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Power Control of DFIG Using Back to Back Converters (PWM Technique)

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Abstract *:- Wind is one of the most widely used non-conventional sources of energy. A back-to-back PWM converter is used as the excitation power supply for the doubly fed induction generator (DFIG) wind power generation of variable speed constant frequency (VSCF).The Simulink model and control strategy of converter which is connected between rotor and grid is analyzed. Stator-flux oriented vector control approach is used for both stator and rotor side converter has been proposed. Taking this into account Performance of double fed induction generator (DFIG) variable speed wind turbine under network fault is studied using simulation developed in MATLAB/SIMULINK results show the transient behavior of the doubly fed induction generator when a sudden short circuit at the generator. After the clearance of short circuit fault, the control Schemes manage to restore the wind turbines normal operation. On the rotor side fluctuations in torque, wind speed, Stator current and rotor current are noticed whereas on the Grid side variations in active power and reactive power is seen with voltage and current.*

Keywords**– Active and reactive power, Back to Back converters, DFIG, IGBT, Simulink model.**

I. INTRODUCTION

Wind energy plays an increasingly important role in the world because it is friendly to the environment during the last decades; the concept of a variable-speed wind turbine (WT) has been receiving increasing attention due to the fact that it is more controllable and efficient, and has good power quality. As the demand of controllability of variable speed WTs increases, it is therefore important and necessary to investigate the modeling for wind turbine-generator systems (WTGS) that are capable of accurately simulating. In order to obtain satisfying output power from the WTGS, control strategies are also necessary to be developed based on the previously obtained WTGS models [1]. These control schemes include the grid-side converter control, the generator-side converter control, the maximum power point tracking control and the pitch angle control. The grid-side converter controller is used to keep the DC-link voltage constant and yield a unity power factor looking into the WTGS from the grid-side. The generator-side converter controller has the ability of regulating the torque, active power and reactive power. The maximum power point tracking control is used to provide the reference values for the active power at the stator terminals. Following are the different technology categorization for DFIG:-

1. Control Circuits
2. Operating Modes
3. Convertor Types
4. Protection Circuits

II. DIFFERENT TECHNOLOGIES CATEGORIZATION

For a variable-speed wind power system, the generator is connected to the grid through power electronic converters connected back-to-back [8]. The converter is needed because the variable speed generator produces a variable frequency voltage that has to be converted to match the constant grid frequency. The generators used may be squirrel cage induction generator, permanent-magnet synchronous generator or Doubly-Fed Induction Generator (DFIG). For the squirrel cage and the permanent-magnet generators, the back-to-back converters are connected to the stator where high power is flowing, so the converters have to be high rated and this is its drawback. The power converters are connected to the rotor in the DFIG configuration and need to carry only the slip power. The stator is directly connected to the grid while the rotor is connected to the grid through back to- back converters, rotor side and grid side converters [5], [6]. A vector control is employed to control the DFIG in order to decouple the active and reactive power flow between the generator and the grid. Wind turbines use a doubly-fed induction generator (DFIG) consisting of a wound rotor induction generator and an AC/DC/AC IGBT-based PWM converter.

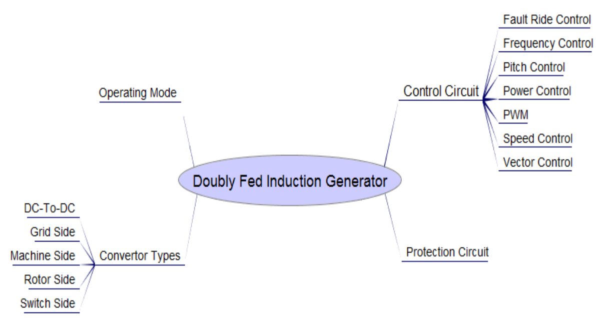

Fig 1 : Different Technology Categorization[7]

The stator winding is connected directly to the 50 Hz grid while the rotor is fed at variable frequency through the AC/DC/AC converter. 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.

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Another advantage of the DFIG technology is the ability for power electronic converters to generate or absorb reactive power, thus eliminating the need for installing capacitor banks as in the case of squirrel-cage induction generator.

