Modeling and Simulation of Wind Turbine under the Condition Prevailing in and around Jodhpur District

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ABSTRACT
Wind energy is the most promising renewable energy and it has been used widely all over the world. In this paper, modeling and simulation of wind turbine power system is presented. The modeling and simulation is performed using MATLAB/Simulink. The output curves of the Simulink model (voltages, currents and power) are also presented. The simulation is carried out to investigate the effect of change of wind speed and the pitch angle on the performance of wind turbine connected to a load. The monthly average wind data is taken for Jodhpur district of Rajasthan. The output power of the system is observed for various values of wind speed and pitch angles The analysis of the results demonstrates the effectiveness of the constructed Simulink model which can be used to predict the performance of the wind turbine generator system.

Keywords
Wind energy, Wind speed, Pitch angle, Simulation,

MATLAB/Simulink.

1. INTRODUCTION
The use of non-conventional energy sources is grown exponentially. The conventional energy sources of electricity such as coal, gas and oil has been reduced from year to year. So there is a need to find another source to produce stable electricity generation. [1]. Wind energy is one of the fastest growing renewable energies in the world. The generation of wind power is clean and non-polluting; it does not produce any byproducts harmful to the environment. Modeling is the basic tool for analysis, such as optimization, project, design and control. Wind energy conversion systems are very different in nature from conventional generators, and therefore dynamic studies must be addressed in order to integrate wind power into the power system [2].

Wind energy has been deemed clean, inexhaustible, unlimited, and environmental friendly. Such characteristics have attracted the energy sector to use renewable energy sources on a larger scale. However, all renewable energy sources have drawbacks. Wind source is dependent on unpredictable factors such as weather and climatic conditions. The wind turbine captures the winds kinetic energy in a rotor consisting of two or more blades mechanically coupled to an electrical generator. The turbine is mounted on a tall tower to enhance the energy capture [3].

2. MODELING AND SIMULATION
The wind turbine is characterized by the non-dimensional curves of the power coefficient as a function of both tip speed ratio and the blade pitch angle. The tip speed ratio is the ratio of linear speed at the tip of blades to the speed of the wind [4]. In order to simulate the wind turbine as part of a distribution system, the wind turbine block available in MATLAB/Simulink taken as the reference block as shown in Fig.1. Default parameters are taken for further work.

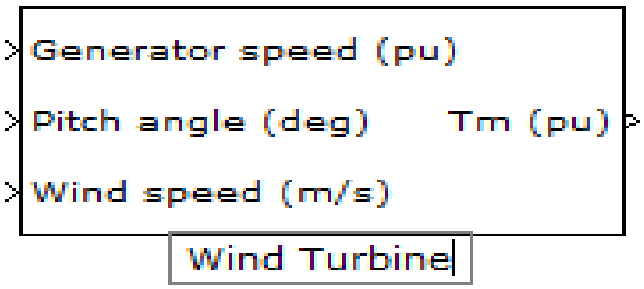

Fig. 1 Wind turbine block

The input quantities are as follows:-

Pitch angle (deg) = 0

Wind speed (m/s) = 10 m/s

Asynchronous Generator (Squirrel-cage rotor type)

Nominal power = 4 KVA

Voltage (line to line) = 400 V

Frequency = 50 Hz

Now, this block is further used to investigate the performance of the wind turbine connected to load for various value of wind speed and pitch angle as shown in Fig. 2.

