

MODELLING AND CONTROLLING OF DFIG BASED WIND SYSTEM USING POWER MATRIX TECHNIQUE

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Abstract - With advance in usage of wind turbine technologies, as compared with other renewable sources the cost of wind turbine becomes competitive. Due to this economic problems, other disadvantages and by considering the global warming, the utilization of wind turbine has increased since last decade. For maintain the active power at constant, the use of Doubly-Fed Induction Generators with Energy Storage System like super capacitor (or) batteries can be used, with a two layer control scheme. This paper presents a novel concept for controlling doubly fed induction generator called power transfer matrix. This power transfer matrix technique is designed based on the instantaneous values of active and reactive power of the system. In order to protect the DFIG during fault conditions a matrix converter scheme based power/current controller is presented.

Key Words: DFIG, Grid Interfacing, Wind Turbine, PWM Technique.

1. INTRODUCTION

The electrical power generated by the wind system is one of the most reliable, efficient and developed renewable energy source. The Doubly Fed Induction Generator is operated by a wind turbine with variable-speed variable-pitch control scheme. This system can be operated either grid connected mode or stand-alone mode. In present scenario the design of the wind turbine power plants is mainly depends on the DFIG technology. This a DFIG-based wind-power/storage system can deliver a specified amount of power to the grid, despite wind power fluctuations.

DFIG has two different control schemes stator flux reference frame used by for Rotor side control (RSC) is one and current reference frame used by Grid side control (GSC) is another to provide the firing pulses to the converters.

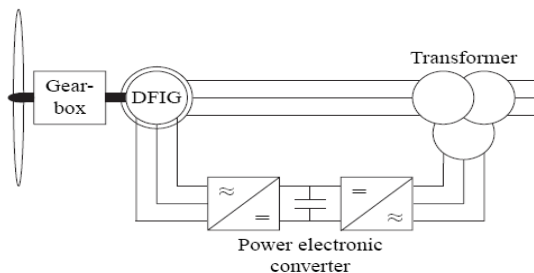


Fig -1: Schematic Diagram for DFIG based wind turbine

Figure 1 shows the schematic diagram for the wind turbine based doubly fed induction generator system. In this the stator is connected directly to the grid system and the rotor is controlled with the help of converters.

2. MODELLING AND DESIGN OF DFIG

The doubly fed induction generator is the better solution for variable speed machines with tolerance $\pm 30\%$ of synchronous speed. The grid and the rotor are directly connected for the main stator winding is controlled with converters via slip rings as shown in figure 2.

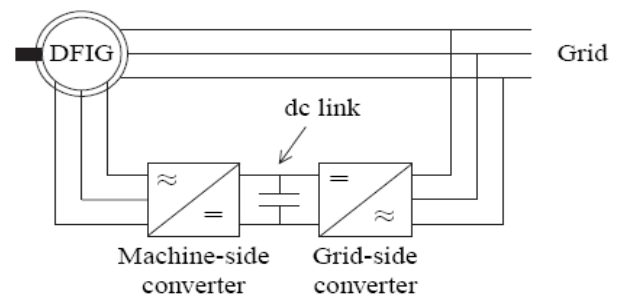


Fig -2: DFIG system with a Back to Back Converter

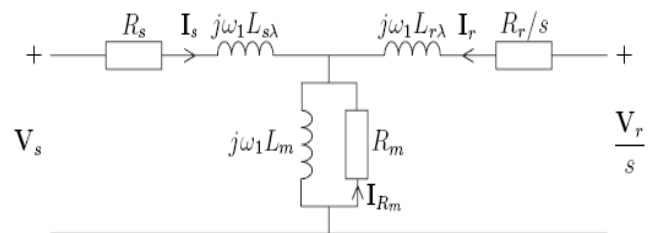


Fig 3: Equivalent circuit of DFIG

From application of kirchoff's voltage law applied to the above circuit 3, the voltage expressions for stator and rotor windings are expressed as,

$$V_s = j\omega 1L_m (I_s + I_r + I_{R_m}) + j\omega 1L_s I_s + R_s I_s \quad (1)$$

$$V_r/s = j\omega 1L_m (I_s + I_r + I_{R_m}) + j\omega 1L_r I_r + R_r/s I_r \quad (2)$$

$$0 = j\omega 1L_m (I_s + I_r + I_{R_m}) + R_m I_{R_m} \quad (3)$$

Rotor flux, stator flux, air-gap fluxes used in equations (1), (2) and (3) are defined below

$$\Psi_m = L_m (I_s + I_r + I_{R_m}) \quad (4)$$

$$\Psi_s = L_s \lambda I_s + \Psi_m = L_s \lambda I_s + L_m (I_s + I_r + I_{R_m}) \quad (5)$$

$$\Psi_r = L_r \lambda I_r + \Psi_m = L_r \lambda I_r + L_m (I_s + I_r + I_{R_m}) \quad (6)$$

