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Influence of the data sampling interval in the estimation of the parameters of the Weibull wind speed probability density distribution: a case study

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Abstract

This paper proposes the use of a methodology to estimate the parameters of the Weibull wind speed probability density distribution and its standard errors. This methodology is applied in the analysis of the influence that the use of autocorrelated wind speeds has on the estimation of the aforementioned parameters and on the approximate confidence bounds of the wind power density function and other statistic functions. A joint contrast test of the first autocorrelation coefficients is performed to estimate the wind speed sampling interval that allows acceptance of the hypothesis of independence. The maximum likelihood method is used to estimate the Weibull scale and shape parameters and the Anderson–Darling test is used to see whether a sample of wind data comes from a population with a Weibull distribution. This methodology is applied to the hourly mean wind speeds recorded over a six year period at a weather station located in the Canarian Archipelago. The results show that the use of autocorrelated successive hourly mean wind speeds, though invalidating all of the usual statistical tests, has no appreciable effect on the shape of the probability density distribution. However, as the calculated uncertainties obtained from dependent or correlated wind speed data for the commonly used wind energy statistic functions are

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over-optimistic, the use of a sample of independent wind speed data is recommended in this paper to estimate these uncertainties. Along these lines, a description is given of the algorithm of the procedure proposed in this paper to select this sample.

Keywords: Weibull distribution; Weibull parameters; Wind power density estimation; Autocorrelation function

1. Introduction

A large number of studies have been published that propose the use of a variety of probability density functions (pdf) to describe wind speed frequency distributions [1–19]. At the present time, however, it is the two parameter Weibull distribution that is the most widely used and accepted in the specialised literature on wind energy and other renewable energy sources [20–37]. According to Tuller and Brett [37], the selection of the Weibull distribution can often be attributed to its flexibility, providing a good fit to the observed wind speed distributions, and to the fact that only two parameters are needed for estimation.

The methods used to determine the parameters of the Weibull pdf have also been numerous [38–44]. There have been three principal tests used to see whether a sample of wind data comes from a population with a Weibull distribution: the Chi-Square goodness of fit test (χ^2) [7,11,38], the Kolmolgorov–Smirnov (K–S) test [37] and the RMS (root mean square) test to estimate the accumulative frequency [11,37,39], though in most papers these tests have not been taken into account. However, one of the most critical statistical assumptions, namely the dependence or independence of the wind speeds used to determine the parameters of the Weibull pdf, has been tested in virtually none of the literature consulted [46–49]. Bearing in mind that the wind speed V recorded at short intervals of time usually presents dependence [38,45,50–54], then the use of such samples violates the hypotheses on which the estimation techniques are based. In other words, in theory, if the randomness assumption does not hold, then: (a) all of the usual statistical tests are invalid, (b) the calculated uncertainties for commonly used statistics become meaningless; and (c) the parameter estimates become suspect and nonsupportable.

This paper proposes the use of a methodology to estimate the parameters of the Weibull wind speed probability density distribution and its standard errors. This methodology is applied in the analysis of the influence that the use of a sample with autocorrelated wind speeds has on the estimation of the parameters and on the approximate confidence bounds of the wind power density function and other statistic functions. The sample used is the hourly mean wind speeds recorded over a six year period at a weather station located in the Canarian Archipelago. The results show that the use of autocorrelated successive hourly mean wind speeds, though invalidating all of the usual statistical tests, has no significant effect on the shape of the probability density distribution. However, as the calculated uncertainties obtained from dependent or correlated wind speed data for the commonly used wind energy statistic functions are over-optimistic, the use of a sample of independent wind speed data is recommended in this paper to estimate these uncertainties. Along these lines, a description is given of the algorithm of the procedure proposed in this paper to select this sample.