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IMPROVING THE POWER SYSTEM STABILITY OF A WIND TURBINE SYSTEM USING DOUBLY FED INDUCTION GENERATOR

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ABSTRACT

This research presents improving the power system stability of a wind turbine system using Doubly Fed Induction Generator (DFIG). This was embarked on with the aim of guaranteeing quality and stable power output irrespective of the variation of wind behavior. A model of 9MW wind turbine was developed and then improved with DFIG as the generators developed with a thyristor based back to back converter system which can optimize power. The model was implemented with Simulink and evaluated. The result showed that the average power generated is 8.931MW which is an efficiency of 87.5%. A comparative analysis of the wind turbine with DFIG and without DFIG was performed and then the power generated without DFIG is 6.573MW giving an efficiency of 73.03% as against with DFIG which the average power generated is 8.931MW which is an efficiency of 88.12%. The percentage difference improvement achieved is 15.09%.

Keywords: DFIG, Wind Turbine, Wind, Converter, Generator, Efficiency, Simulink

I. INTRODUCTION

Over the years the inadequate power generation in Nigeria has triggered the need to adopt alternative measures for power generation by private individuals. One of the most used is the wind turbine. However, the unstable nature of the energy source has remained a major problem as the power output is always unstable (i.e when the wind speed is slow or reduced, the power generated is reduced). To solve this problem various control solutions were proposed which try to improve the extraction of wind energy via remote sensing using devices like the laser diode (Rodrigo et al., 2014; Steve and Eamon, 2016) and also the employment of generators like induction generators (SubirDatta et al., 2014; Shwe, 2014), however despite their success there is still the problem of instability in power generated via the wind turbine system. To solve this problem there is need for a system which has the capacity to regulate the power to steady state, irrespective of the wind speed so as to achieve quality of power output. This will be achieved in this research using doubly fed induction generator. This is an electromechanical system which has the capacity to control power fluctuation when wind speed reduced and guarantee steady state using power electronic components like the thryristors.

II. Model of a wind turbine system

The model of the wind turbine under study is a 9MW wind turbine system which is made up of the turbine system which converts the wind energy into mechanical energy; the generator then converts the mechanical energy into electrical energy and then transmits to the grid via the transformer as shown in the figure 1.

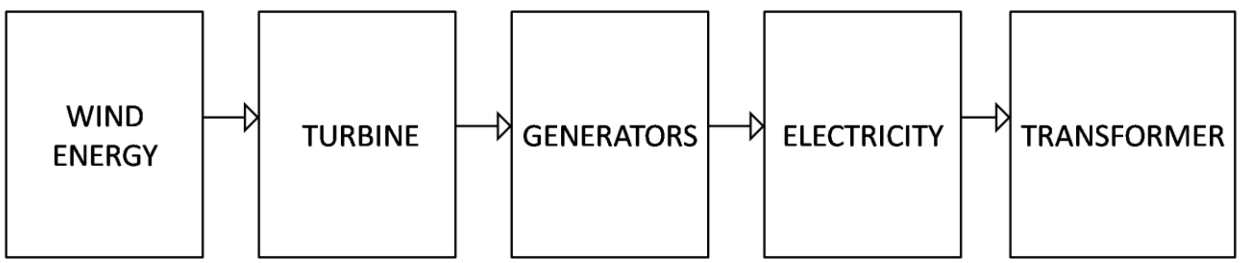

Figure 1: Wind turbine block diagram

The turbine extracts the energy from nature then the 9MW DFIG which has a rotor and stator based on the principle of electromagnetic induction converts the mechanical energy created by the turbine from using the energy extracted to generate electricity and then send to the 12.5MVA, 25/132KV transformer for grid integration. The Simulink model of the turbine is presented in figure 2;

