Copula-based joint distribution analysis of wind speed and wind direction: wind energy development for Hong Kong

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Abstract

Accurate assessment of wind energy potential can provide important implication regarding the optimalization of micro-siting of wind turbines and increase of wind power generation. It is, however, noteworthy that most previous studies on wind energy resource assessment focused solely on wind speed, whereas the dependence of wind energy on wind direction was much less considered and documented. In the current study, a copula-based method is proposed to better characterize the direction-related wind energy potential at six typical sites in Hong Kong. In the first step, several widely used statistical models are adopted to fit the marginal distributions of wind speed and direction. The joint probability density function (JPDF) of wind speed and wind direction is therewith constructed by various copula models. The goodness-of-fit evaluation indicates that Frank copula has the best performance to fit the JPDF at hilltop and offshore sites, while Gumbel copula outperforms other models at downtown sites. More importantly, the derived JPDFs are applied to estimate the direction-related wind power density at each of the considered sites, finding a maximum value of wind energy potential of 506.4 W/m2 at a hilltop site. In addition, site-to-site variability is also identified regarding the prevailing wind resource directions. The outcome of this study is expected to be useful for the site selection of wind turbines, as well as the strategic development of wind energy in Hong Kong. Notably, the proposed copula-based method can also be applied to characterize the direction-related wind energy potential somewhere other than Hong Kong.

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