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Comparative Analysis of DFIG-Based Wind Farms and SG-Based Wind Farms using Matlab Simulation

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Abstract* – The development of wind generation in Asian country began in Nineties, and has significantly increased in last few years. India ranks fifth in the wind generation capability worldwide. 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 heading towards a future atmosphere disaster. During last few decades demand for breakthrough inventions in green energy production has increased rapidly. Solar cells, hydropower, bio fuels and wind turbines have all improved in performance and are sizing up.

With the strong push in renewable energy generation during the last few years, particularly in the wind energy generation, new grid codes have been released, stipulating specific requirements regarding grid support during the steady-state procedure and grid faults. However, most of the renewable energy generation systems square measure supported different generation principles and use trendy management hardware like power electronic devices (converters) like DFIG. On the other hand, the control strategies of a conventional power plant with SG are rather slow. Immediately after fault clearing The dynamic behaviour during this period is dominated by the inertial response of SG, which is then followed by the clients affected by the excitation system [1-2].

II. WIND TURBINE GENERATORS

Wind turbine power generation technology is rapidly gaining momentum and is becoming the preferred method of power generation. The wind turbine under observation is a variable turbine speed variable pitch turbine, connected to a speed-lying gear box to move a 3 phase rotor synchronous generator. The variable frequency energy generated by the generator is transferred to a 50 Hz power system energy by a full power AC / DC / AC electronic converter. The control system includes feedback control loops for turbines, generators, rectifiers and inverter. Active and reactive forces are controlled at the point of interrelation. The results show satisfactory performance of the entire wind turbine generator model.

As mentioned in Figure 1, the wind turbine generator consists of a wind turbine with a horizontal axis 30 m three-bladed rotor, 2 MW nominal power, multiplied by a 25 rpm turbine rotor from a gear box to 1800 rt. Generator rotor, a. Can do. The three-phase wound phase rotor is a synchronous generator, self-ducted, brushless and diode rectified excise system, a full power AC / DC / AC converter with 50 Hz output, and a three power phase power transformer to connect to the power system.

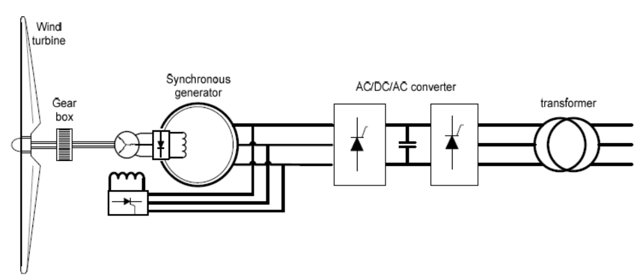

Figure 1: WTG with wound-rotor synchronous generator and full power converter.

Wind turbines that use synchronous generators usually have electromagnets in the rotor that are fed by direct current from the electric grid. Since the grid supplies alternating current, they have to be alternately converted to current flow before sending them into the coil winding around the electromagnet in the rotor. The rotor is attached to the current using a brush and slip ring on the axle (shaft) of the electromagnet generator[3-5].

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. 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[5-8].

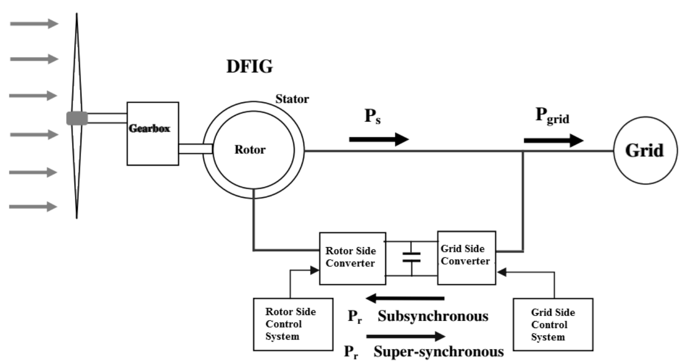

Figure 2: DFIG baised Wind Turbine Genrator System

III. SIMULATION MODEL

The comparison between a conventional power plant and a Wind turbine using DIFG technology is been established on the technical yardstick and limits regarding system voltage support during faults. A MATLAB/Simulink model is developed by using SimPower Systems Toolbox of Simulink and simulating it, in the time domain based on instantaneous values. Constant wind speed of 15 m/s is maintained in the 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[1-5].