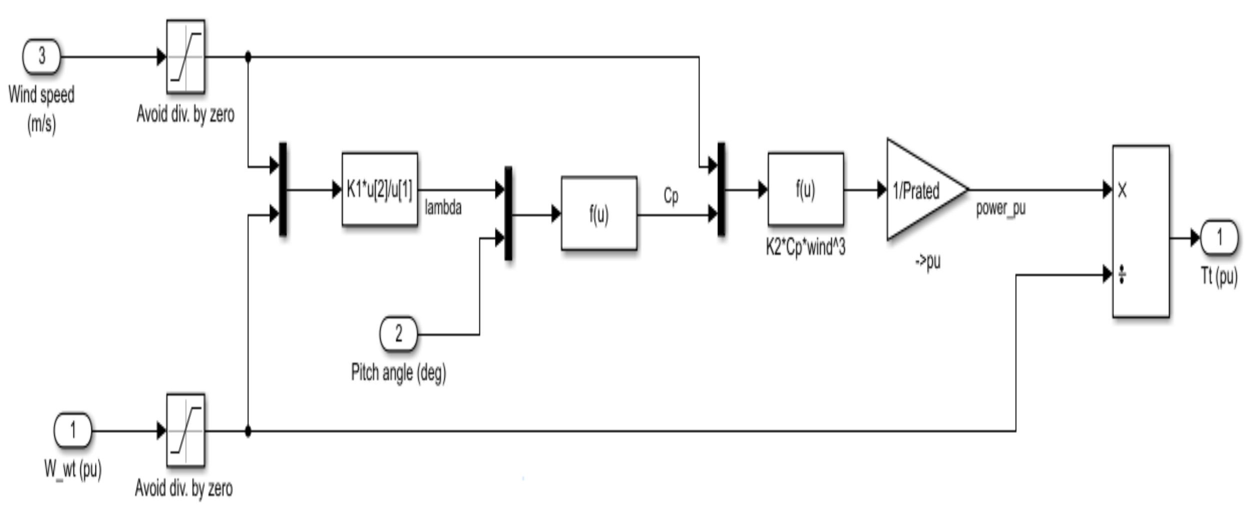

Figure 2: Simulink model of the turbine

The figure 2 presented the mathematical function which modeled the relationship between the system output for every input using Simulink block and mathematical models. The figure 3 presented the transfer function model of the turbo generator;

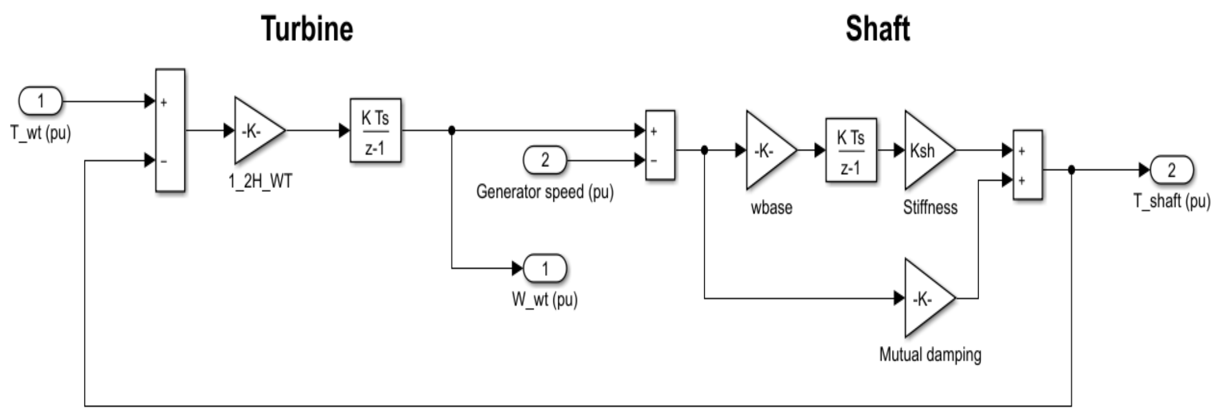

Figure 3: Transfer function model of the turbo generator

The figure 3 presented the transfer function model of the turbo generator showing the relationship between the turbine and the generator. The properties of the turbine model is 9MW for power rating, stator voltage rating o 0.69KV, Y type connection, nominal turbine speed of 18rpm, turbine radius of 50m for the blades, shaft stiffness of 83.10^6Nm/rad, torsional damping of $1.4.10^6$Nms/rad, inertia at the rotor $6.2.10^6$kg-mm^2, stator resistance is 0.013ohm, 2 poles, rated current of 2KA, and mutual inductance of 0.0135H, rotor inductance of 0.0136H and stator inductance of 0.0135H (Subir et al., 2014).

