ABSTRACT

A New Wind Speed Frequency Modelling (WSFM) Methodology and its Applications

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The area of Wind Speed Frequency Modelling (WSFM) in the field of wind engineering is important for Wind Energy Conversion System (WECS) studies for power system planning and reliability studies. Currently, research and new information in this area is minimal as the current WSFM methodology is well established. However, the work in this thesis has identified problems relating to the misuse of statistical theory in the current WSFM methodology sub areas; namely the probability density function (PDF) modelling method, PDF model selection, PDF model definition and PDF model validation. This is mainly due to the desire by practitioners for computational conveniences and ignorance of the assumptions for modelling the complex wind phenomena. A new general four stage WSFM methodology is formulated to solve the theoretical violations. Failure to correct the violations diminishes the confidence of the scientific conclusions. Two new simulation forecasting tools via the new WSFM method are offered for the practitioners in order to provide a more detailed scientific

judgement of WECS viability for any regime. The second tool requires a WECS performance mathematical modelling (WPM) study and, this updates the literature. For testing and illustration of the new WSFM, the unpublished logged February 1980-1990 hourly mean wind speed (HWMS) data set of the Crown Point Meteorological Station, Tobago is used. The mathematics are detailed and automated in EXCEL and Matlab. From the research, the following have been developed to formulate the new WSFM method and its applications:

a) A new PDF modelling method: This is suggested on the concept of a pseudo time series of repeatable PDF models to replace the current method that was proven to be theoretically invalid. The heterogeneous wind speed spectrum is now structured into the homogeneous mean wind speed categories of low (<3m/s), moderate (3-5 m/s) and high (<5m/s) at 10m.

b) A new catalogue of wind speed models: It was found that there is insufficient justification for use of the current PDF standards. Since it is very difficult to theoretically justify a wind speed model, empirical justification is suggested. A new catalogue of flexible three parameter models belonging to the Johnson, Gamma, Extreme Value, Wakeby and Logistic families that are physically adaptable to wind speed are defined and evaluated. Moment Ratio Diagrams (MRD's) are newly applied as the model identification tool with the L-MRD recommended for superior discrimination power. New model estimation methods are investigated as alternatives to the shortcomings of the envogue methods. It was found that there is no standard estimation method and the Probability Weighted Moments (PWM) method performed well for the entire

wind speed spectrum. The standard models were found to be inferior to the new catalogue and there is no universal model as currently advocated. General lookup tables are established of suitable models defined according to wind speed category and, this can be useful for any wind speed application.

c) A new and powerful model validation method: The envogue methods were found to be inappropriate. The Anderson-Darling (A^2) or Cramer-von Mises (W^2) statistical tests are recommended for final model validation. The popular chi-square (χ^2) is recommended as a preliminary screening tool.

d) Two new forecasting tools: A simulated wind resource tool (W/m^2) with 95% confidence is provided. A second tool of simulated WECS power outputs for pitch or stall regulated types is provided once the recommended 4^{th} or 5^{th} order WECS polynomial performance model is convolved with the best ranking three parameter model.

Keywords: wind engineering; WECS; wind speed; statistical techniques