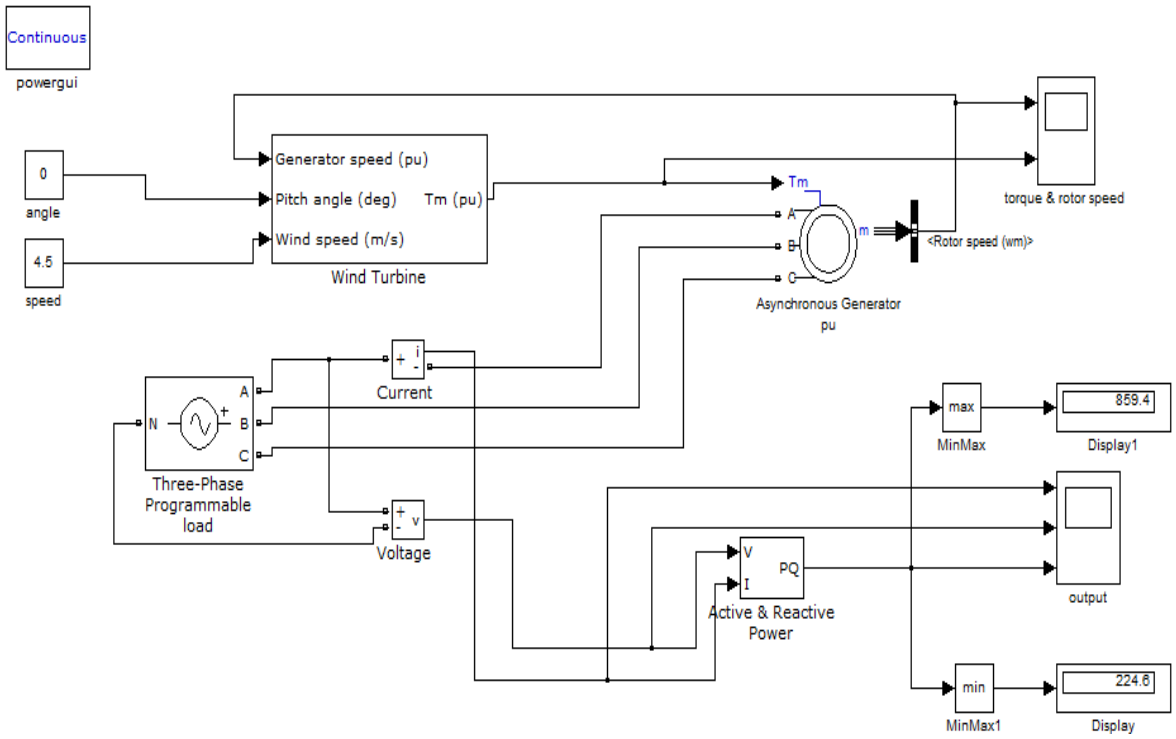

Fig. 2 Wind turbine model

The final model shown in Fig. 2 takes wind speed and pitch angle as input parameter and gives the output current, output voltage and output power as shown in Fig.3.