DFIG Modeling

DFIG wind turbines utilize a wound rotor induction generator, where the rotor winding is fed through back-to-back variable frequency, voltage source, converters. A typical configuration of a DFIG–based wind turbine is shown schematically in Figure 4. The converter system enables variable speed operation of the wind turbine by decoupling the power system electrical frequency and the rotor mechanical frequency.

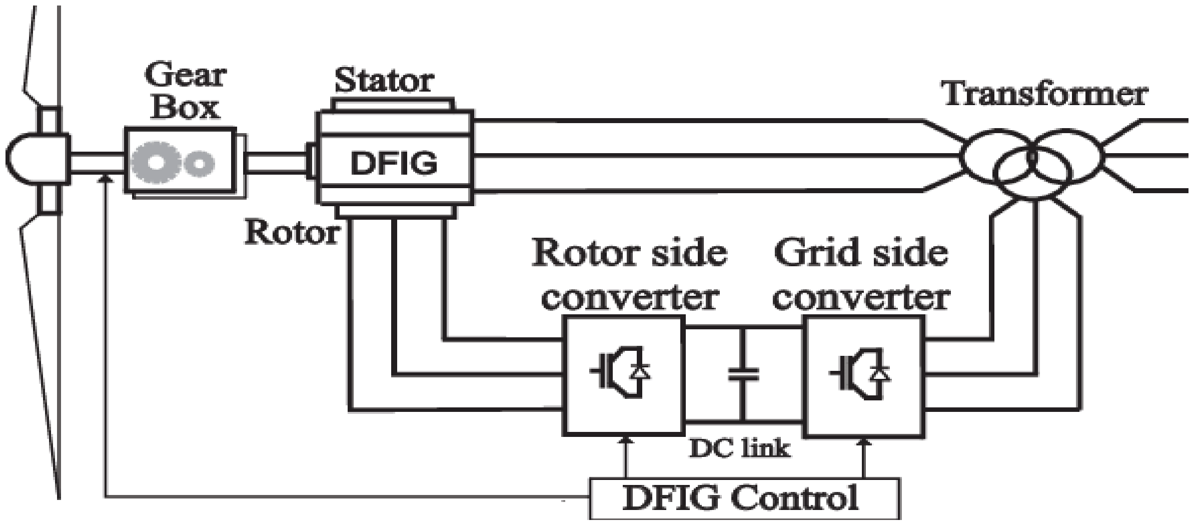

Figure 4: Model of the DFIG (Anaya et al., 2009)

From the model in figure 4, the rotor side converter was used to extract maximum power generated from the wind turbine and then control the DFIG output for reactive power. The model shows how the generator uses two Insulated Gate Bipolar Junction Transistor (IGBT) converters inter connected with a capacitor to improve the variable power from the wind turbine due to wind speed changes and achieve a stable power output which was feed to the transformer.

III. IMPLEMENTATION

The section presented the system implementation of the wind turbine model developed using the mathematical transfer functions models developed for the turbo generator and the model of the DFIG which was used to improve the power generated by the turbine. The Simulink model of the DFIG is presented in figure 5;

