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Modeling the fluctuations of wind speed data by considering their mean and volatility effects

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ABSTRACT

An accurate modeling of the fluctuations of wind speed data can always provide a beneficial effect, particularly in regard to wind energy conversion systems. Regarding this matter, a statistical modeling process and analysis has been widely used in the process of wind energy assessment to provide better insight into the behaviors and the variability of the wind regime in a particular area.In fact, a good statistical model will provide accurate forecasting of the wind speed. This will minimize scheduling errors and increase the reliability of the electric power grid. This study investigated the effect of the mean and volatility on the realizations of the wind speed by using a combination of the Autoregressive Integrated Moving Average model and the Autoregressive Conditional Heteroskedasticity model (ARIMA-ARCH model). The results that were obtained show that the ARIMA-ARCH model is able to better forecast the wind speed data than is a single ARIMA model. Thus, it can be conclude that the ARIMA-ARCH model is a good model to use when describing the characteristics of wind speed data.

Contents

1. Introduction

The utilization of wind energy as an alternative source of power is found to provide many advantages in terms of the environment and the economy. In particular, this is true when comparing wind energy and the power that is generated by other energy resources, such as oil, nuclear resources, and coal-based resources, which significantly contribute to environmental pollution and global warming. Wind energy has been recognized as one of the most promising clean energy options worldwide due to its falling cost, while other renewable energy technologies are becoming more expensive [1]. In addition, wind energy can easily be generated in every region that has a suitable wind speed and suitable direction

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Table 1
The 010C Wind speed sensor specifications [10].

Performance characteristics	
Maximum operating range	0–125 mph (0–60 m/s)
Starting speed	0.5 mph (0.22 m/s)
Calibrated range	0–100 mph (0–50 m/s)
Accuracy	± 1% (0.15 mph) (0.07 m/s)
Temperature range	−50 °C to +65 °C (−58 °F to +149 °F)
Distance constant	Less than 5 ft (1.5 m) of flow (meets EPA spesifications)
Electrical characteristics	
Power requiments	12 VDC at 10 mA, 12 VDC at 350 mA for interal heater
Output signal	11 volt (pulse frequency equivalent to speed)
Output impedance	100 Ω maximum
Physical characteristics	
Weight	1.5 lbs (0.68 kg)
Finish	Clear anodized aluminum; Lexan cup assembly
Cable and mounting	
PN 1953	Cable Assembly; specify length in feet or meters
Mounting	PN 191 Crossarm Assembly

characteristics. Thus, the potential of wind energy should be thoroughly investigated in every nation so that the advantages of this easily available source of power can be obtained.Table 1.

In Malaysia, energy efficiency under the Eighth Malaysian Plan (2001–2005) and Ninth Malaysia Plan (2006–2010) also mentioned targeting renewable energy as a significant contributor to the better utilization of energy resources, particularly for wind and solar energy. This emphasis is an effort to integrate alternative energy sources while reducing dependence on petroleum consumption. In fact, various institutions of higher learning and research institutions, such as Universiti Kebangsaan Malaysia, Universiti Malaya and Universiti Teknologi Malaysia, have conducted active research and development in the field of wind energy. Separate from this research, Ong et al. [2]. reported that a 150 kW wind turbine, which was built in Terumbu Layang–Layang in 2005, had demonstrated a certain degree of success. In 2007, the Malaysian Government, under a joint venture partnership with the State Government of Terengganu and Tenaga Nasional Berhad (TNB), which is the only electricity supplier in Malaysia, embarked on the project of integrating the power supply at Pulau Perhentian. The project consists of installing two wind turbines, a solar farm (Solar Panel), a generator and a battery. Conversely, the Ministry of Rural and Regional Development built eight small units of wind turbines in Sabah and Sarawak for the local communities [3,4].