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[5-11].

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

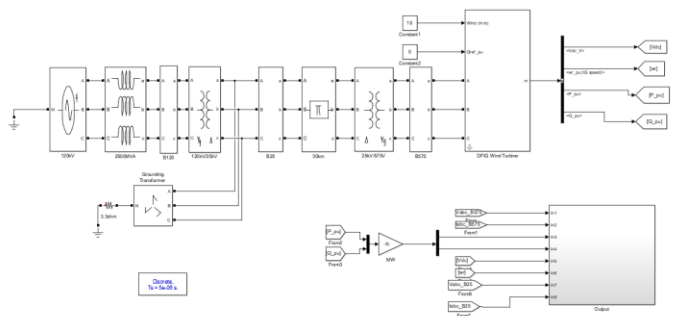

Figure 4: Simulink Model of DIFG Based WTG system connected to grid

IV. SIMULATION RESULTS

The series of Figure shown below is output waveform by workspace of MATLAB Simulation of both SG and DFIG [6-9].

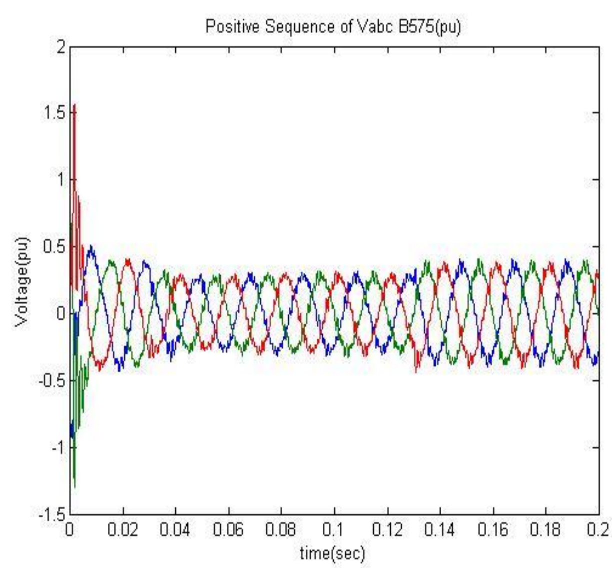

Figure 5 (a) Vabc_B575 (p.u.) for Synchronous Generator

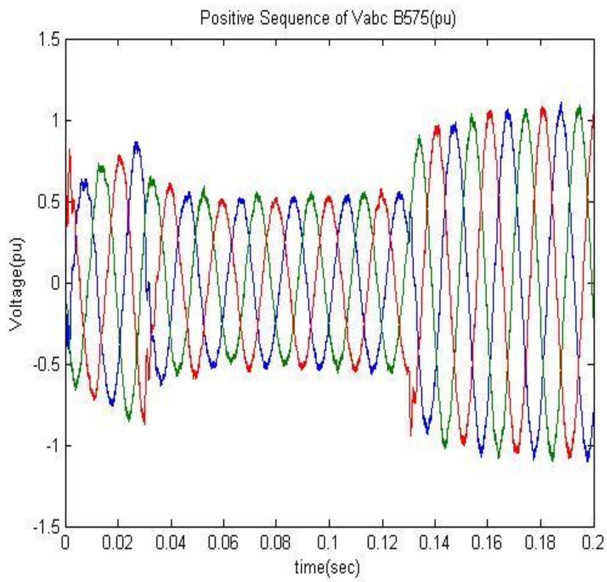

Figure 5 (b) Vabc_B575 (p.u.) for DFIG

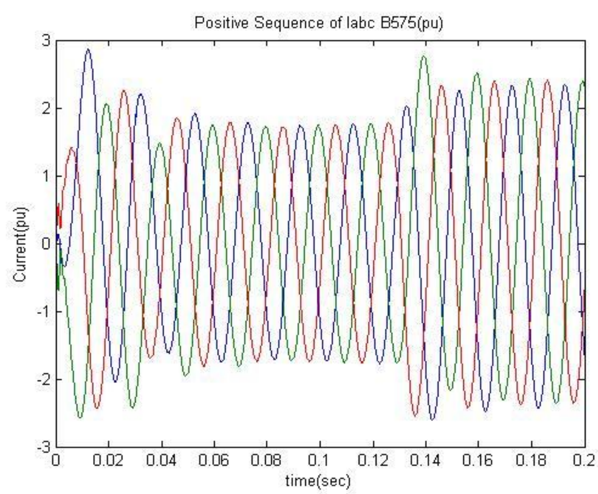