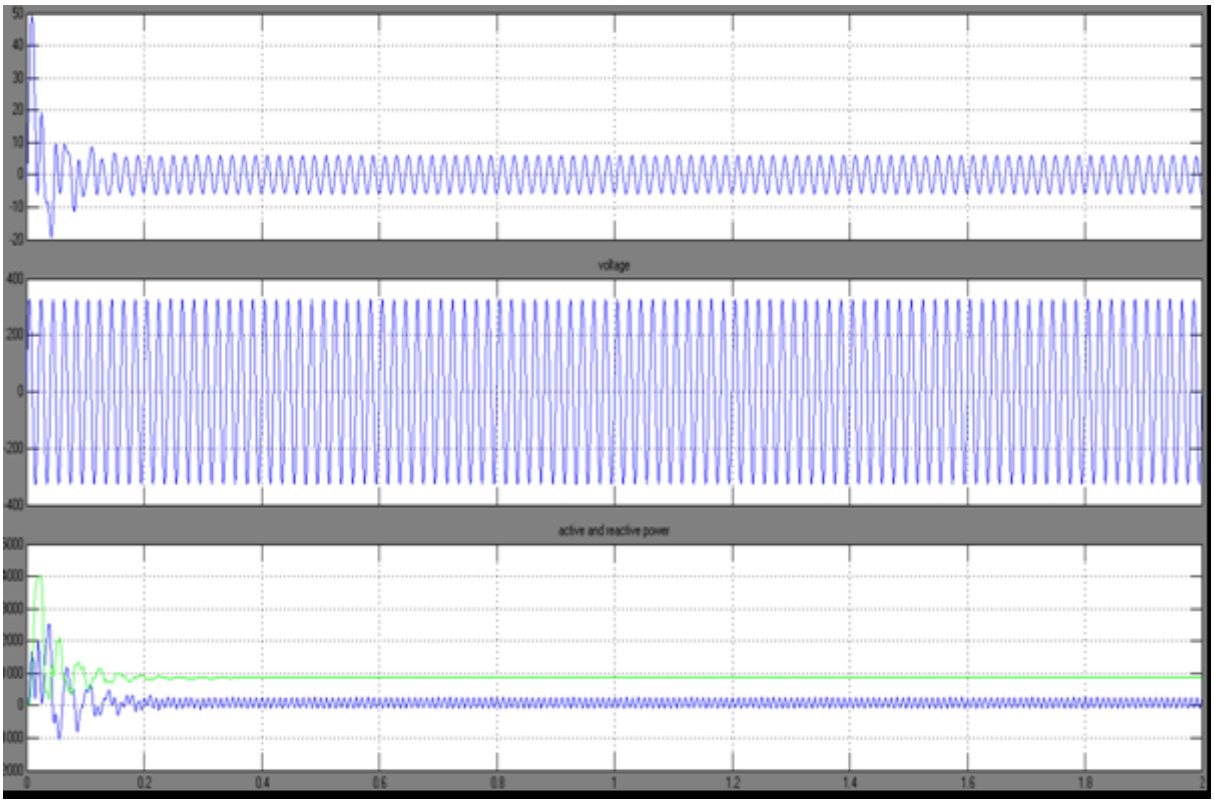

Fig. 3 Wind turbine model output

3. PERFORMANCE CHARACTERISTICS

Both wind speed v/s output power and pitch angle v/s output power characteristics of developed model have been simulated. The average monthly wind speed data is taken for Jodhpur district as shown in Fig. 4. [5]

