Typhoon wind hazard assessment for Donghaitang wind farm (China): A case study

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Objective & Background

Currently, offshore and coastal wind power resources are growing rapidly around the world, especially in China. However, systematic research on the hazard assessment of wind farms under typhoon conditions remains lacking. The extreme wind speeds, violent changes in wind direction, and excessive intensity of turbulence during the passage of tropical cyclones can have substantial impact on the structural safety of wind turbine units in offshore wind farms, and represent the main causes of damage to wind turbine units. Therefore, the risk posed to wind turbine units by tropical cyclones should be assessed with regard to future development of offshore wind power resources.

Method

This study simulated the wind field of typhoons based on a parameterized typhoon wind field model, and analyzed the characteristics of historical typhoons in Donghaitang wind farm (Zhejiang, China). Four extreme typhoon hazard factors including the maximum wind speed (V_{max}), maximum duration of wind direction change (T_{max}), maximum cumulative wind direction change ($\Delta\vartheta_{max}$) and maximum rate of change in wind direction (ΔD_{max}) were proposed and examined. Then a comprehensive hazard assessment model for wind farms based on the analytic hierarchy process was established, and the risk to the Donghaitang wind farm represented by typhoons during 1949–2021 was evaluated.

Conclusion

Results showed that the number and intensity of tropical cyclones made landfall near the coast of Donghaitang wind farm gradually increased with time, which results in a gradual increase in the composite tropical cyclone risk level of the Donghaitang wind farm with time. The numbers and risk levels of tropical cyclones traveling northwestward were much larger than those traveling northward or northeastward. Moreover, the average composite risk index for tropical cyclones passing to the left of the wind farm was 14.3% higher than that for tropical cyclones passing to the right. Specifically, the average composite risk index for tropical cyclones traveling northwestward was 0.0614, i.e., much larger than that for tropical cyclones traveling northward (0.0285) and northeastward (0.0160). The large values of V_{max} and ΔD_{max} are main reasons for the high risk of the wind farm, while the other two hazard factors (T_{max}, $\Delta\vartheta_{max}$) proposed to account for the wind turbine backup power are also of great importance in the design, selection and operation stages of offshore wind turbines. The findings of this study could provide support for hazard assessment of offshore and coastal wind farms exposed to tropical cyclones, including macro-site selection of wind farms and type selection of wind turbines.

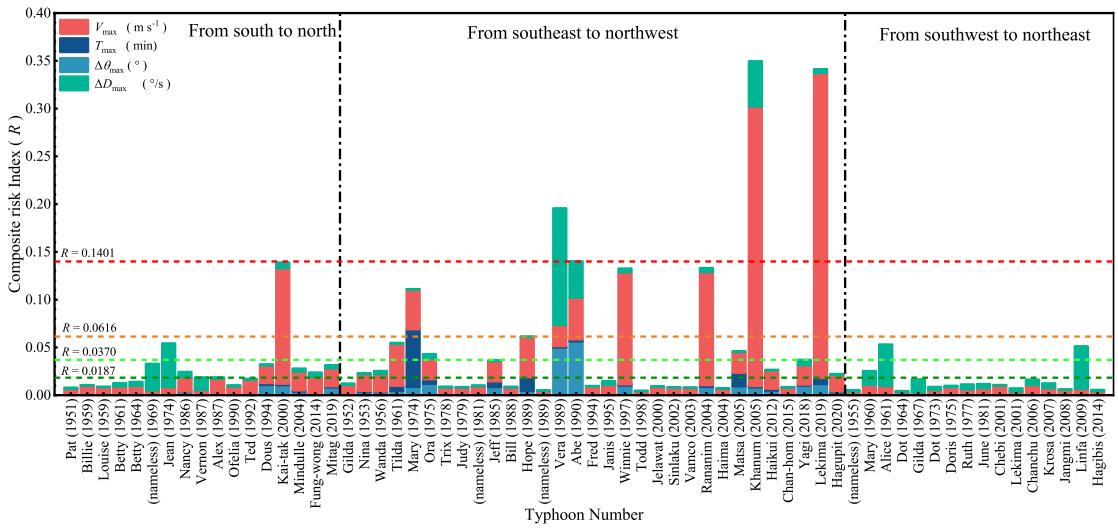

Fig. 1 Distribution of historical tropical cyclone composite risk index for the Donghaitang wind farm area. Red, dark blue, blue, and green bars represent the proportion of V_{max}, T_{max}, $\Delta\vartheta_{max}$, and ΔD_{max} in the composite risk index for tropical cyclones. Dark green, green, orange, and red horizontal dashed lines are the threshold cutoffs when R equals 0.0187, 0.0370, 0.0616, and 0.1401, respectively, and the vertical black dot-dashed lines are the tropical cyclone path cutoffs: (left to right) south to north, southeast to northwest, and southwest to northeast.