Figure 6(a) Iabc_B575 (p.u.) for Synchronous Generator

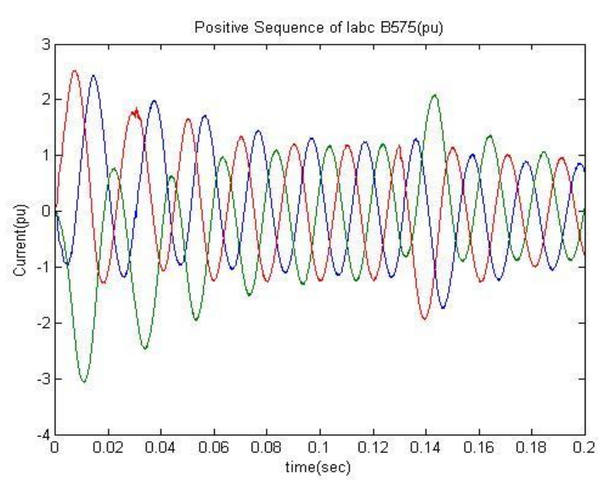

Figure 6(b) Iabc_B575 (p.u.) for DFIG

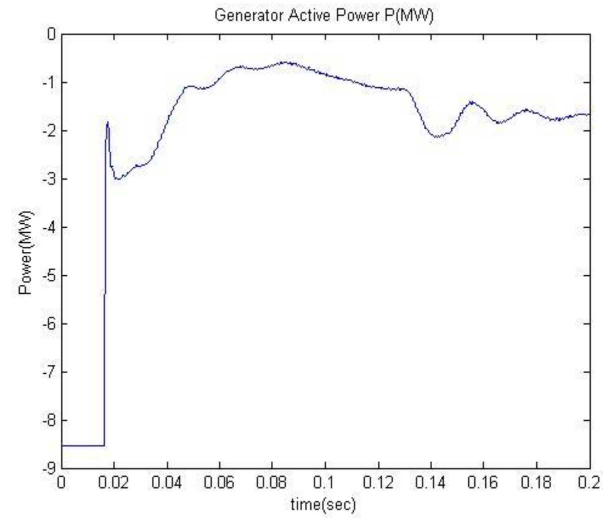

Figure 7(a) P for Synchronous Generator

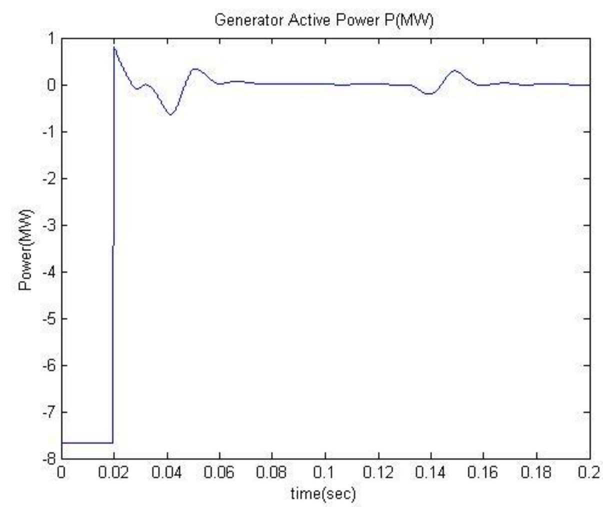

Figure 7(b) P for DFIG

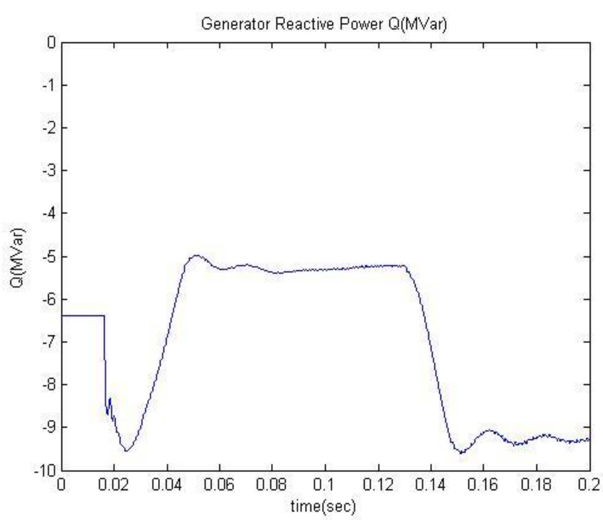

Figure 8(a) Q in Mvar for Synchronous Generator

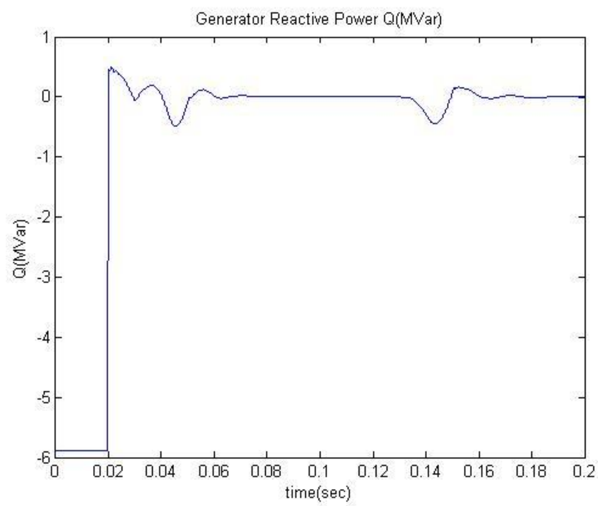

Figure 8(b) Q in Mvar for DFIG

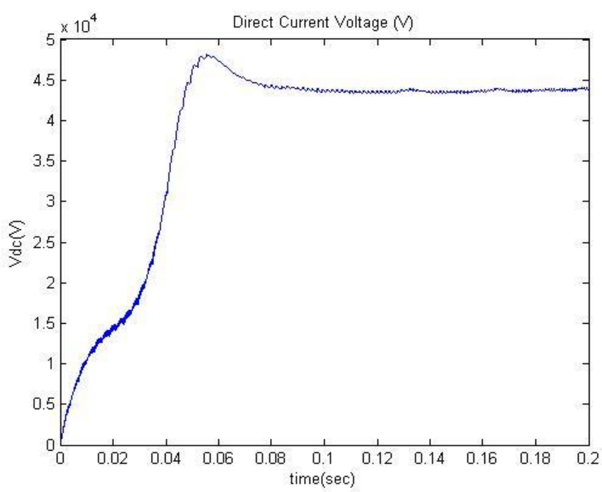

Figure 9 (a) Vdc (V) for Synchronous Generator

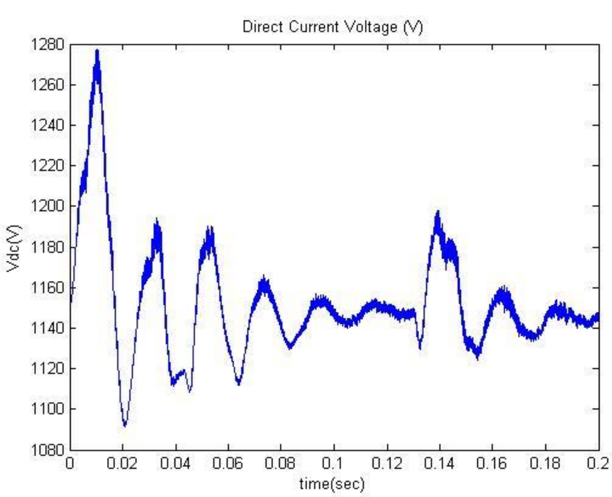

Figure 9(b) Vdc (V) for DFIG

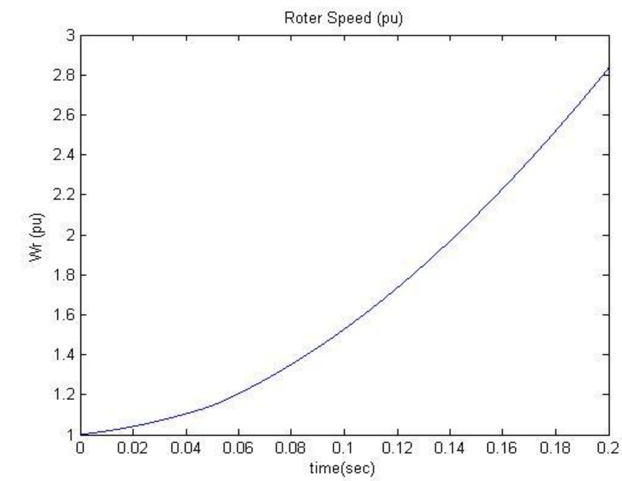

