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Comparative Analysis of DFIG-Based Wind Farms and Conventional Wind Farms with Synchronous Generator using Matlab Simulation

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Abstract – The wind energy industry is booming due to its capability of producing sustainable energy. Modern wind technology includes each aspect of grid integration , power quality , and stability issue in the field of reliable power generation to consumer end. The paper offers a suitable model of doubly fed induction generator (DFIG) for wind turbine system is developed in MATLAB/Simulink, then this model is analysed by simulating it in time domain. This Model simulation analysis is used to study the effect on system stability while replacing conventional generation system with synchronous generator by DFIG based wind generation system. The results show that the oscillatory behaviour associated with the dominant mode of the synchronous generator is improved when the DFIG-based wind turbine is connected to the system.

Keywords: DIFG, Wind Energy Generation, System Stability, Synchronous Generator, Matlab Simulation.

I. INTRODUCTION

With a society direction towards a future atmosphere disaster the demand for breakthrough inventions in green energy production has increased rapidly during the last periods. Solar cells, hydropower, bio fuels and wind turbines have all improved in performance and are sizing using modern control hardware such as power electronic devices like DFIG. By contrast, the control of a conventional power plant with SG is rather slow. Generally synchronous generator (SG) is directly connected to the power system via a power transformer and the control of terminal voltage is by the field excitation, but in the DFIG-based wind turbines are connected with the use of two back-to-back converters, while the stator windings are connected directly to the network via a power transformer. Out of these, doubly fed induction generator is more preferable because of its several advantages. The DFIG technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses on the turbine during gusts of wind. In this paper MATLAB/Simulink model of wind farm with synchronous generator and DFIG is compared to analyse their performance, limitations and, control strategy of wind farm[1].

II. WIND TURBINE GENERATORS

A synchronous generator operates at the synchronously rotating speed of an alternating current system to which it is connected. A synchronous generator requires direct current to be supplied to the rotor winding via slipping to produce the rotor's magnetic flux. The prime mover (wind) drives the generator rotor forming a rotating magnetic field that induces a voltage in the stator windings of the unit. The windings of the stator are arranged so that a three-phase voltage is produced. Interactions of rotating magnetic field of synchronize rotation, which inducts a three-blade voltage[2-3].

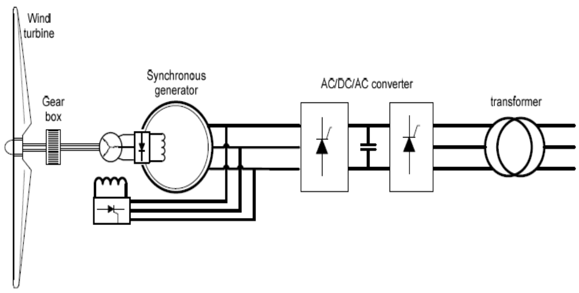


Figure 1: WTG with wound-rotor synchronous generator and full power converter.

A variable speed wind turbine-generator system (WECS) schematic is shown in Figure 3. The stator phase windings of the doubly-fed induction generator (DFIG) are directly connected to the grid, while the rotor phase windings are connected to a bidirectional power converter via slip rings. The bidirectional power converter consists of two converters, i.e., grid side converter and rotor side converter, and between the two converters a dc-link capacitor is positioned.

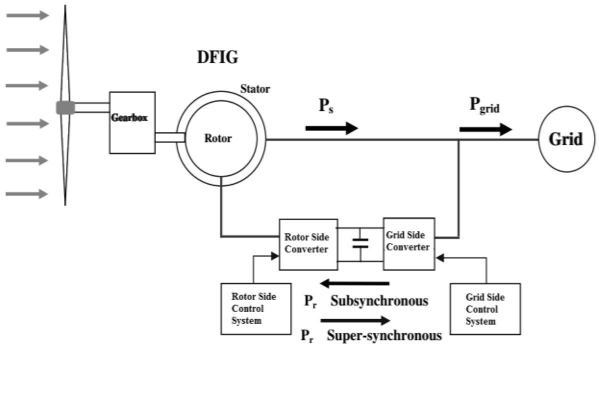


Figure 2: DFIG baised Wind Turbine Genrator System

The main objective for the grid-side converter is to keep the variation of the dc-link voltage small. With control of the rotor side converter, it is possible to control the torque, the speed of the DFIG as well as its active and reactive power at the stator terminals. Since the back-to-back power converters could be operated in bi-directional mode, the DFIG could thus be operated either in sub-synchronous speed mode or super synchronous speed mode. Here, the speed range for the DFIG is around ±30% of the synchronous speed [4]. In this thesis, the model of the variable speed wind turbine with a DFIG was developed in a Matlab/Simulink environment.