III. FOR ROTOR SIDE CONTROL

The control strategy made for the machine side converter is shown in Fig.2. The main purpose of the machine side converter is to maintain the rotor speed constant irrespective of the wind speed and also the control strategy has been implemented to control the active power and reactive power flow of the machine using the rotor current components. The active power flow is controlled through i_{dr} and the reactive power flow is controlled through i_{qr}. To ensure unit power factor operation like grid side converter the reactive power demand is also set to zero here. The standard voltage oriented vector control strategy is used for the machine side converter to implement control action. Here the real axis of the stator voltage is chosen as the d-axis. The vector diagram is shown in Fig. 2.The rotor-side converter is used to control the wind turbine output power and the voltage measured at the grid terminals. The power is controlled in order to follow a pre-defined power-speed characteristic, named tracking characteristic..

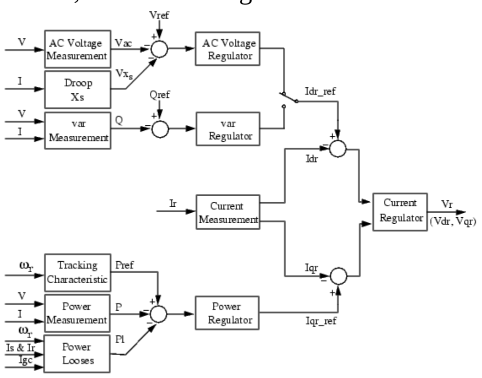

Fig 2 Rotor converter control block diagram[2]

For the rotor-side controller the d-axis of the rotating reference frame used for d-q transformation is aligned with air-gap flux. The actual electrical output power, measured at the grid terminals of the wind turbine, is added to the total power losses (mechanical and electrical) and is compared with the reference power obtained from the tracking characteristic. A Proportional-Integral (PI) regulator is used to reduce the power error to zero. The output of this regulator is the reference rotor current Iqr_ref that must be injected in the rotor by converter Crotor.

$V = V_{ref.} + I^* X_s$

where,

V Positive sequence voltage (p.u.)

I Reactive current (p.u./Pnom) (I > 0 indicates an inductive current)

X_s Slope or droop reactance (p.u./Pnom)

Pnom Three-phase nominal power of the converter specified in the block dialog box

When the wind turbine is operated in var regulation mode the reactive power at grid terminals is kept constant by a var regulator. The output of the voltage regulator or the var regulator is the reference d-axis current Idr_ref that must be injected in the rotor by converter C_{rotor}. The same current regulator as for the power control is used to regulate the actual I_{dr} component of positive-sequence current to its reference value. The output of this regulator is the d-axis voltage V_{dr} generated by C_{rotor}. The current regulator is assisted by feed forward terms which predict V_{dr}. Vdr and V_{qr} are respectively the d-axis and q-axis of the voltage Vr.

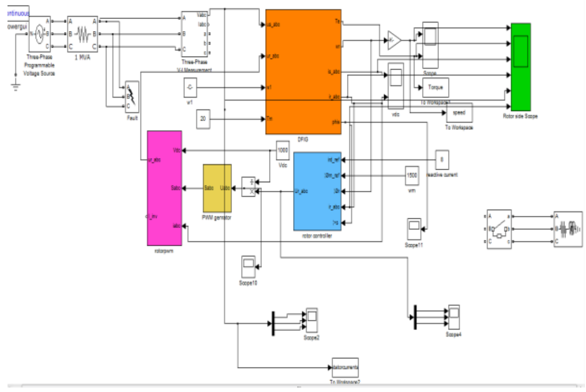

Fig 3 Simulink model for DFIG(Rotor Side)

A. Results under normal condition

Under the normal condtion, DFIG works under no load condition and and having no fault on the rotor side. Fig 4 shows the waveforms for rotor and stator currents wherseas Fig 5 shows the waveforms for wind speed and torque produced by doubly fed induction generator.

