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Petri net model for wind turbine speed characteristics

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Abstract:
Making use of the energy generated from wind is challenging, because the produced energy is greatly affected by the inconsistency of wind speed. Such different wind speeds cause fluctuating wind power to be generated. Renewable energy can be developed as a substitute to fossil energy to overcome its limitations and avoid the greenhouse gas emissions, which are harmful to our environment. Based on wind velocity measurements, this paper models such random wind speeds as would have an impact on the wind power generation; using Petri Nets (PN) to create a Mat lab model of the wind turbine. Petri Nets use 7 places and 7 transitions in this paper. Likewise, a PN transition is defined as a function that uses the uniform function to generate random values. Wind speed data generated over 500 seconds were compared to observed wind speeds. Similar statistical characteristics have been revealed when generated wind speed values are compared with the observed wind speed values.
Key Word*: wind energy; wind speed; modeling; Petri net; wind turbine; random wind speed.*

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I. Introduction

Wind energy is one of the sources of renewable energy; wind energy is characterized as clean and inexhaustible. Due to the random nature of wind, it is difficult to control the speed and direction of wind, and it is also difficult to use wind energy during certain periods of time; therefore, average wind speed is used (1,2). Varying wind speeds cause the maximum wind power, output from the wind energy conversion system (WECS), to vary as well; the grid frequency is also affected and exhibits variations that cause the deterioration of the quality of the power delivered to the load. Hence, the need for accurate modeling and forecasting, to improve the operation of wind turbines and control the energy conservation systems, has arisen (1).The most critical components of the wind turbines, which are constructed from fiber-enhanced polymer composites, are the blades. The wind blades are manufactured from fiber-enhanced polymer composites, which are resistive to being loaded in hundreds of millions of loading cycles over a more extended period and minimize gravity loads consequences (3). Nowadays, available fiber-enhanced polymer composites are electronic or epoxy resin composites which, as described above, fulfill most conditions at reduced costs. This is why many efforts are made to develop new, more robust and damage-resistant, composites that can be used to produce wind turbines; the produced wind turbines are more environmentally friendly, more recyclable and quicker to produce. Epoxy resin systems have high strength, Low Shrinkage, Excellent adhesion to various substrates. Effective electrical insulation and low-cost lead to less production defects in the blades (4). It is believed that "one of the most cost-efficient electrical energy sources will be wind energy shortly" (5). Giant wind turbines currently constitute the majority of the large wind turbines, which are based on variable speed operations with pitch control. The total system expenses were reduced owing to their ability to capture wind power better, compared with wind turbines at fixed speeds. Due to changes in the electronic power and control equipment of the variable frequency converter systems, it is now possible to optimize the weather conditions efficiently. If the wind turbine is below its wind speed, maximum wind area should be maintained by the rotor blades (6,7) . The timing of the rotor blade is adapted by a variable pitch mechanism to minimize the wind speed and its performance ratio; therefore, the variable timing mechanism plays a vital role in the initial production of wind turbines. The electrical pitch control mechanisms and the hydraulic control mechanisms are currently usually segregated (5). For modeling wind speed, various other methods use neural networks. Utilizing a Markov method (8), statistical wind speed models can be created. Petri Nets may use the underlying Markov model to construct wind speed models and overcome this problem. PN is a state-based modeling method that is more stringent in semantics than an event-based method. Compared to Markov models, PN has fewer states, making the model more straightforward. PN can model a process that has a random and stochastic property. Based on the Markov model, PN has been developed. The advantages of PN models, when compared to other stochastic methods, are straightforwardness (9) and ease of use in conjunction with a State transition diagram. A Petri Net (PN) combines mathematical theory with the representation of the system's dynamic behavior (10). The Petri Net frame provides a robust set of components, used for determining state transition as well as event planning mechanisms in the discrete stochastic event system (2)(11) .The main aim of this project is to model random and variable wind speed characteristics. Our approach relies on Petri net modeling to model the wind power generation. An improvement on the prediction accuracy of the system is also sought.