III. SIMULATION MODEL

Both models simulation has been performed of SG and DFIG for comparative analysis of system stability. Wind speed is maintained constant at 15 m/s in these models. The reactive power produced by the wind turbine is regulated at 0 Mvar. This paper represents the steady-state operation of wind turbine and its dynamic response to voltage sag resulting from a remote fault on the 120-kV system. 10 MW is produced initially in wind farm. The corresponding turbine speed is 1 p.u. of generator synchronous speed.

The 120 kV voltage source is programmed to create six-cycle 0.5 p.u. voltage drop at t=0.03 sec. The DC voltage is regulated at 1100 V and reactive power is kept at 0 Mvar. At t=0.03 s the positive-sequence voltage suddenly drops to 0.5 p.u. causing an increase on the DC bus voltage and a drop on the wind turbine output power[3-9].

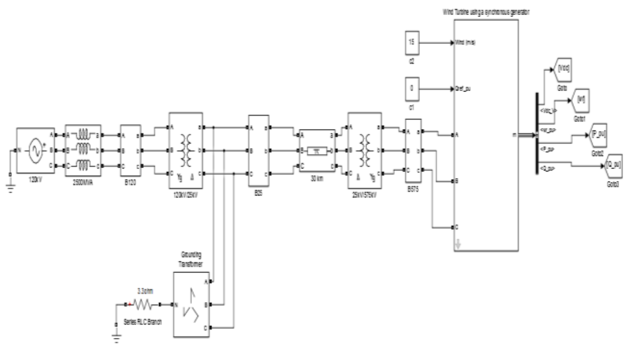


Figure 3: Simulink Model of SG Based WTG system connected to grid

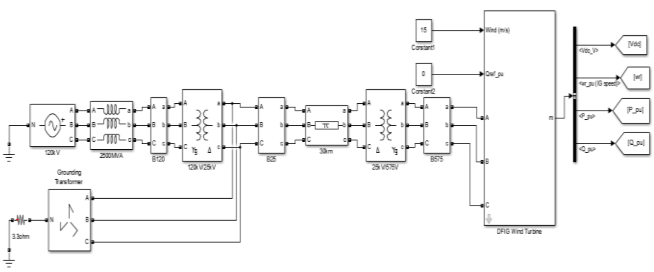
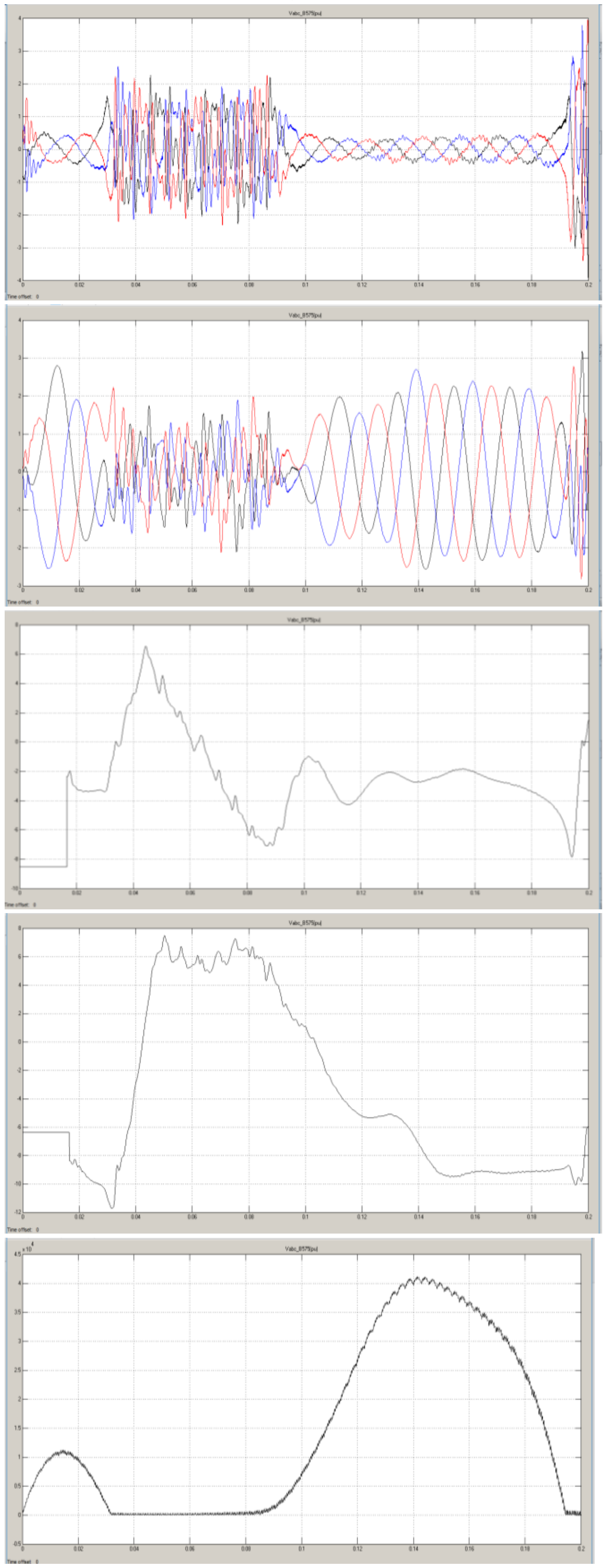


