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IMPROVING THE POWER GENERATION EFFICIENCY OF WIND TURBINE GENERATION USING WIND TRACKER

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Abstract

This work presents improving the power generation efficiency of wind turbine generation using wind tracker. The aim is to optimize the performance of the turbine by sensing the direction where the wind has its maximum intensity and then adjust the turbine to that direction. This was achieved using mathematical modeling of the wind turbine and then the development of the wind tracker system to model the improved wind turbine system. The models were implemented on Simulink platform and evaluated. The result showed that 3259KW of power was average generated when simulated which is 93% efficient. The result of comparative analysis with a characterized wind turbine without wind tracker achieved 3146KW as against 3255KW in the new system, thus presenting a percentage improvement of 3.35%.

Keywords: wind tracker, wind turbine, generator, Simulink, wind energy, power

I. INTRODUCTION

Currently the demand and rate of power consumption has increased drastically on a global level and the use of fossil fuel as the only means of power generation on a global scale has become unreliable. Therefore, researchers have proposed various other alternative means for the generation of power to improve the already existing power generating system. Wind energy has been a major focus as one of the most promising sources of sustainable renewable energy.

According to Knudsen et al., (2015), the application of wind energy for power generation experienced a huge growth of about 3% of the global power production as in the year 2014, according to the global wind energy council.

Kim et al., (2013) posited that wind energy has experienced a substantial growth in recent times; it produced over 194.4GW of power in 2010; despite the economic crises. This growth has contributed to the industrial growth and revolution of businesses and production sector. Although this means of energy production success is posed with its own challenges and limitations. The most disturbing of the challenges is that of the blade rotor structure which is composed of a subsystem that is susceptible to damage as well as bearing, spindle or gearbox failure (Ogbuefi, 2018). Facts show that an estimate of 63.4% of the structural damages encountered in the wind turbines that leads to accident is caused by the sudden deformity or displacement changes between the blade and the tower in the early stage of the turbine's life (Alfreido et al., 2017).

It has been observed that researchers have paid more attention to the electrical and electronic contribution of this technology, thereby paying less or no attention to the mechanical or aerodynamic aspect of it (Karagali, 2012). Therefore, this paper presents a different scope for this means of power generation by employing an intelligent methodology which will help in optimizing the generation capacity of the wind turbine using wind tracker.

The wind tracker is a novel approach which tracks the direction and speed of the wind around a turbine, then uses a controller to adjust the turbine to the path of the incoming wind. By this way, the turbine will exact a maximum wind energy exposure, thereby ensuring an improved power generation capacity (Smith et al., 2004).

II. METHODOLOGY

The methodology developed a 3500KW wind turbine system using the turbine, synchronous generator, and wind tracker. The wind turbine extracts the wind energy from the environment into mechanical energy then the 3.5KVA, 2-pole 230V; 50Hz asynchronous generator converts the mechanical energy into electrical energy. The wind tracker was installed on the turbine to optimize the energy extraction via the tracking of wind direction based on Doppler effects. The improved wind turbine developed was modeled using self defining equations and implemented with Simulink.

III. SYSTEM DESIGN

This section presented the modeling of the wind turbine system and the wind tracker to optimize energy extraction and power generation as;

Wind Turbine Model

To develop the model of the wind turbine, the relationship between the air density, pitch angle, wind speed, swept area and mechanical output are related using the equation 1;

$$P_m = c_p(Л, ß)\frac{pA}{2}v^3{}_{wind} \qquad (1)$$

Where Pm is the mechanical power output of the generator (W), c_p is the coefficient o the turbine performance, P is the air density, A is the swept area, v_{wind} is the wind speed, Λ is tip speed ratio of the rotor blade speed to wind speed and B is the pitch angle of the blade. The total power (P_w) delivered to a wind turbine can be estimated by the derivative kinetic energy resulting in the equation as;

$$P_w = \frac{\rho A u^3}{2} \qquad (2)$$

A is the swept area of turbine blades, in m^2; ρ = air density, in kg/m^3; u = wind speed, in m/s.