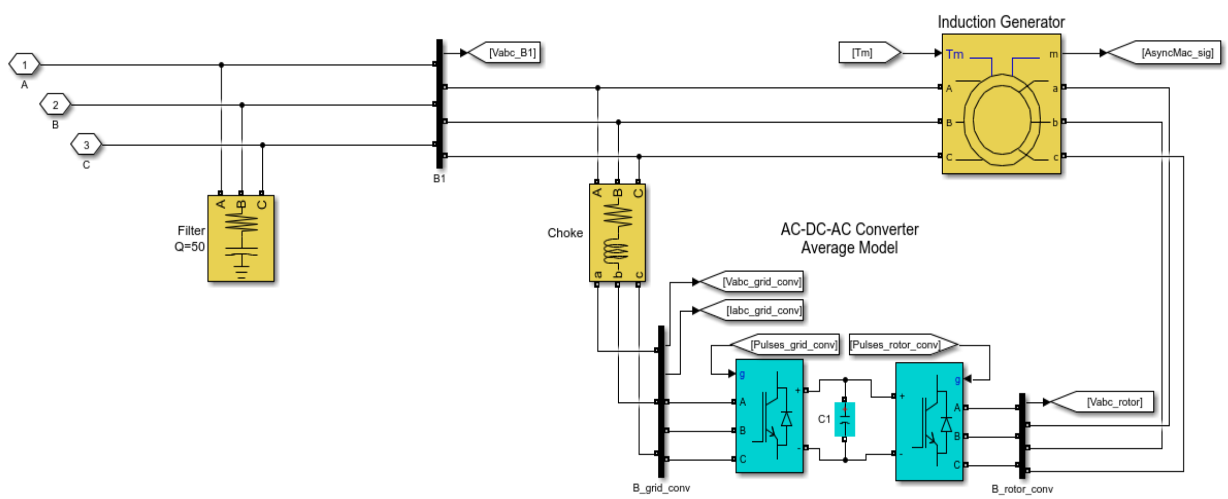

Figure 5: Simulink model of the DFIG

The DFIG model in figure 5 showed how the back to back converters connected to the generator allows extracting maximum mechanical stress on the turbine during wind gusts. The optimum turbine speed produces maximum mechanical energy for a given wind speed proportionally to the wind energy. For a low wind speed under 10m/s the rotor runs at sub-synchronous speed, while when the wind speed is high the speed increases to hyper-synchronous state. The Simulink model of the wind turbine when connected to the grid is presented in figure 6;

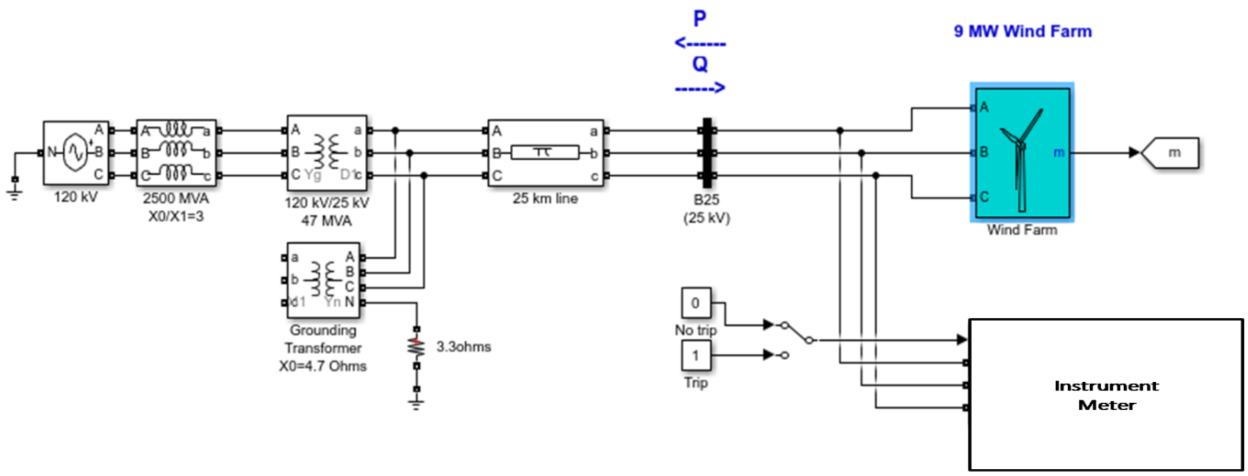

Figure 6: Simulink model of the DFIG wind turbine system

The figure 6 presented the wind turbine system which extracts wind energy and converts to electrical energy using the DFIG and then send to the 25KV bus network which transmit to the 25/120kv transformer which then send to the grid. The instrument meter was used to measure the amount of power generated by the turbine while the results were discussed in the next section.

IV. RESULTS OF SIMULAITON

This section discussed the result of the wind turbine system developed. The performance of the turbine power generated at variable wind speed was measured using the wind turbine power model in (Zaijum et al., 2013) and the result generated was presented in figure 7;