II. PETRI NET MODELS OVERVIEW

A Petri net model expresses asynchronism and finds the logical relationship between image and system operations through simple mesh graphics. It has strict mathematical definitions. Petri nets are excellent at representing the fluidity of resources in a system. When establishing a Petri net model for a system, the system's places and transitions should be determined first. Petri networks are also very useful for modelling and analyzing versatile production systems, as they provide precise models and efficient analysis methods (4,12) .

III. MATERIALS AND METHODS:
APPLINY PETRI NET IN THE MODELING OF WIND SPEED

The collected data are modeled and combined for 10 minutes. We model wind speeds on a time scale in categories. It takes only a few seconds to 1800 seconds, which is helpful to regulate taken measures. Wind speed data, generated synthetically over an interval of 500 seconds, are obtained as shown below (Figure 1).

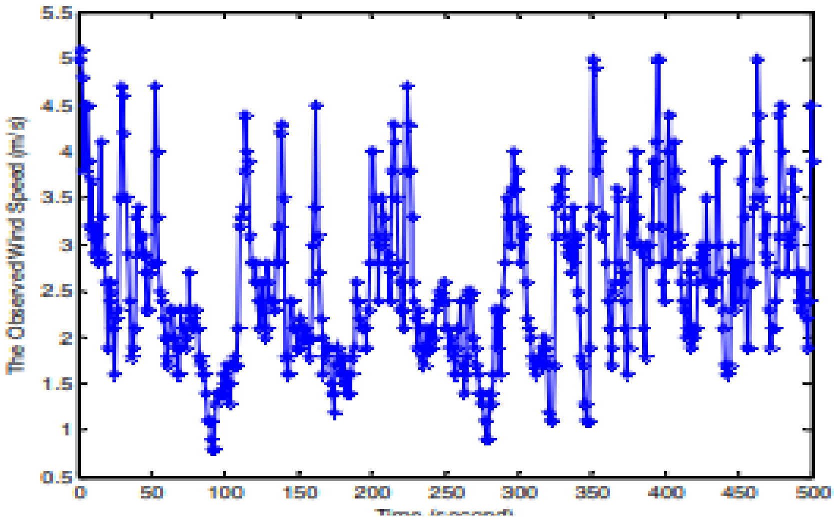

Figure no 1: Wind Speed Data observed

The probability is solved with an equation for each of the classes:

$$P_i = \frac{N_s}{N_t} \quad \_\_\_\_\_\_\_\_\_\_\_\_ (1)$$

$$0 < P_i < 1 \quad \_\_\_\_\_\_\_\_\_\_\_\_ (2)$$

$$\sum_{i=1}^{6} P_i = 1 \quad \_\_\_\_\_\_\_\_\_\_\_ (3)$$

N_s indicates how many wind speed entries there are, N_t indicates the number of wind speed data entries in total. The total probability of all the classes is 1, the calculation of the probability is shown in Table 1.

Table no 1: Wind Class Probability

wind class	Rang M/S	Probability
class one	0-1 M/S	.02
class two	1-2 M/S	.32
class three	2-3 M/S	.43
class four	3-4 M/S	.16

