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Empirical investigation of wind farm blockage effects in Horn Rev 1 offshore wind farm

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Keywords
Offshore wind farms, inflow distortion, wind resources

Summary
We present an empirical study of wind farm blockage effects based on Horns Rev 1 SCADA data. The mean inflow non-uniformities in wind speed are analyzed by calculating the mean power outputs of turbines located along the outer edges of the farm for different wind directions, wind speeds and stability conditions. This forms a basis for understanding of the blockage effects and their influence on wind farm production.

Abstract
In most of the present yield estimation models the inflow to a wind farm cluster is assumed to be uniform and exactly the same as the free, undisturbed wind far upstream from turbine locations. However, it has been observed that for certain wind directions the average wind speeds measured at turbine locations vary significantly along the outer edges of the farm. This phenomenon is attributed to flow field distortion caused by the wind farm itself (hence the name: blockage effect). It encompasses both variations in wind speed as well as wind direction in the vicinity of the farm.

In this paper the existence of the described phenomenon is confirmed and thoroughly analyzed. The order of magnitude of power output variations along the edge is estimated for the Horns Rev 1 case. The influence of wind direction, wind speed, turbulence intensity and atmospheric stability (derived from mast measurements) on the blockage effects is studied. Also, the order of magnitude of the error associated with neglecting the blockage effects in AEP calculations is estimated.

Since the analysis is based on wind farm SCADA data, methods for data treatment and ambient wind derivation as well as their limitations are discussed.

Figure 1 and Figure 2 present the power output variation along the south-western edge of HR1 for wind direction of 200 [deg], wind speed range of (7,9) [m/s] and stable atmosphere. As seen, the variation is significant. Turbines T08 and T18 are located in a flow deceleration zone, while T01 experiences a significant increase in wind resource.

The study provides basic understanding and quantification of blockage effects. As no similar research is publicly available, it is believed to be novel and is hoped to inspire further investigation on the topic.

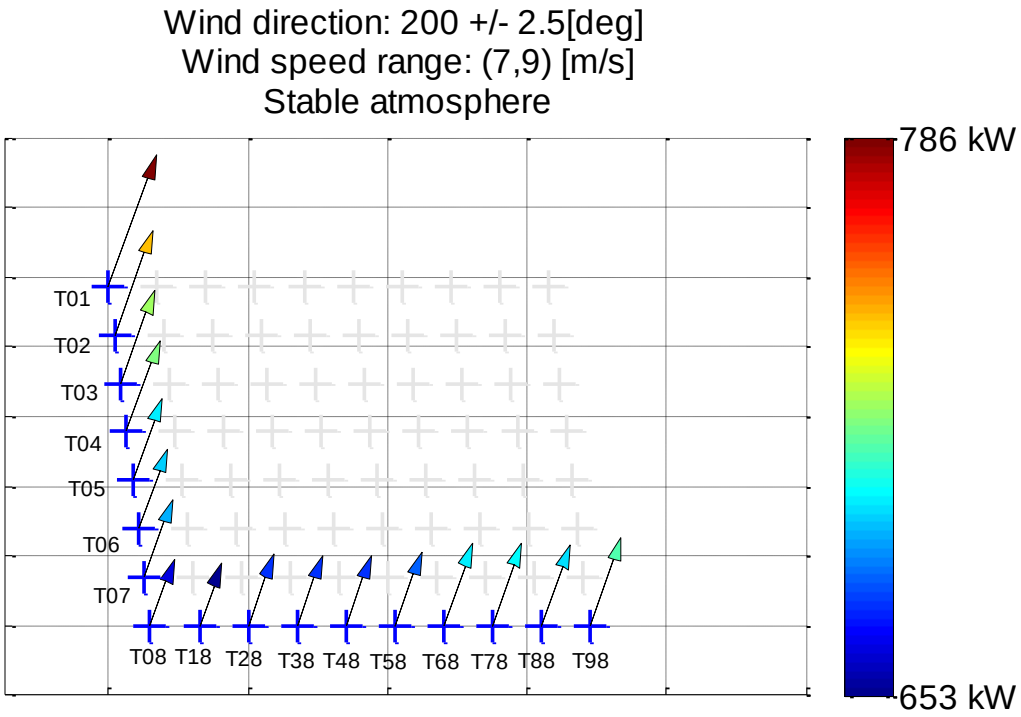

Figure 1 – An example of power output variation along the south-western edge of Horns Rev 1 (the color and length of arrows is scaled with mean turbine power output, while their direction depicts wind direction in the considered flow case)

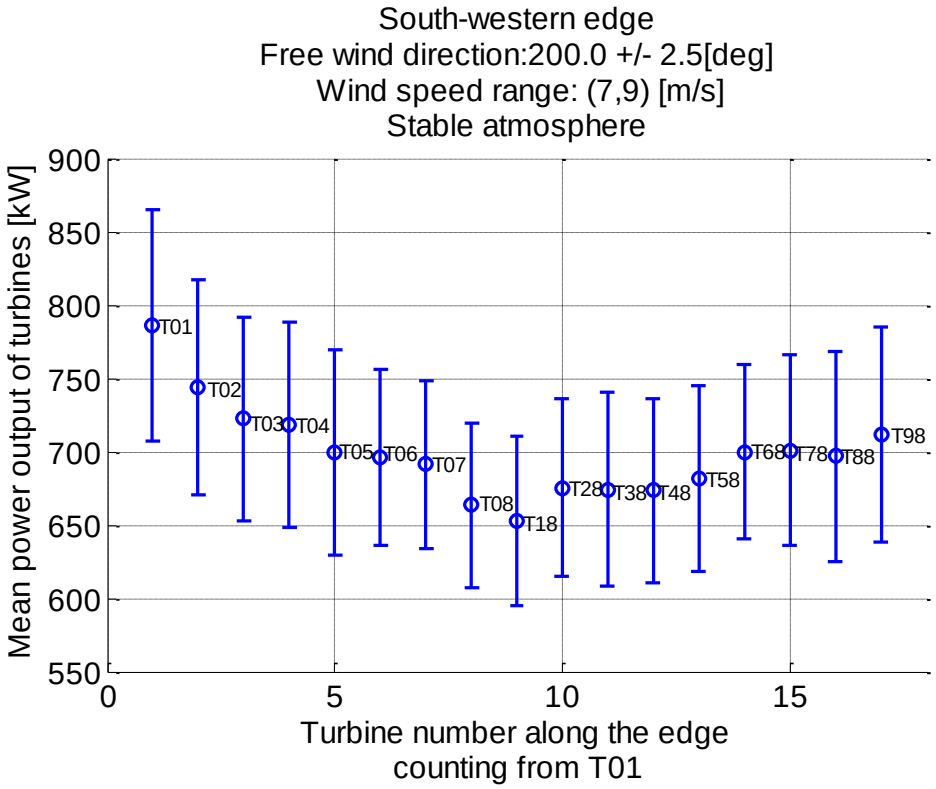

Figure 2 – An example of power output variation along the south-western edge of Horns Rev 1