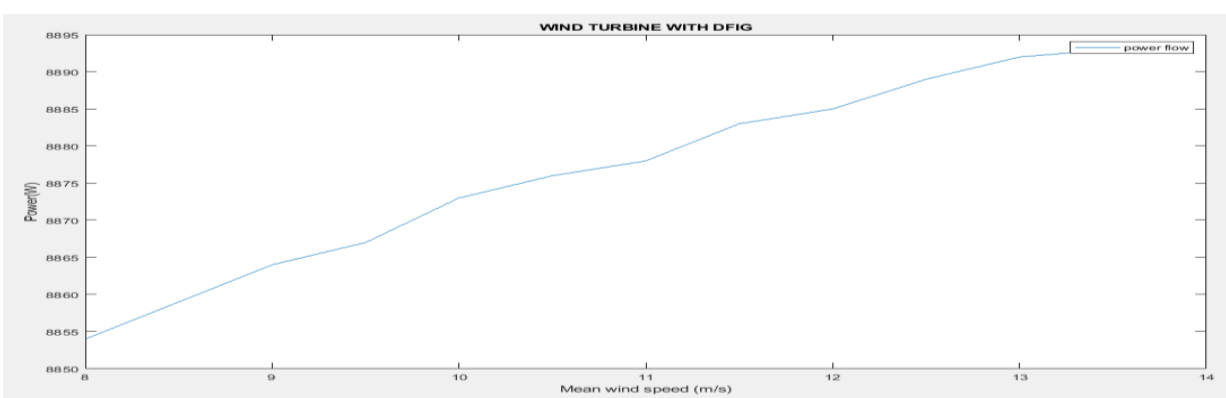

Figure 7: The performance of the wind turbine with DFIG

The result in figure 7 shows that the wind speed affects the power generated but in a very slow manner as the power generated despite the wind variation changes very slowly at a rate which is tolerable with an average power generation capacity of 7.873MW despite the variation of wind which is an efficiency of 87.5%. The performance when integrated as Destinet energies which satisfied the conditions in (see below figure 3), tested and evaluated as shown in table 1;

Table 1: Result of System integration with DFIG

Time (hr)	Mean wind speed (m/s)	Power (W) with DFIG
15:00	08.oo	7.855
14:00	08.5o	7.860
13:00	09.0o	7.880
12:00	09.5o	7.890
11:00	10.0o	7.904
10:00	10.5o	7.914
9:00	11.0o	7.920
8:00	11.5o	7.930
7:00	12.0o	7.950
6:00	12.5o	7.960
5:00	13.0o	7.974
4:00	13.5o	7.980
3:00	14.0o	7.985
2:00	14.5o	7.980
1:00	15.9o	7.990
average	11.55	7.931

The table 1 presented the of the system integration with DFIG. The result showed the amount of power generated and the mean wind speed for 15 hours of the day. The average power generated is 8.931MW which is an efficiency of 88.12%. The comparative performance of the turbine with DFIG and without DFIG is presented in table 2;

Table 2: Comparative Analysis of wind turbine performance

Time (hr)	Mean wind speed (m/s)	Power (W) with DFIG	Power (W) without DFIG

15:00	08.oo	7.855	5.700
14:00	08.5o	7.860	5.770
13:00	09.0o	7.880	5.830
12:00	09.5o	7.890	5.930
11:00	10.0o	7.904	6.050
10:00	10.5o	7.914	6.100
9:00	11.0o	7.920	6.220
8:00	11.5o	7.930	6.330
7:00	12.0o	7.950	6.550
6:00	12.5o	7.960	6.720
5:00	13.0o	7.974	6.740
4:00	13.5o	7.980	6.890
3:00	14.0o	7.985	7.940
2:00	14.5o	7.980	7.950
1:00	15.9o	7.990	7.820
Average	11.55	7.931	6.573

The table 2 presented a comparative analysis of the wind turbine with DFIG and without DFIG. The power generated average without DFIG is 6.573MW which is an efficiency of 73.03% as against with DFIG which the average power generated is 8.931MW which is an efficiency of 88.12%.

V. CONCLUSION

This work has successfully proposed and implemented a wind turbine system using the double feed induction generator. The essence is to boast the power production chain of the turbine even when inadequate wind energy is provided. This will help produce a more stabilized and quality power supply to the load. The work was developed using the necessary process model and implemented with Simulink. The performance was tested at variable wind conditions and the result shows that stabile power of average capacity of 8.931MW. A comparative analysis of the wind turbine with DFIG and without DFIG, the power generated average without DFIG is 6.573MW which is an efficiency of 73.03% as against with DFIG which the average power generated is 8.931MW which is an efficiency of 88.12%. The percentage difference improvement achieved is 15.09%.

VI. REFERENCES

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