class five	4-5 M/S	.06
class six	5-6 M/S	.01

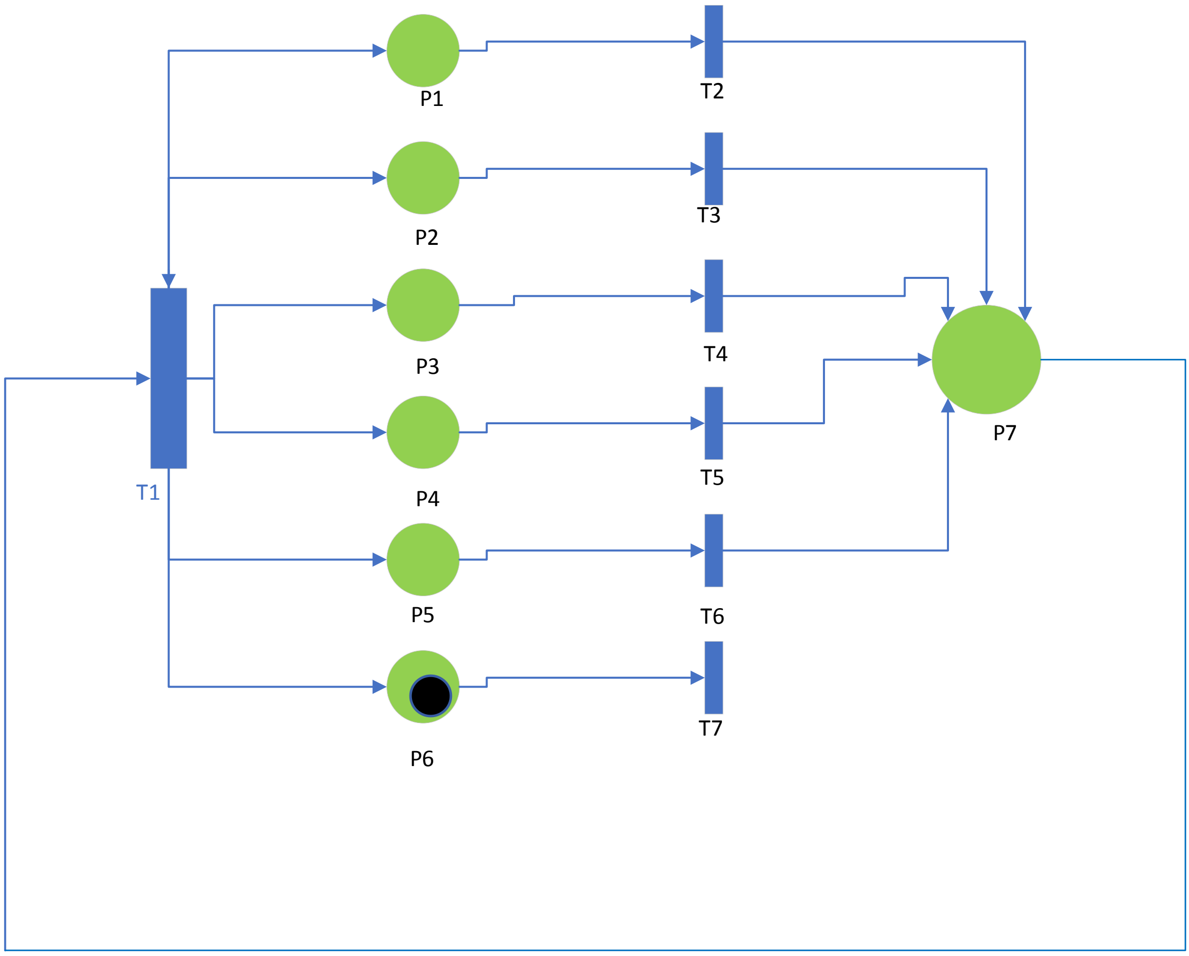

Figure no 2: Petri net model of wind speed

Random variables for speed when using Petri Net:

$$W = (P, T, I, O, Mo, h) \quad (4)$$

"P is the set of places, and T is the set of Transitions," O is the output matrix, and I is the input matrix. "Mo is the initial marking, and h is the probability of the different wind classes." The Markov chains mark the PN over time. PN is defined as a function that uses a unified function to generate random values (11). Similarly, a wind class is determined using uniform random values for the generation of wind speed values. T1, for example, "uniformly generates a random value to determine the locations (P1–P6), which contain a token based on a class probability. If P6 includes the token, T7 can produce a uniform random value. Place P7 contains a token which is the resulting wind speed value".

Table no 2: Explanation of Place and Transition

place	Explanation	Transition	Explanation
P1	First wind class	T1	Generating value for determining
P2	Second wind class	T2	Generating value for range 0-1m/s
P3	Third wind class	T3	Generating value for range 1-2m/s
P4	Fourth wind class	T4	Generating value for range 2-3m/s
P5	Fifth wind class	T5	Generating value for range 3-4m/s
P6	Sixth wind class	T6	Generating value for range 4-5m/s
P7	Generated wind speed data	T7	Generating value for range ≥5m/s