Figure 4: Simulink Model of DIFG Based WTG system connected to grid

IV. SIMULATION RESULTS

In Figure shown below the series of output waveform from the MATLAB Simulation model of synchronous generator and DFIG is shown respectively[6-9].



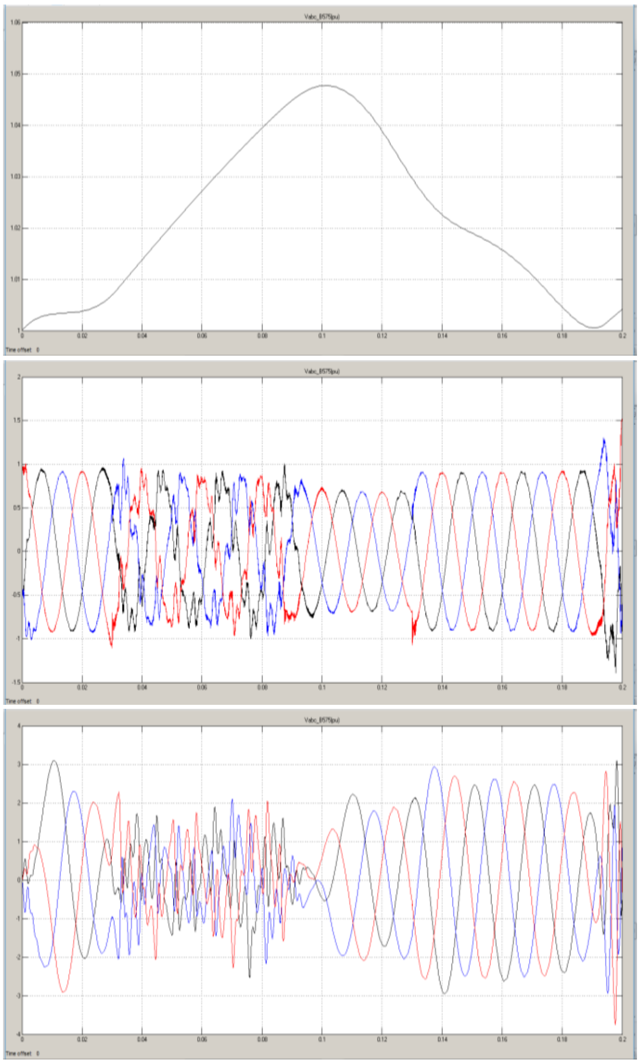
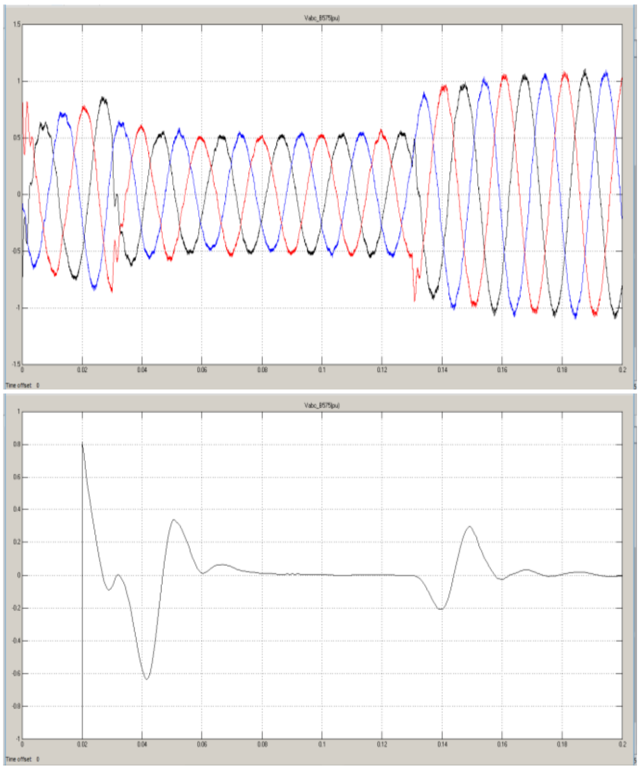