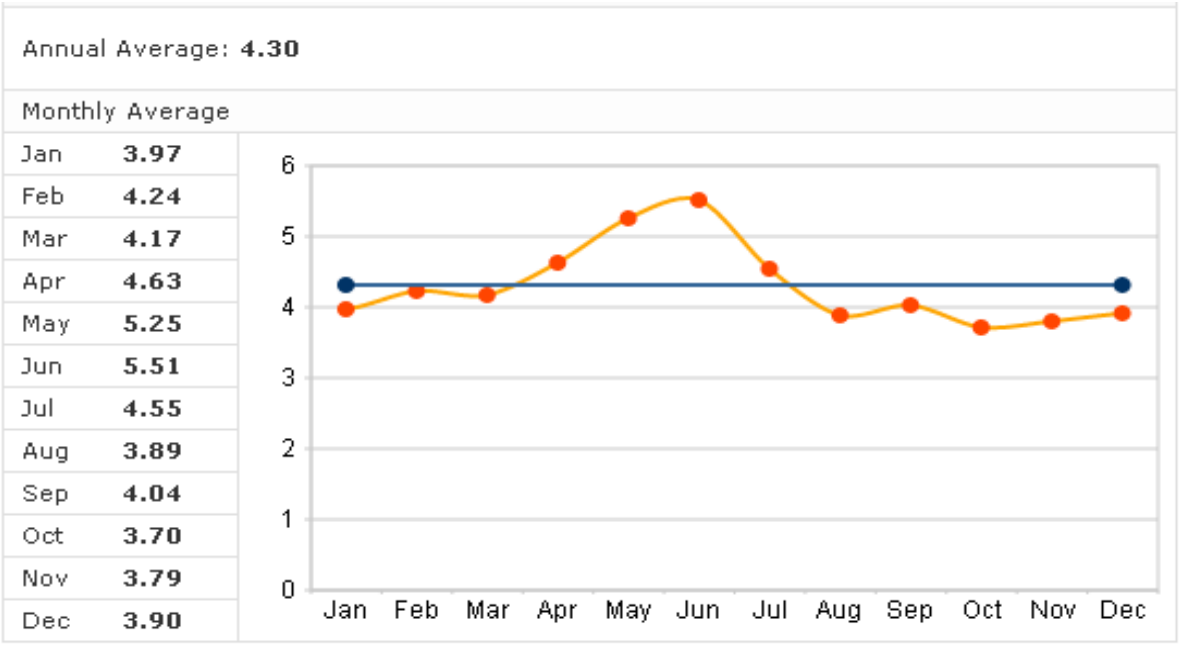

Fig. 4 Average monthly wind speed data

3.1 Simulation for Different Wind Speeds

The maximum and minimum value of output power for different wind speeds is shown in Table 1.

Table 1. Maximum and minimum value of output power for different values of wind speed

Month	Wind speed (m/s)	Max. power (W)	Min. power (W)
Jan	3.97	858.5	249
Feb	4.24	858.9	238.2
Mar	4.17	858.7	241.4
Apr	4.63	859.7	215.3
May	5.25	861.9	161.9
Jun	5.51	863.3	134.5
Jul	4.55	859.4	221.4
Aug	3.89	858.4	251.3
Sep	4.04	858.5	247.3
Oct	3.70	858.2	256.1
Nov	3.79	858.3	254
Dec	3.90	858.4	251.1

Wind speed v/s power output characteristics under different wind speeds with constant pitch angle are obtained and are shown in Figures 5(a) and 5(b).

Base wind speed = 10 m/s

Pitch angle = 0 degree

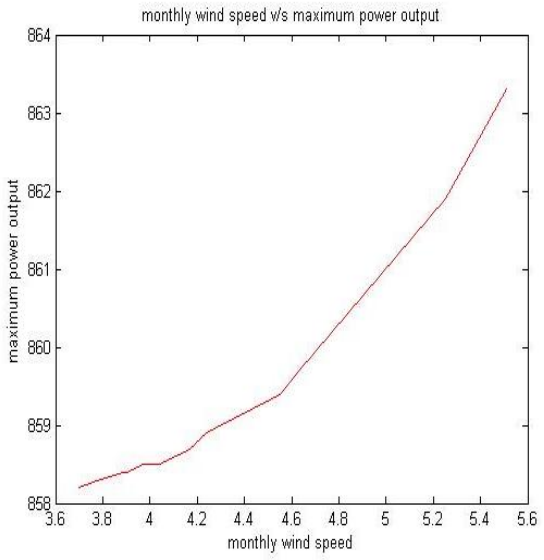

Figure 5(a) Wind speed v/s maximum power output characteristics for different wind speeds

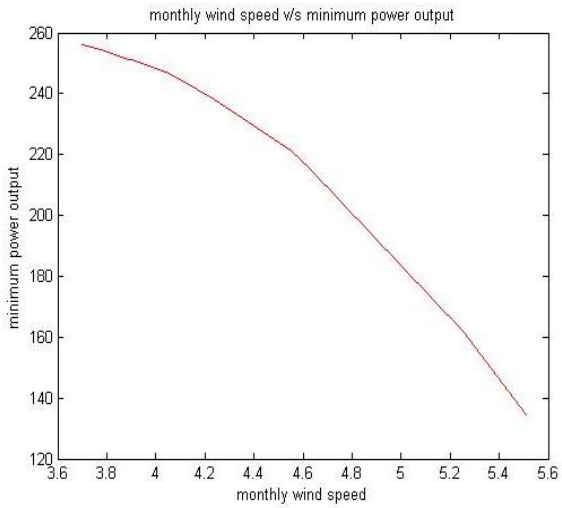

Figure 5(b) Wind speed v/s minimum power output characteristics for different wind speeds

3.2 Simulation for Different Pitch Angles

The maximum and minimum value of output power for different wind speeds is shown in Table 2.