The process of converting wind power to electrical power results in low efficiency and losses. The electrical power output (P_e) of a practical wind turbine can be described using the following equation as:

$$P_e = \frac{C_{tot}\,\rho\,Au^3}{2} \qquad (3)$$

WhereC_{tot} = overall efficiency, while other variables were already defined. The overall efficiency is between 0.3 and 0.5, and varies with both wind speed and rotational speed of the turbine. For a fixed rotational speed, there is a rated wind speed at which electrical power generated by the wind turbine is near its maximum (P_{er}), and overall efficiency at this point is denoted as (C_{totR}).

$$P_{er} = \frac{C_{totR}\,p\,Au^3}{2} \qquad (4)$$

Development of the Wind Tracker

The wind tracker employed the Doppler effects properties to track the wind speed and direction based on boundary layer reflections using wake model in equation 5 to determine the wind angle and velocity and then extract the scattering particles as the wind energy and feed to the turbine for power generation. Wake model was used to estimate the wind angles and other aerodynamics parameters at dynamics physical processes as shown in equation 5 (Mollica, 2017) while the flow chart of the wind tracker is in figure 1;

$$V_x = V_a[1 - \frac{\sqrt{1-C}}{1+2a\{\frac{x}{2(R+ax)}\}^2}] \quad (5)$$

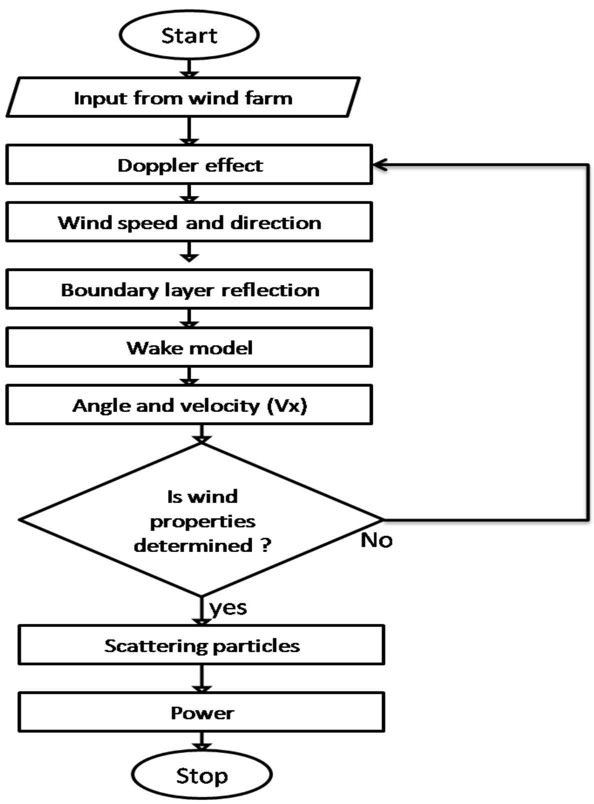

Figure 1: Data flow chart of the wind tracker

IV. IMPLEMENTATION

The model of the wind turbine system was implemented with Simulink. This was achieved using the wind turbine model, the wind tracker model, the model of the wind tracker and the asynchronous generator. The Simulink transfer function of the motor is presented in figure 2, while the Simulink of the transfer function of the wind turbine is presented in figure 3;