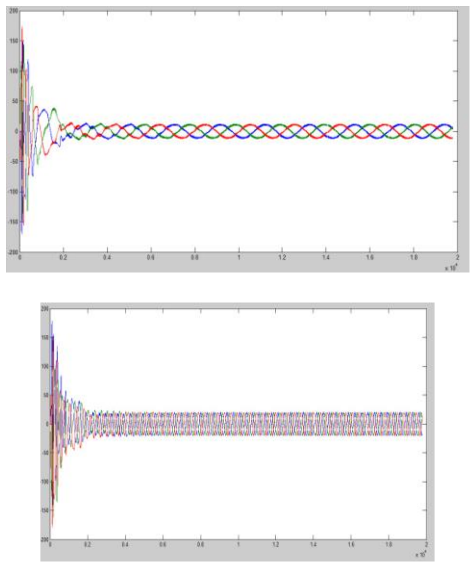

Fig 4 :Stator & Rotor currents

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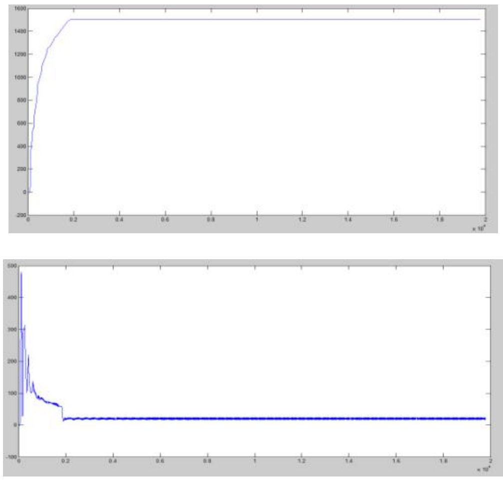


Fig 5: Variation in Torque and Rotor speed

B. Results under fault condition (Double phase to ground Fault)

In this section Double phase to ground fault is put on to the rotor side of doubly fed induction generator. The variation in stator current and rotor currents are shown by fig 6, and variations in wind speed and torque are shown in fig 7.

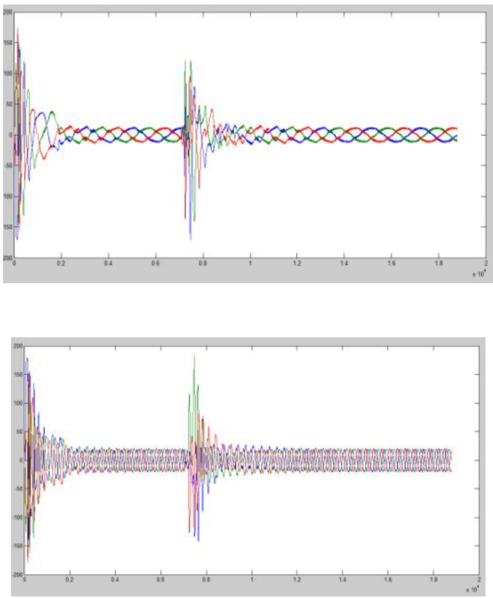
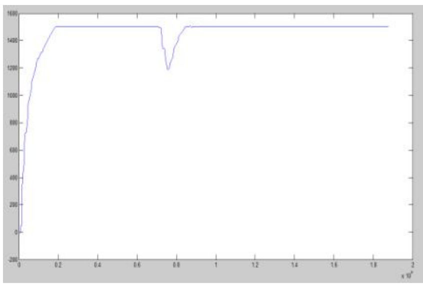


Fig 6: Stator & Rotor currents



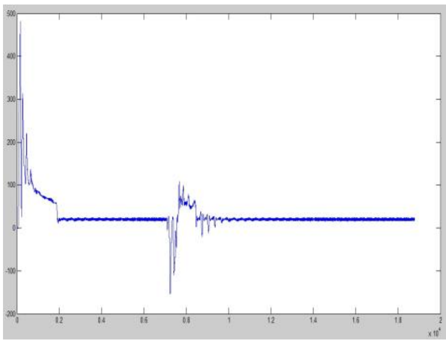


Fig 7: variation in Torque and wind speed

IV. GRID SIDE CONTROL

The Grid side converter is used to regulate the voltage of the DC bus capacitor. For the grid-side Controller the d-axis of the rotating reference frame used for d-q transformation is aligned with the positive sequence of grid voltage. This controller consists of:-

1. A measurement system measuring the d and q components of AC currents to be controlled as well as the DC voltage Vdc.
2. An outer regulation loop consisting of a DC voltage Regulator.
3. An inner current regulation loop consisting of a current Regulator.

