchmark work package in EERA-DTOC, is re-calibrated and validated for single wake case in Horns Rev-I offshore wind farm.