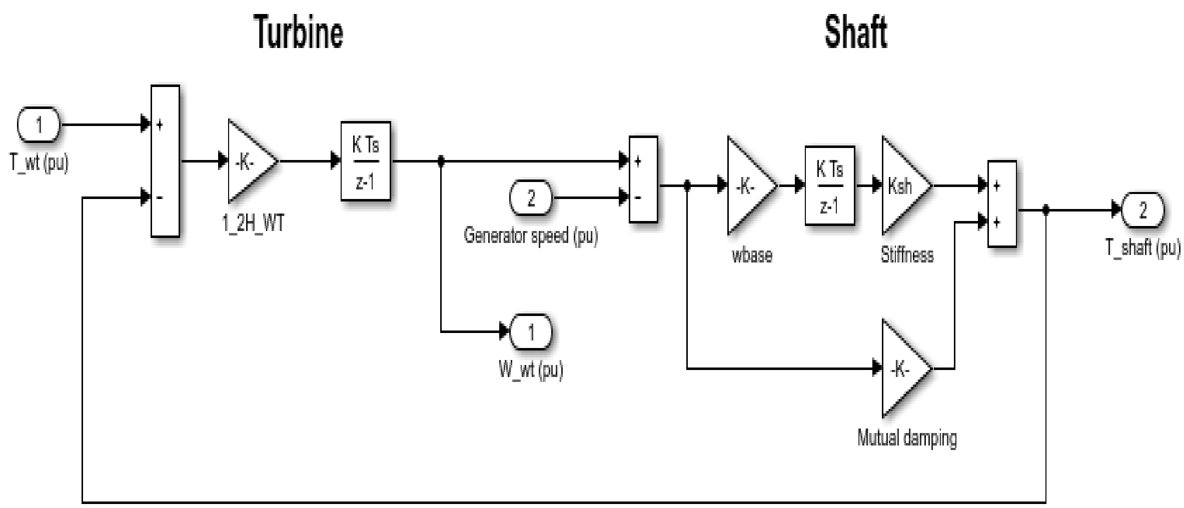

Figure 2: Simulink transfer function of the asynchronous motor

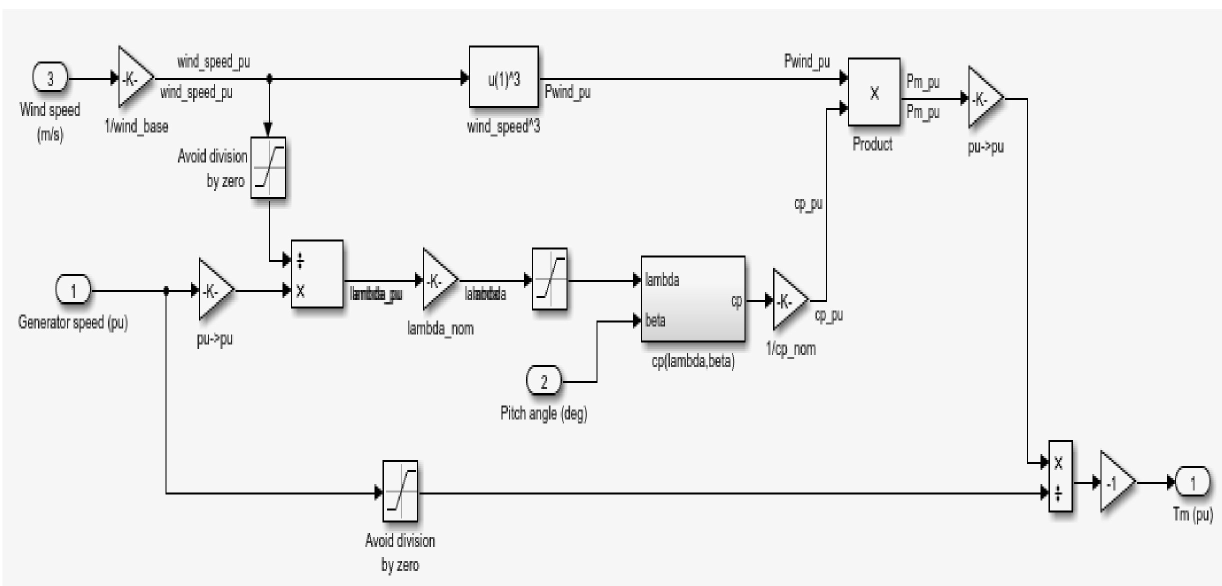

Figure 3: Simulink transfer function of the wind turbine

The model in figure 2 and figure 3 were used to develop the optimized wind turbine system with tracker using power system toolbox as shown in figure 4;