Figure 10(a) Speed (p.u.) for Synchronous Generator

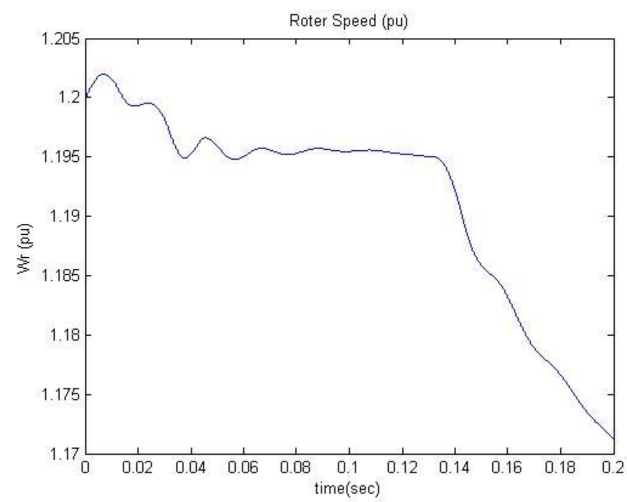

Figure 10(b) Speed (p.u.) for DFIG

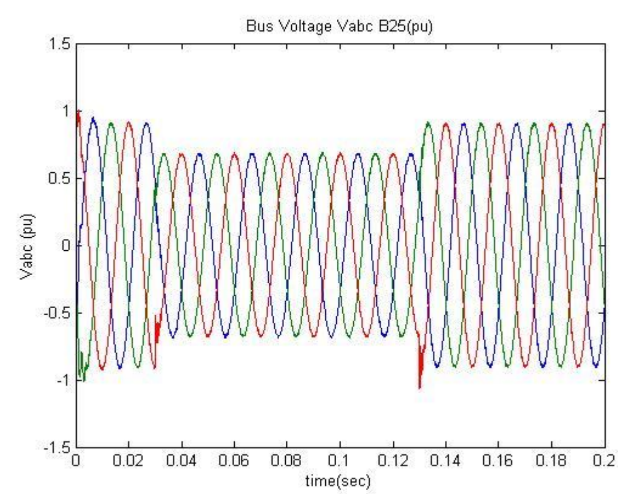

Figure 11(a) Vabc_B25 (p.u.) for Synchronous Generator

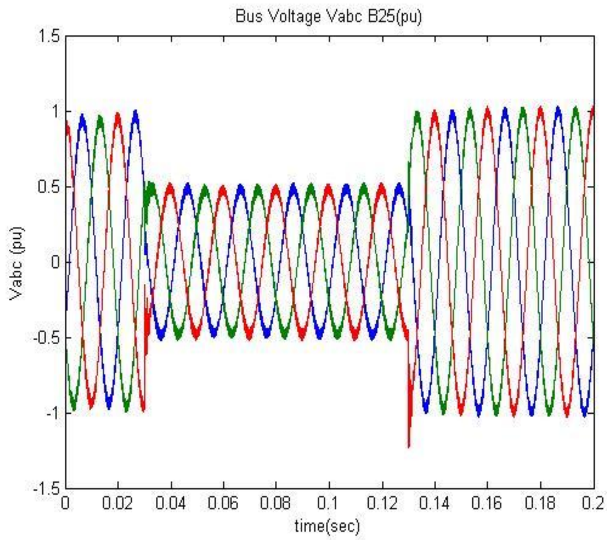

Figure 11(b) Vabc_B25 (p.u.) for DFIG

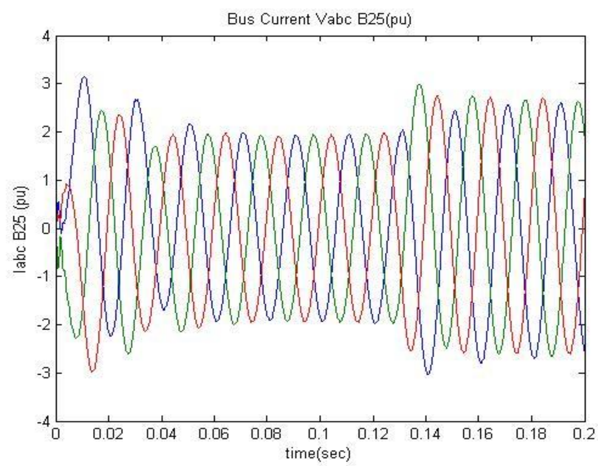

Figure 12(a) Iabc_B25 (p.u.) for Synchronous Generator

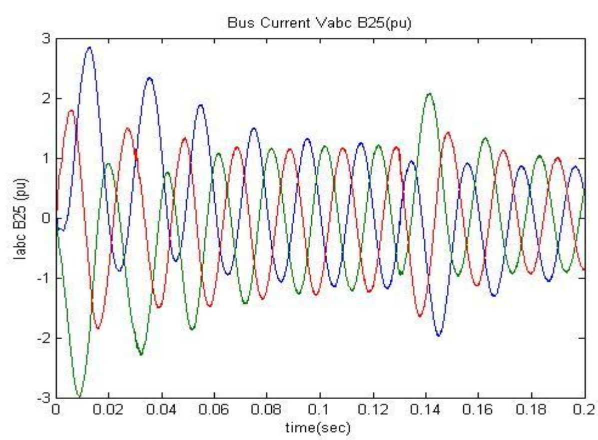

Figure 12(b) Iabc_B25 (p.u.) for DFIG

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

The electrical energy efficiency of wind turbine systems equipped with DFIG in comparison to conventional WTGS has been analyzed. In comparison to a direct-driven wind turbine synchronous generator, which is controlled by a converter or a two-speed generator scheme the difference in energy efficiency was found to be small. Moreover, the converter losses of the DFIG can be reduced if the available rotor-speed range is made smaller.

Dynamic models of DFIG wind turbine generator and SG wind turbine have been virtually demonstrated. Simulation output of the dynamic response to voltage dip of DFIG and SG wind turbine is being presented. Simulations were performed with a full converter model. Both models gives acceptable output results. Voltage dip, and ride-through capabilities of different variable-speed wind farm have been analyzed and compared.

A variable-speed wind farm with a full-power converter system can handle voltage sags very well. In addition, the generator can handle the maximum torque that is reduced in proportion to voltage sag. The cost of energy production of the full-power converter system was seen three notches higher as compared to ordinary DFIG system without ride through capability.

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