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Effects of Positive versus Negative Yaw Angles on Wind-Turbine Performance: An Application of BEM Theory

Majid Bastankhah and Fernando Porté-Agel

Wind Engineering and Renewable Energy Laboratory (WIRE), École Polytechnique Fédérale de Lausanne (EPFL), Switzerland (fernando.porte-agel@epfl.ch)

Wind-turbine wakes have negative effects on wind-farm performance. They are associated with: (a) the velocity deficit, which reduces the generated power of downwind turbines; and (b) the turbulence level, which increases the fatigue loads on downwind turbines. Controlling the yaw angle of turbines can potentially improve the performance of wind farms by deflecting the wake away from downwind turbines. However, yawed conditions induce unsteady loads on turbine blades which affect the generated power quality and fatigue life. To better understand these effects, the blade element momentum (BEM) theory, which is modified to take into account the unsteadiness of yawed conditions, is used in the present work. The comparison between the BEM results and the wind-tunnel measurements of a yawed model turbine in the uniform flow shows reasonable agreement for yaw angles smaller than 30 degrees. Special emphasis is placed on the use of BEM to investigate the difference between the effect of positive and negative yaw angles on the performance of turbines in uniform and boundary-layer flows. In general, it is found that for a yawed turbine in uniform flows, the thrust force and the generated power corresponding with each turbine blade vary as the blade rotates. This variation is, however, similar for both positive and negative yaw angles with just a shift in time with respect to each other. On the other hand, it is found that turbines in boundary-layer flows do not behave in the same way for positive and negative yaw angles. Although the time-averaged thrust force and generated power are approximately the same for positive and negative yaw angles, the variation of forces acting on blades is lower in one of these cases compared to the other one. In fact, the rotational direction of turbine blades determines which case introduces smoother variation of forces acting on blades. This finding is of great importance to increase the life-time of turbines working in yawed conditions.