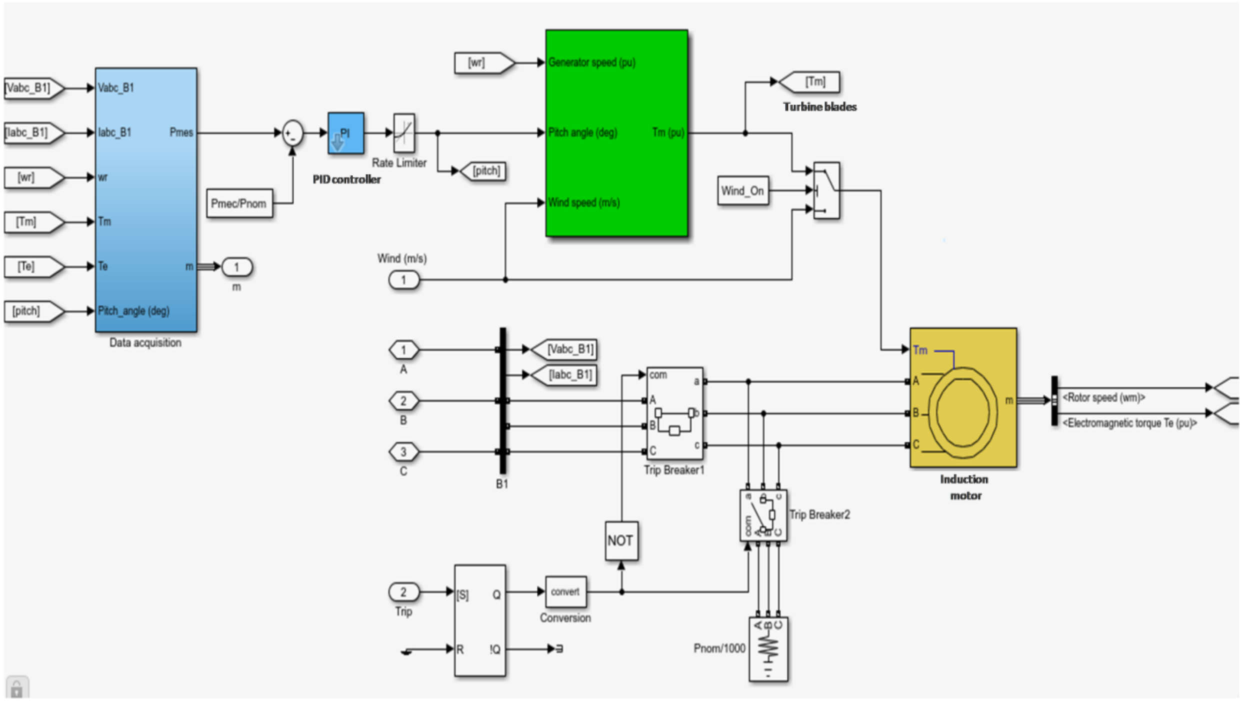

Figure 4: Simulink model of the wind turbine

The Simulink model of the wind turbine presented in figure 4 showed the data acquisition system using the wind tracker developed the wind turbine system which extracts the data acquired by the blades and then converts to electrical energy using the asynchronous generator. The simulation of the wind turbine was done using the parameters in table 2;

Table 2: Simulation Parameters

Parameters	**Values**
Power rating of generator	3500W
Stator voltage	0.69KV
Connection	Y type
Nominal turbine speed	18rpm
Radius of the turbine blade	50m

Shaft tensional damping	1.4.10^6Nms/rad
Shaft stiffness	83.10^6Nm/rad
Rotor inertial of turbine	6.1.10^6kg-mm^2
Stator resistance	0.012ohm
Rotor resistance	0.012ohm
Number of pole pairs	2
Rated current	1900A
Mutual inductance	0.0135H
Rotor inductance	0.0136H
Stator inductance	0.0137H

V. RESULTS AND DISCUSSION

This section presented the performance of the wind turbine when simulated with the parameters in table 2 and the result is presented in figure 5;