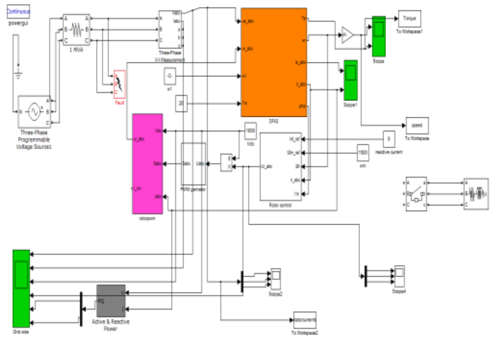


Fig 8 Simulink model for Grid side control

The current regulator controls the magnitude and phase of the voltage generated by converter C_{grid} (Vgc) from the Idgc_ref produced by the DC voltage regulator and specified Iq_ref reference. The current regulator is assisted by feed forward terms which predict the C_{grid} output voltage.

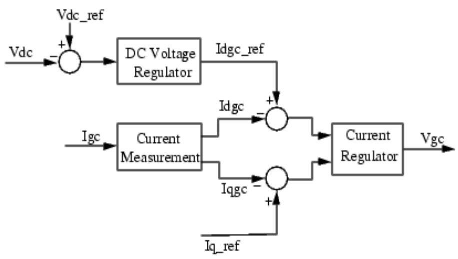


Fig 9: Grid side controller [5]

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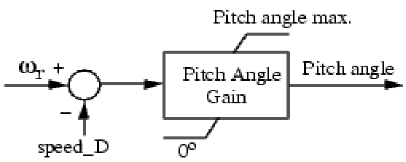


Fig 10: Pitch angle control method [5]

The pitch angle is kept constant at zero degree until the speed reaches point D speed of the tracking characteristic. Beyond point D the pitch angle is proportional to the speed deviation from point D speed. For electromagnetic transients in power systems the pitch angle control is of less interest. The wind speed should be selected such that the rotational speed is less than the speed at point D.

A. Results for Grid side control under Steady state conditions

Whenever there is any Variations occur on the grid side on the doubly fed induction generator it will create effects on the active and reactive power of the DFIG and also affects the voltage and current. The fig 11 and 12 reveals the waveforms of Voltage and current respectively under normal conditions whereas Fig 13 shows the waveforms for active and reactive power.

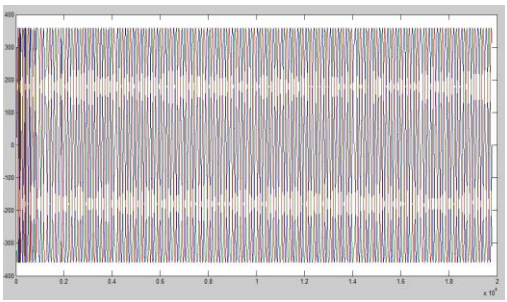


Fig 11: Change in Vabc

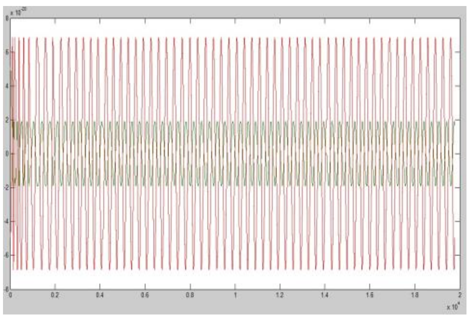


Fig 12: Change in Iabc (current)

