A Generalized Cascaded Approach to Estimate Missing Wind Data Using Multivariate Weibull Distribution Network

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***Abstract*— Networked sensors in smart grids allow techniques like sensor fusion including: sensor similarities, as well as, sensor complementarities to be integrated to obtain new information or feature that is not measured directly. On the other hand, these techniques can be extended to get trusted readings at different correlated areas based on historical observations and their corresponding probabilistic distributions of sensors at these areas. In this paper a stochastic modelling of multivariate within the platform of cyber-physical systems has been discussed. A proposed multivariate Weibull distribution (WD) modeling is adopted to predict wind speed (WS) at a certain site given data at other correlated place(s). The proposed methodology has been implemented on some cases of study to illustrate the effectiveness of the adopted technique using bivariate or trivariate models. It has been revealed that the same methodology could be extended to any multivariate WD for any stochastic modeling problem. In this paper a comparison between the proposed trivariate, and bivariate Weibull is established to show their efficiency on estimating WS at a location that has a faulty sensor, that fails to deliver its data.**

Keywords*— *Multivariate Distribution, Probability Density Function, Smart Microgrid, Stochastic modeling, Wind-data Estimation.

I. Introduction

Increasing the rate of consumed power around the world with decreasing in fossil fuel reserves. Due to these reason and negative effects of traditional power stations on environment, researchers do all efforts to seek for clean and pollution free energy, which are cheaper and sustainable [1-3]. Wind power is the most suitable energy sources and effective solution for environmental recession. Nowadays, many countries are encouraging/supporting the use of wind energy instead of fossil fuels [1-5].

One of the major properties of wind energy generation is the irregularity nature of wind, as a result wind estimation/forecasting is very desirable especially with high accuracy. Therefore, researchers have focused on developing precise stochastic models for wind prediction [6]. Usually, in new microgrids they use huge amount of measuring devices to collect data continuously [5,7,8]. The recorded data become massive with respect to the past. This real big data could be inaccurate, uncertain and usually incomplete. Thus, this big data mining using straightforward highly efficient theories became hot topic for research using intelligent methods [8]. Weather Multi-variable modeling involves correlating different variables such as: WS, pressure, and temperature [4,6].

In new microgrids, the networked-sensor architecture allows to fuse these sensors and generate a new information using complementarities of such network [9-13]. Missing information from any specific sensor can be estimated utilizing other sensors' data (may be in neighborhood sites), while the specific sensor recordings were missing. The correlation between recorded data obtained from these sensors depends on probabilistic past observations [13].

II. Features of Wind Speed

The speed of wind changes continuously, making it necessary to be described by statistical approaches, such as mean and standard deviation (μ, σ) [9-12].

A. Wind Weibull

In 1930s, a mathematician named Waloddi Weibull applied a distribution function for material tension and fatigue, named lately WD [14]. It provides a close approximation to the probability laws of many phenomena. It has been used to represent WS distributions for application in wind studies for a while. WD has drawn the attention of statisticians working on theory and methods of statistics for a long [14,15].

Obtaining WS characteristics at a certain place is highly important. This job is way difficult due to the randomness of wind, as it does not follow any known statistical distribution exactly. Therefore, the best way to characterize the wind at a certain place is to perform site measurements [14].

Challenges arises in selecting the most suitable Probability density function (PDF) that mimics the WS distribution. Even though there are several PDFs for this purpose, researchers most commonly use the Weibull function to describe wind, that apparently related to the nature of the wind in certain conditions. Weibull parameters are usually derived using familiar estimation criteria, e.g., Max. likelihood. In wind power applications, evaluating the energy that can be produced in a specific place is one of the most important information associated with the estimation process [1,14].

B. Wind Speed Distributions

WS is usually measured at weather stations. The resulting WS series can be represented as in equation (1), while equation (2) describes WS data in histogram.

$$v = \{ v_\iota \mid \iota = 1,2,\dots.n \}, \tag{1}$$

where n is the number of data points.

$$fr_j = n_j / n \tag{2}$$

where n_j is the number of data points falls inside the bin represented by WS, and fr_j is a probability of repeated WS