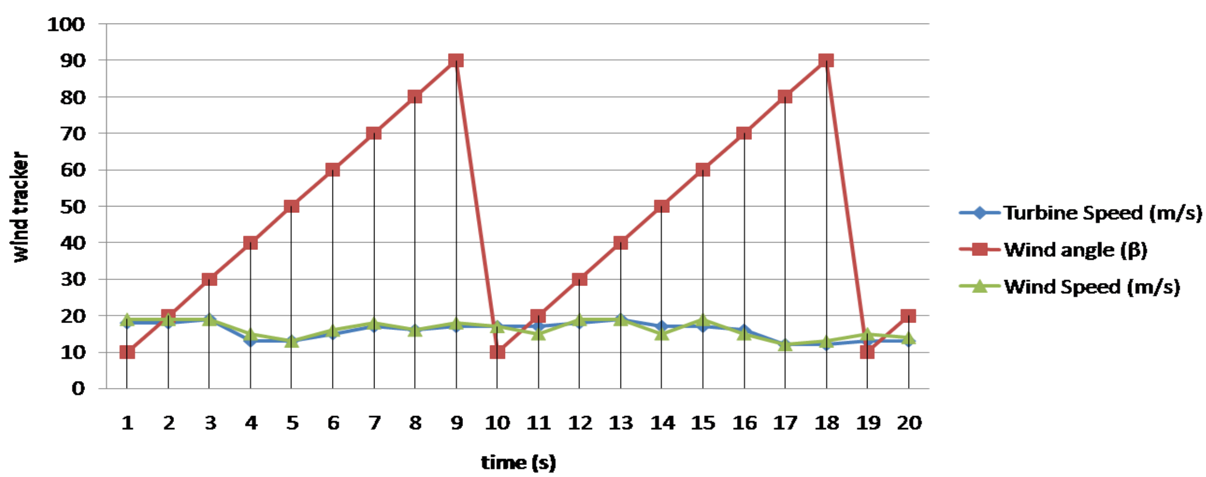

Figure 5: performance of the wind tracker

The figure 5 presented the performance of the wind tracker how it was able to tracker the wind properties based on Doppler Effect to determine the wind angle and speed and hence extract the scattering particle by the turbine blade and feed to the generator for energy conversion. The power output generated by the turbine is presented in figure 6;

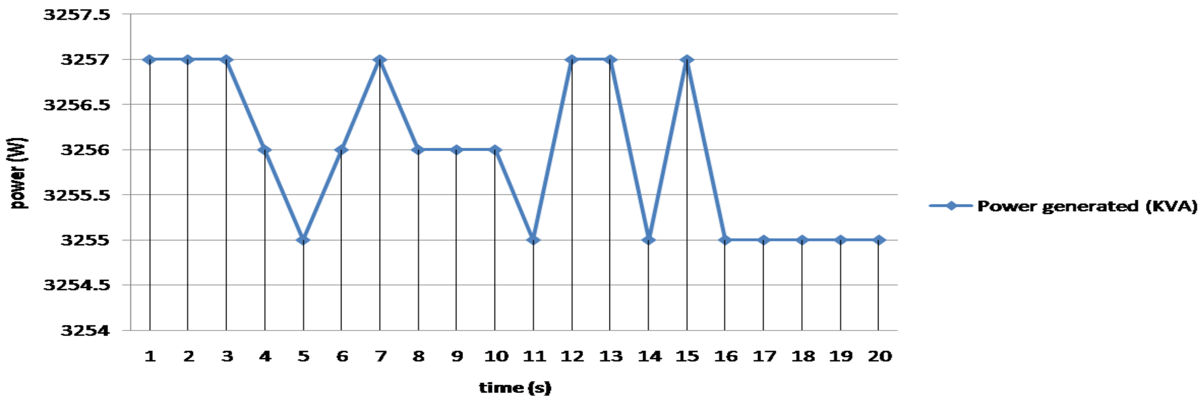

Figure 6: Power generated with wind tracker

The figure 6 presented the power generated in the wind turbine using the model in equation 3.2. The result showed that the wind tracker was able to guide the turbine to generate enough energy which ensured maximum power generation with an average capacity of 3256KW and efficiency of 93%. The figure 7 presented the performance of the turbine without wind tracker.