Table 2. Maximum and minimum value of output power for different values of pitch angel

Pitch angle	Max power	Min power
0	859.4	224.6
10	860.2	203.7
20	856.6	311.7
30	854.5	431.1
40	854.5	565.1
50	857.2	710.7
60	866.9	863.2
70	1043	873.4
80	1225	888.6
90	1425	909.9

Wind speed v/s power output characteristics under different pitch angles with constant wind speed are obtained and are shown in Figures 6(a) and 6(b).

Base speed = 10 m/s

Wind speed = 4.5 m/s (avg)

The inclusion of pitch angle control in a wind turbine is though very valuable but it is very costly. [6] So much so the turbine blade junction becomes weak and is prone to failure. Due to this reason most of the practical installations do not use this feature. However, additional advantages of extracting more power from the wind by pitch angle control have been obtained by simulation as shown in table 2.

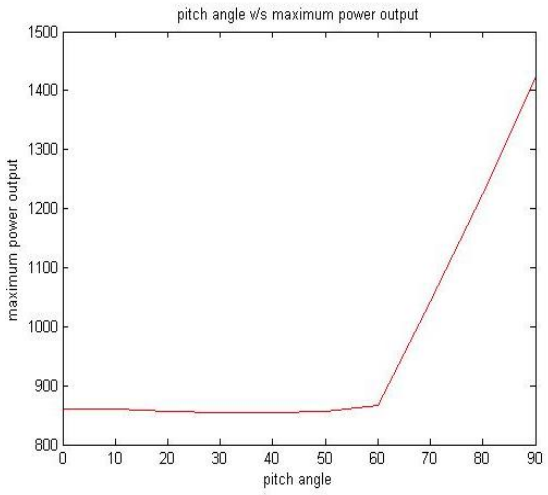

Figure 6(a) Wind speed v/s maximum power output characteristics for different pitch angles

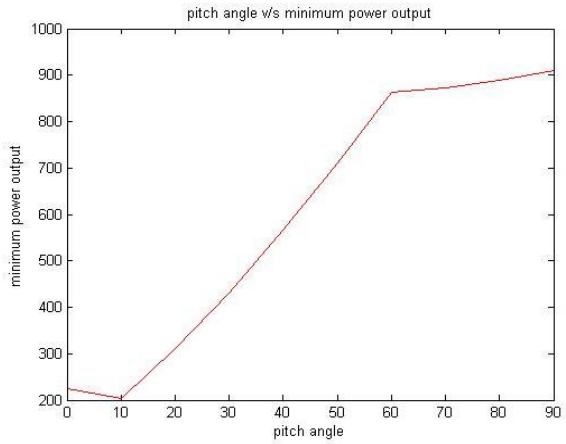

Figure 6(b) Wind speed v/s minimum power output characteristics for different pitch angles

4. CONCLUSION

Modeling and simulation has been conducted for investigating performance of a wind energy system. The modeling and simulation is performed using MATLAB/Simulink. Different output has been taken for various values of wind speed with constant pitch angle and also for different values of pitch angle with constant wind speed. To test the performance o the proposed model, wind turbine responses both to a steep increase in wind speed and blade pitch angle were simulated. In both cases, the proposed model gave valuable insight into the performance of the variable speed wind turbine. As expected, the power generated increases with the wind speed, confirming the need of some sort of power control. On the other hand, an increment in the blade pitch angle proved to shed the aerodynamic power. As a normal dynamic simulation time step was adopted, this model was proven to be computationally efficient. This paper also provides a clear and concise understanding of the output characteristics of wind turbine and the effect of change of wind speed and pitch angle on these characteristics. The proposed model is expected to serve as the basis model for carrying out study by the researchers in the field of wind turbine modeling.

5. REFERENCES

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