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Technical note

MEP-type distribution function: a better alternative to Weibull function for wind speed distributions

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Abstract

The probabilistic distribution of wind speed is one of the important wind characteristics for the assessment of wind energy potential and for the performance of wind energy conversion systems, as well as for the structural and environmental design and analysis. In this study, an exponential family of distribution functions has been developed for the description of the probabilistic distribution of wind speed, and comparison with the wind speed data taken from different sources and measured at different geographical locations in the world has been made. This family of distributions is developed by introducing a pre-exponential term to the theoretical distribution derived from the maximum entropy principle (MEP). The statistical analysis parameter based on the wind power density is used as the suitability judgement for the distribution functions. It is shown that the MEP-type distributions not only agree better with a variety of the measured wind speed data than the conventionally used empirical Weibull distribution, but also can represent the wind power density much more accurately. Therefore, the MEP-type distributions are more suitable for the assessment of the wind energy potential and the performance of wind energy conversion systems.

Keywords: Wind speed distribution; Maximum entropy principle; Weibull distribution; Wind energy

1. Introduction

Renewable energy sources, including hydro, wind, solar, geothermal, biomass, wave and tide, and ocean thermal energy, have attracted increasing attention from all

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over the world due to their almost inexhaustible and nonpolluting characteristics. As one of these important sources, wind energy, which is perhaps the most suitable and cost effective for electricity production, is vigorously pursued in many countries. Wind turbine technology has been the subject of intensive development over the last two decades [1,2]. There are no significant unsolvable technical barriers to the widespread implementation of wind energy, and comparing with nuclear power plants, the safety of wind energy is much less of concern. In the late part of 1990s, wind energy was the fastest growing energy technology in terms of percentage of yearly growth of installed capacity per technology source [3].

The wind speed distribution, one of the wind characteristics, is of great importance for not only structural and environmental design and analysis, but the assessment of the wind energy potential and the performance of wind energy conversion system as well. Over the last two decades many researchers have devoted to develop an adequate statistical model to describe wind speed frequency distribution. The Weibull, Rayleigh and Lognormal functions are commonly used for fitting the measured wind speed probability distribution. Patel [4] claims that the Weibull probability distribution function with two constant parameters is the best one to describe the variation in wind speed. And the Weibull function is extensively used to assess the wind potential and economic viability for different regions in different countries [5–11].

The Weibull distribution with two parameters can be written as

$$f(V) = \frac{k}{c}\left(\frac{V}{c}\right)^{k-1}\exp\left[-\left(\frac{V}{c}\right)^{k}\right] \tag{1}$$

where k is the shape parameter (dimensionless) and c is the scale parameter having the dimension of speed. The distributions will take different shapes with different values of k, the shape parameter. The unknown parameters k and c can be determined with several different methods. Stevens and Smulders [12] summed up five of them for wind energy utilization purpose.

When the shape parameter k is set equal to 2, the resulting Weibull distribution is often called the Rayleigh distribution which has a bias towards the small wind speed and is a subset of the Weibull distribution. It is also used as the wind speed distribution function in some cases and sometimes even provides a better fitting than the Weibull distribution having two parameters [13]. In general, the Weibull distribution is more versatile with two parameters while the Rayleigh distribution is simpler to use because of only one parameter involved. In order to determine the empirical parameters in these empirical wind speed distributions, actual wind speed measurements are often carried out for a course of several years or even decades. These detailed wind speed measurements not only are time-consuming, but also may not be available for the sites of interest.

Recently, Li and Li [14] used the maximum entropy principle (MEP)—a statistical inference method for the first time to the wind energy field, and proposed a theoretical approach to analytically determine wind speed distribution. The maximization of the Shannon's entropy was carried out subject to the conservation principles for the wind mass, momentum and energy, and an exponential function is derived for the probabilistic