Figure 5: Simulink Result of SG



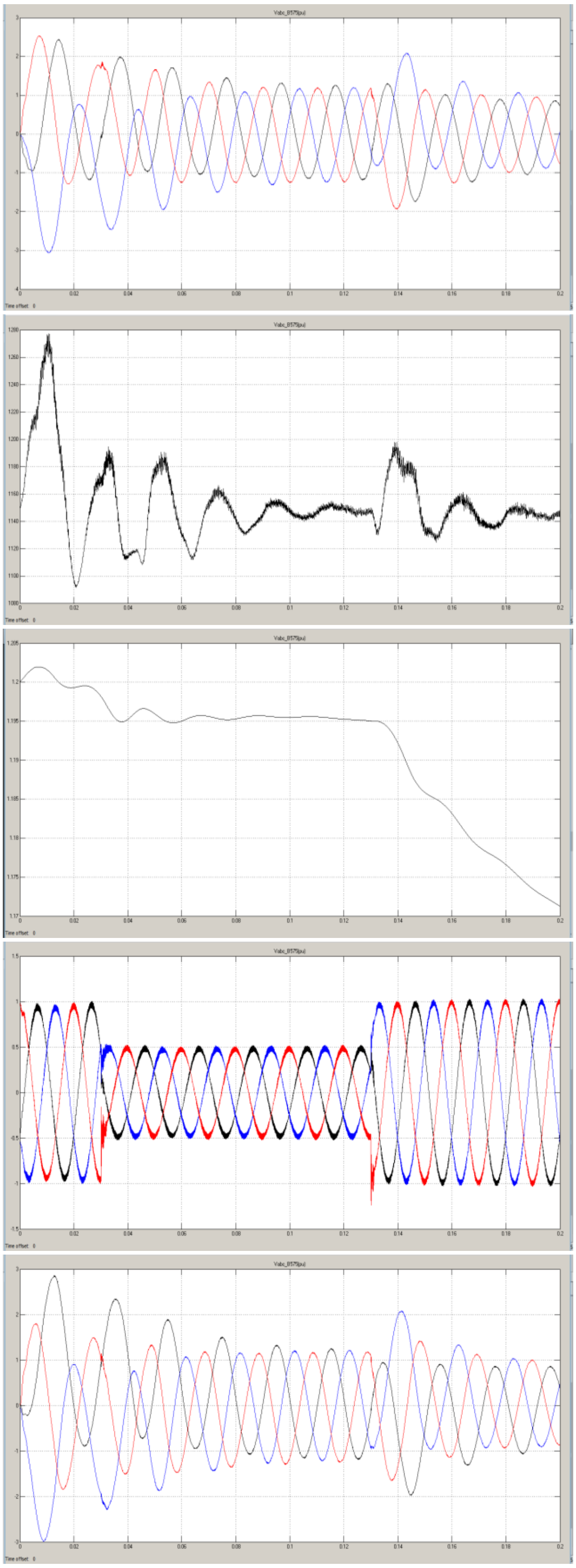


Figure 6: Simulink Result of DFIG

It is found that the synchronous generator’s response is more oscillatory in nature as compare to DFIG. During the voltage dip the SG feeds in a higher reactive current compared to the DFIG system. After fault clearing the DFIG reduces the reactive current to zero immediately, whereas the SG goes to under excited mode for at least one second. This fact in combination with the increased active current in-feed countervails the voltage return. The result shows that the oscillatory behaviour associated with the dominant mode of the synchronous generator is improved when the DFIG-based wind turbine is connected to the system.

V. CONCLUSION

In this paper a comparison between a SG-based and a DFIG-based wind farm has been done using MATLAB/SIMULINK model. The results are presented and discussed considering the performance of terminal voltages and the reactive power injections. The DFIG has some limitations to control the terminal voltage during fault; however, it can operate without disconnecting from the network.

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