The evaluations of wind energy potential in a particular region involve two major types of assessment: the statistical approach and the site-assessment approach (physical basis) [5,6,7]. The site-assessment approach uses many physical considerations to reach the best prediction precision, for examples see [8,9,10]. While the statistical approach describes a relationship of the on-line measure of power data in order to provide the best short-term prediction, for examples see [11,12,13]. An analysis and modeling that are related to short-term wind speed and its turbulence have been a crucial issue in the wind power industry because the critical difficulty in the utilization of wind energy is that the electricity that is generated by wind power systems is not as stable as the electricity that is generated by other sources. Thus, it becomes challenging to transform wind energy into traditional electricity systems. This problem can be effectively mitigated if the operation of wind farms can be manipulated according to the accurate information of the mean and turbulence of wind speed [14]. Section 2 provide some reviews regarding the rationale reasons behind the wind speed modeling.

2. Some reviews regarding the rationale reasons behind the wind speed modeling

Wind is a motion of air that having a driving force due to the resulting process of the uneven cooling and heating of the earth's surface. The motion of wind is generally being measure in term of speed and its direction with respect to the horizontal movement of the air that corresponds to the parallel to the earth's surface [15]. However, the movement and speed of wind is always having a high variability in time and space. These characteristics of wind need to be describe using the concept of stochastics properties. In the context of wind energy production, the stochastic fluctuation of wind speed will always affect the performance of wind farm. The stochastic fluctuations of the wind speed make a process of forecasting the power produced in a wind farm become very difficult. In fact, the wind speed has been considered as one of the most difficult weather parameters to be model and forecast. Consequently, its cause a difficulties in the energy conversion and power balance of the network. Thus, a good model that able to make a reliable forecasting of wind power is crucial for the management of the wind farm [16,17].

Shamshad et al. [18]. and Lui et al. [19]. described that the electricity generated by a wind power systems are not stable as those generated by other sources, and thus it is more difficult to be integrated into traditional electricity systems. The challenge results from the highly volatile nature of the wind resource. This problem can be significantly mitigated if the operation of wind farm can be controlled based on the accurate information of dynamic wind speed prediction. As such, improving the accuracy of short-term wind speed forecasting has been a longstanding challenge for wind power industry. The same argument has been mentioned by a lot of researchers in the field of wind power research. For example, Sancho et al. [20]. and Guo et al. [21]. described that the performance of the wind power generation always depends on the wind speed fluctuation. The high variability of wind speed makes it be very difficult to forecast the power which will be injected in the distribution network, which can cause difficulties in the energy transportation. Mohammad et al. [22]. stated that the power generating efficiency of a wind turbine will be limited for the shortage of accurate wind information. Thus, wind speed prediction is crucial for the control, scheduling, maintenance, and resource planning of wind energy conversion systems. In addition, Rajesh and Krithika [13]. mentioned that the subject of wind speed forecasting is always becoming increasingly important and pertinent to the operation of electric utilities which integrate wind energy. Jung and Tam [6]. mentioned that the penetration of wind power is limited due to its uncertain and intermittent nature. In order to fully benefit from wind power, accurate wind power forecasting is an essential tool in addressing this challenge. This has motivated a lot of researchers to develop better model to forecast the wind resources and its resulting power. Apart from that, Erdem and Shi [23]. described that the several major problem in the wind power conversion is an intermittent energy source that stemming from various factors, such as wind speed, air density, and turbine characteristics. These problem causes a large variability in the production of wind energy. Among that factors, Erdem and Shi [23]. stated that the wind speed plays an important role for the amount of electricity generated by the wind turbines. The theoretical amount of energy that might be generated from the wind is proportional to the cube of wind speed and slight changes in the wind speed might cause significant changes in the amount of the total electricity generated from the wind. Therefore, an accurate modeling and forecasting of the wind speed will always carries a particular importance. Apart from all of these statements, that a lot of the researchers that has mentioned the same reason regarding the important of wind speed modeling in providing an efficient power energy management.