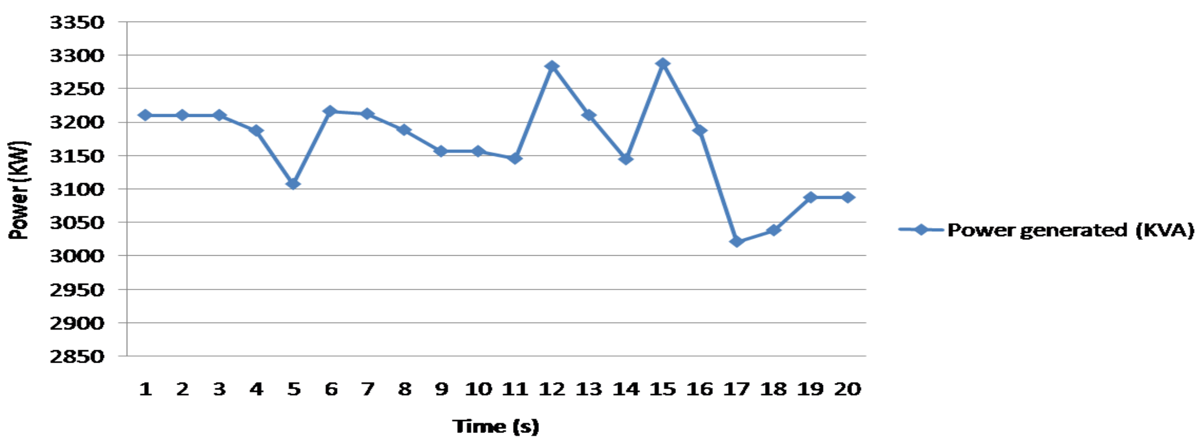

Figure 7: Power generated without wind tracker

From the figure 7, the average power generated without wind tracker was analyzed in the graph of figure 7 and the result showed that 3146KW was achieved. The result also showed that there is high nonlinear behavior in the power generated due to the unstable nature of wind input. The figure 8 was used to present a comparative analysis conducted on the result with wind tracker and without wind tracker.

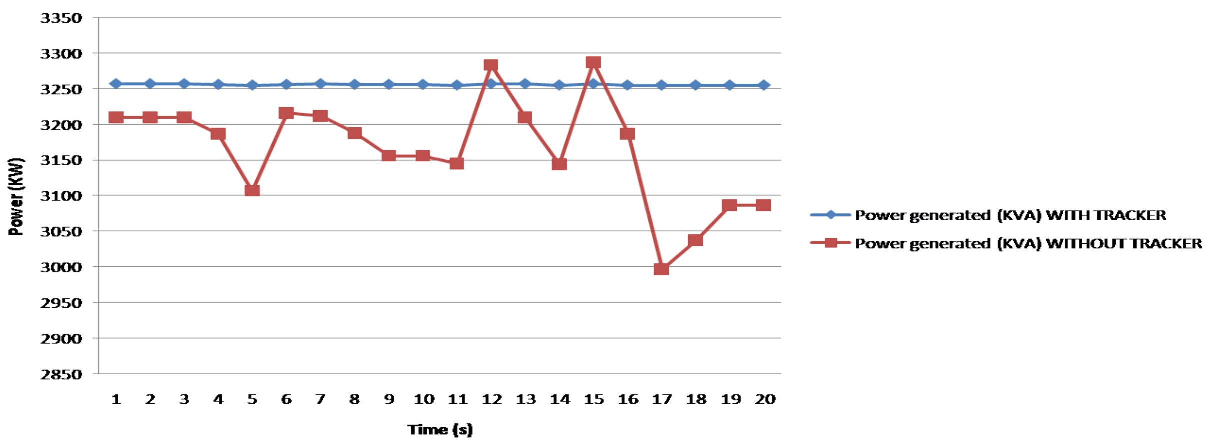

Figure 7: Comparative performance of the power generated

From the comparative analysis it was observed that with the wind tracker, the power generated was fairly constant unlike without wind tracker of which the power generated fluctuated based on the dynamics of wind. The average power generated is 3255KW as against 3146KW without tracker, thus presenting a percentage improvement of 3.35%.

VI. CONCLUSION

This paper showed how wind tracker was used to improve the efficiency of power generation in a wind turbine. The wind tracker was developed and integrated on the wind turbine for optimal extraction of wind energy. This was implemented with Simulink and evaluated. The result showed that with the tracker, power generation was improved by 3.35%.

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