Abstract

Optimization of yaw misalignment may improve energy output of wind farms. An analysis was made of the potential power loss of the Horns Reef wind farm due to yaw errors. The method for the estimate was to measure the yaw error on an identical V80 onshore wind turbine and to extrapolate these findings to all turbines in the wind farm. The yaw errors were measured to be significant and in average about 10° on the onshore V80 turbine. The flow inclination angle was measured to be significantly influenced by wake rotation from the neighboring wind turbines. The average power loss factor in the wind speed range 3-12m/s was found to be 0.971. Adjusting for a target yaw error interval of ±5° the estimated power loss was 2.7%. When considering the Horns Reef site and assuming all turbines to yaw as the onshore turbine and adjusting for the relevant power loss wind speed interval then we end up with an estimated power loss of 1.6%, which corresponds to the production from 1.3 wind turbines.

Objectives

The objectives was to estimate the yawing errors and performance losses of the wind turbines in the offshore Horns Reef wind farm west of Esbjerg. The wind farm consists of 80 V80 2MW wind turbines that have been in operation since 2002. An identical turbine is located onshore at Tjæreborg.

Methods

The method for estimation of yaw errors and performance losses on Horns Rev wind farm are based on measurements and analysis on one onshore V80 wind turbine, configured exactly like the wind turbines at Horns Rev wind farm. The onshore wind turbine is located as turbine no 5 in a small wind farm of 5 wind turbines at Tjæreborg, see Figure 2, all of the same size as the V80 wind turbine.

The inflow to the rotor centre is measured with a spinner anemometer [1-4], see Figure 1, on the V80 wind turbine. The output of the spinner anemometer is the local wind speed at the spinner nose, the yaw error and the flow inclination angle.

Figure 1 Spinner anemometer mounted on V80 turbine no 5

Figure 2 Tjæreborg wind farm site

Figure 3 shows the spinner anemometer wind speed relative to the met mast cup anemometer from the open sector 212° -252° during operation. It is clearly seen that the spinner anemometer wind speed is reduced in the range 4-12m/s. The induced wind speed in the rotor centre is quantified by the induction factor as shown in Figure 4. The induction factor is seen to have a maximum value of about 12%.

Figure 3 Spinner wind speed re. cup

Figure 4 Induction factor at rotor centre

Results

The ratio between the spinner anemometer and the hub height cup anemometer is shown in Figure 5 for all directions for half a year of measurements.

Conclusions

The wakes of the turbines on the mast measurements and on the spinner anemometer measurements are indicated by the colored labels. Two open sectors, where both turbine 5 and the met mast see free flow, are identified: 212° -252° and 320° -35° . The wakes of the closest turbine no 6 on turbine 5 in the direction 201° and on the mast in the direction 173° is clearly seen, as well as the wakes from the other turbines.

The yaw error measurements for a two month period with the spinner anemometer are shown in Figure 6. The average yaw error is about 10° and the spreading of data is about 5°. Only for one wind direction, which is in the wake of turbine 6, the yaw error is spreading more, from -10° to 14°.

The flow inclination angle is shown in Figure 7. A dramatic change of inflow angle is seen in the wake of turbine 6. At 192° the inflow angle is almost 14° while at 207° the inflow angle is -13°. This inflow angle pattern is due to the rotation of the wake of turbine 6.

The estimate of the power loss due to yaw error is estimated assuming the power is regulated down so a power loss is taking place in the wind speed range 3-15m/s, and considering only a power loss in the wind speed range 3-15m/s, and assuming all turbines to yaw as the onshore turbine and consider only the relevant 3-15m/s wind speed range. We end up with an estimate of the power loss of 1.6%, which corresponds to the production from 1.3 wind turbines.

References


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