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Analysis of Wind Turbine Farms under Thunderstorm Downbursts

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ABSTRACT

Wind energy is one of the fastest-growing resources of clean and renewable power. A wind turbine farm is a group of wind turbines installed at the same area in order to maximize the use of local wind resources. A wind farm can include hundreds of wind turbines and cover hundreds of square kilometers. Wind turbine farms are commonly installed in rural locations remote from cities to allow the serving of other civil usages in urban areas. Rural areas are vulnerable to thunderstorms and strong wind events, which are anticipated to become more frequent and more severe as a result of climate change. Downbursts are High Intensity Wind (HIW) events linked with thunderstorms that occur frequently in a rapid and localized manner. There is a lack in the literature for studies on wind farms exposed to downbursts. As such, a previously developed numerical model to investigate the behaviour of a single wind turbine under downbursts is extended in the current study such that a group of wind turbines can be studied under such events. The developed numerical model, HIW-FARM, incorporates the downburst wind field generated using previously conducted Computational Fluid Dynamics (CFD) simulations integrated with an array of wind turbine structural models. HIW-FARM takes into account downburst characteristics including the jet velocity, jet diameter, and its location within the wind farm center. The numerical model also considers different wind farm layouts by varying the distances between wind turbines along and across the wind direction. The pitch angle of the blades is another variable considered in the numerical model. A parametric study is carried out on a regular wind farm layout, as a case study, by changing the downburst parameters to predict the peak moments at the tower base with various pitch angles. These moments are compared to the corresponding values resulting from wind loads recommended by the wind turbine design code (IEC 61400-1, 2005). The ratio between the moments obtained by the downburst analysis and those specified by the design code is determined, and wind turbine towers with ratios greater than one are considered unsafe

if designed according to the design code. Downburst critical configurations which lead to the maximum number of unsafe wind turbine towers are determined for each blade pitch angle. An optimum pitch angle for the blades is suggested in order minimize the downburst effect on the maximum number of wind turbine towers in a wind farm.

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