IV. MATLAB SIMULATION FOR WIND TURBINE MODEL

The variable-speed variable-pitch process can be established according to the control strategy. When the wind speed is less than 5m/s, the output power of the wind turbine is so low that it cannot be benefited from. " When the wind speed is more than 5m/s, the wind turbine is in operation and starts generating electrical energy". The speed of the wind turbine is adjusted in time; to maintain the best tip ratio and obtain maximum wind power capturing, the wind turbine is controlled by the control system. The speed of the wind turbine is changed through the control system if its wind speed exceeds the set speed rating (13).The blades' angle of attack limits the wind energy collection to keep the rated power output; the turbine is shut down if the wind speed exceeds the safe value (to 25m/s) to ensure the wind turbine functions correctly. The procedure is as follows: When 0 m/s ≤ V < 5m/s, the wind turbine generator is in shutdown state and the output power P = 0; When 5 m/s ≤ V <7 m/s, the wind turbine is in a paused state and the output power P = 0; When 7 m/s ≤ V < 14 m/s, 5 m/s is the cut-in wind speed and 14 m/s is the rated wind speed, the wind turbine is in operation and the control system is used for variable speed control. At this stage, the pitch angle is 0, and the output power is shown in formula 5:

$$P = 0.5 p \pi R^2 V^3 C_p \qquad (5)$$

When 14 m/s ≤ V < 25 m/s, the wind turbine is in operation, it uses the control system to perform pitch control to limit the capturing of wind energy, and the output power P tends to the rated value and reaches the maximum; When V ≥ 25 m/s, to prevent the wind turbine from malfunctioning, the wind turbine performs an emergency shutdown, and the output power P = 0 at this time (14).

V. RESULTS

The generated random variables and wind speed data (Figure 2), applied in Petri Net, show little similarities with the observed data shown in Figure 1; however, this data has a higher average than the data in Figure 1, as shown below.