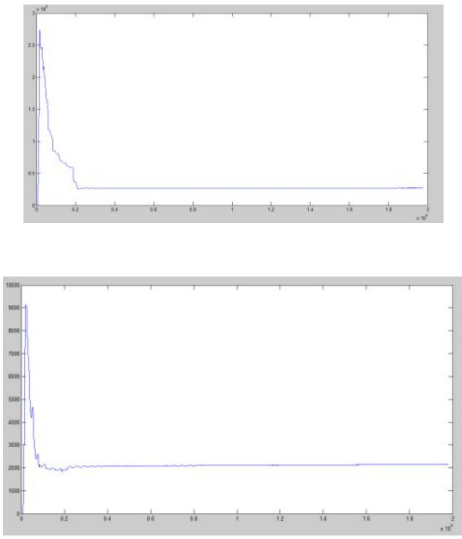


Fig 13: Variation in Active & Reactive power

B. Results for Grid side control under Transient conditions

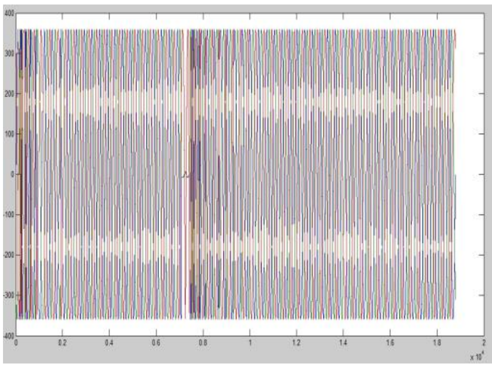


Fig 14: Change in Vabc

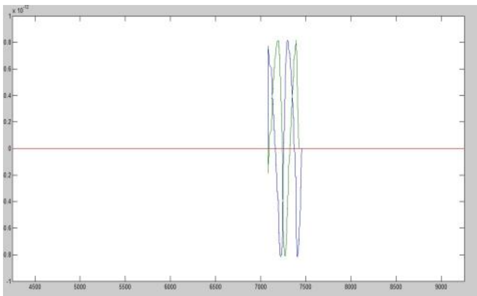
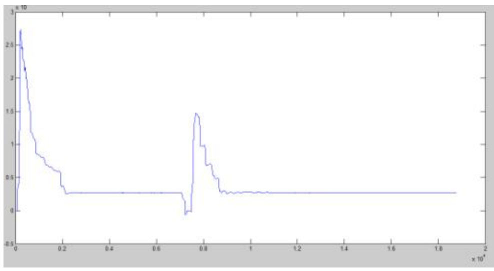


Fig 15: Change in Iabc (current)



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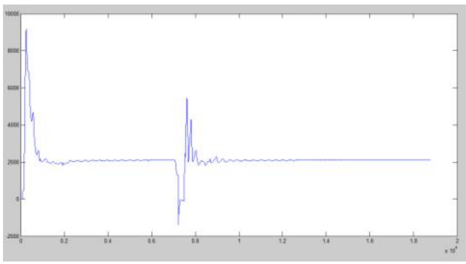

Fig 16: Variation in Active & Reactive power

V. CONCLUSION

The dynamic behavior of DFIG under power system disturbance was simulated both using MATLAB coding and MATLAB/SIMULINK platform using matrix /vector space control concept. Accurate transient simulations are required to investigate the influence of the wind power on the power system stability. The DFIG considered in this analysis is a wound rotor induction generator with slip rings. The stator is directly connected to the grid and the rotor is interface via a back to back partial scale power converter (VSC). Power converter are usually controlled utilizing vector control techniques which allow the decoupled control of both active and reactive power flow to the grid. In the present investigation, the dynamic DFIG performance is presented for both normal and abnormal grid conditions. The control performance of DFIG is satisfactory in normal grid conditions and it is found that, both active and reactive power maintains a study pattern in spite of fluctuating wind speed and net electrical power supplied to grid is maintained constant. During grid disturbance, considerable torque pulsation of DFIG and torsion oscillation in drive train system has been observed. The detailed results of steady state and faulty or unbalance grid conditions has been noted and analyzed in this paper.

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