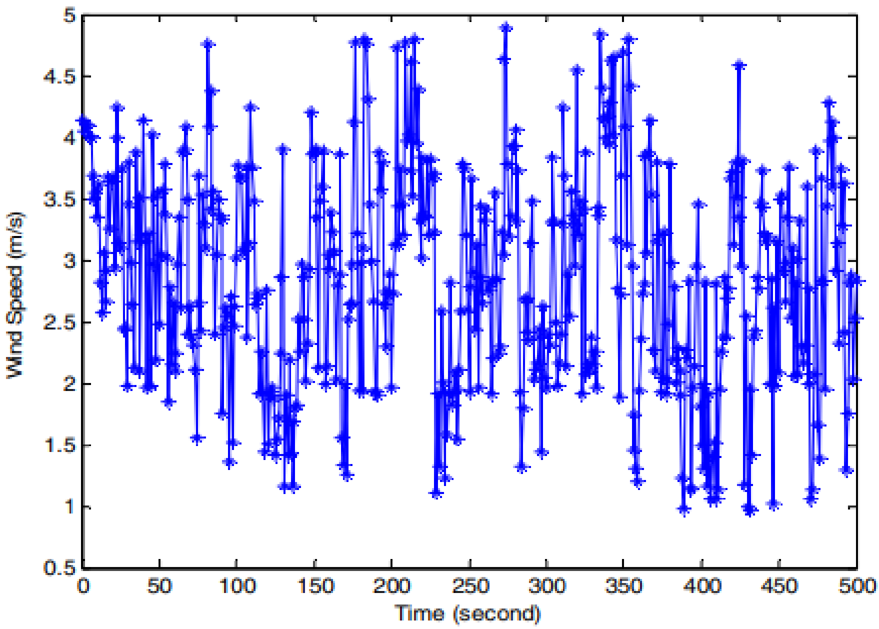

Figure no 3: Generated Random Wind Speed data

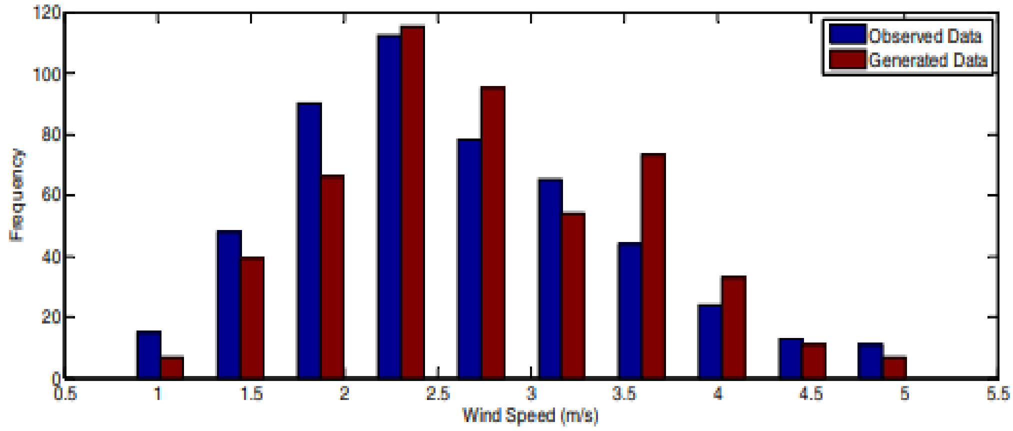

Figure no 4: Frequency results for both observed and random wind speed data

When generated synthetically, wind speed data have been found to have a standard deviation that is comparable to the observed data; its average is higher though. Modeled wind speed was different by a mean of 0.17 m/s, with a comparable standard deviation. According to (15), using Markov model results in a 0.08 m/s mean difference and a 0.08 m/s standard deviation difference. However, the simple wind speed models produced by stochastic petri nets have a number of states that is less than the number of states of wind speed models produced by the Markov model. The calculation of frequency (or histograms), taken from the generated wind speed, was also carried out, and then the comparison with the observed data followed (shown in Fig.4). As seen in the Figure, the values and classes of the highest frequency, manifested in both the generated and observed wind speed data, are the same.The results are shown in the table below.

Table no 3: wind speed data observed and wind speed randomly Generated

	observed Speed Data	Random Wind Speed
Min	1.7 M/S	1.9 M/S
Max	6.11 M/S	5.96 M/S
Mean	3.57 M/S	3.73 M/S
Deviation	0.77 M/S	0.77 M/S

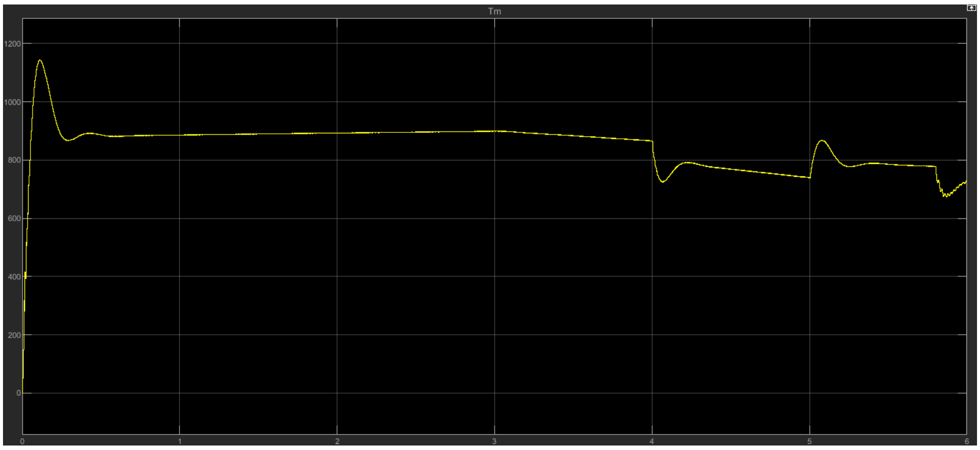

Figure no 5: Output Mat lab Simulation for Wind Turbine Model

VI. DISCUSSION

This control technique is made more accessible by directly measuring the wind speed rate, but this is not a suitable method, as precise wind speed is difficult to calculate. "Indeed, when the speed of the rotor reaches the turbine's maximum rotor speed, the angle of pitch is increased to minimize the Ct torque of the turbine. The speed is compared to the reference of the controlling rotor. In terms of synthetic wind speeds, our simulations are statistically similar to those of the observed wind speeds. The standard difference between the calculated wind speed is the same as that of the produced data. Wind speed is a random phenomenon that is hard to monitor. Our plan is to model wind speeds observed over short terms with colorful Petri networks and explore the long-term model for wind speed forecasting in our future work. A Petri's networking model for an information processing system is developed and analyzed to inform us of the system structure and dynamics; will help test and change the system to be created. Control mechanisms are seen in detail and concisely in Petri networks, in particular, the complex behavior.

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