The electro-mechanical torque is obtained from the above equations is expressed as

$$T_e = 3npI_m \Psi_r I_r^* = 3npI_m \Psi_m I_r^* \quad (7)$$

The rotor and stator powers are determined as

$$P_s = \text{Re} [S_s] = 3R_s |I_s|^2 + 3R_m |I_{R_m}|^2 + 3\omega 1I_m [\Psi_m I_r^*] \approx 3\omega I_m [\Psi_m I_r^*] \quad (8)$$

$$P_r = \text{Re} [S_r] = 3R_r |I_r|^2 - 3\omega 1_s I_m [\Psi_m I_r^*] \approx -3\omega 1_s I_m [\Psi_m I_r^*] \quad (9)$$

From these DFIG mechanical power equations are calculated by

$$P_{\text{mech}} = 3\omega_r I_m [\Psi_m I_r^*] = 3\omega 1I_m [\Psi_r^*] - 3\omega 1_s I_m [\Psi_m I_r^*] \quad (10)$$

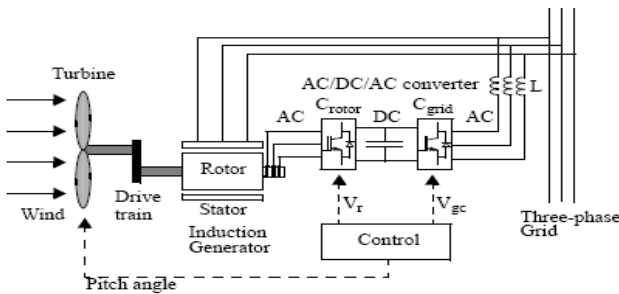


Fig 4: DFIG Connected to Wind Turbine

With the help of induction generator conversion of electrical energy from generated mechanical power from the wind blades and by the stator it is connected to the grid and the rotor converter terminals. Rotor voltage command signal Vr and grid command signal Vgc and the pitch angle command are generated by the control techniques and the and respectively in order for controlling wind turbine power, the DC bus voltage between the rotor and stator converters and the voltage at the grid terminals.

3. CLOSED LOOP CONTROL DIAGRAM FOR ROTOR SIDE CONTROLLER:

In the RSC, the controller is used for controlling rotor power Ps and the power Qs in terms of controlling rotor regulation and rotating reference frame.

By considering the simplified equivalent circuit for stator winding as shown in figure 3 and write the equations by using KVL as

$$\bar{V}_r = \bar{I}_r R_r + \frac{d\psi_r}{dt} \quad (11)$$

$$\bar{\psi}_r = L_r \bar{I}_r + M \bar{I}_s e^{-j\epsilon} \quad (12)$$

Substituting the value of $\bar{\psi}_r$ in above equation e get

$$\begin{aligned} \bar{V}_r &= \bar{I}_r R_r + \frac{d}{dt} (L_r \bar{I}_r + \frac{M}{L_s} \bar{\psi}_s e^{-j\epsilon} - \frac{M^2}{L_s} \bar{I}_r) \\ &= \bar{I}_r R_r + \frac{d}{dt} \left(L_r \bar{I}_r - \frac{M^2}{L_s} \bar{I}_r \right) + \frac{d}{dt} \left(\frac{M}{L_s} \psi_s e^{-j\epsilon} \right) \end{aligned}$$

Fig 5 shows the overall RSC control scheme which is having two cascade loops. The active and reactive powers of the DFIG is controlled by the outer loop and direct axis current component I_{dr}^* , quadrature axis current component I_{qr}^* are generated. Inner-loop current regulation is the second cascaded control loop. V_{dr0} and V_{qr0} are the from the two regulated current controllers outputs. And these signals are used for generating Pulses to RSC converter by PWM technique.

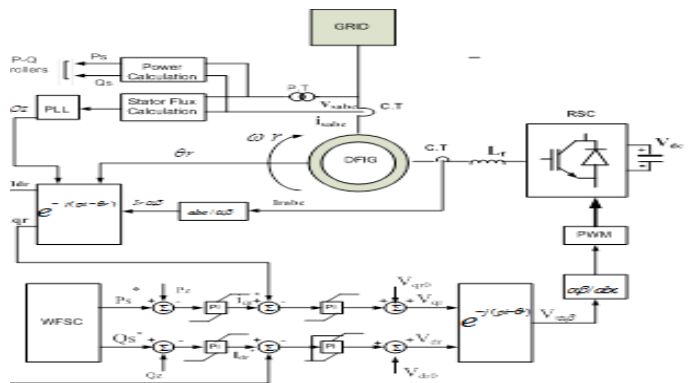


Fig -5: Control Diagram for the rotor side controller

4. CLOSED LOOP CONTROL DIAGRAM GRID SIDE CONVERTER:

Controlling of the reactive power Qg which is exchanged between the stator side converter and the grid with the help of dc link voltage is the complete control scheme for the GSC. Form the equivalent circuit shown in figure 3. Applying KVL to above circuit we get

$$v_a = I_a R_f + L_f \frac{dI_a}{dt} + v_{ag} \quad (13)$$

$$v_b = I_b R_f + L_f \frac{dI_b}{dt} + v_{bg} \quad (14)$$

$$v_c = I_c R_f + L_f \frac{dI_c}{dt} + v_{cg} \quad (15)$$

Transform the above three phase coordinates in to two phase d-q transformation and separate real & imaginary terms we get

$$v_{sd} = I_{sd}R_f + L_f \frac{dI_{sd}}{dt} - \omega_s L_f I_{sq} + v_g$$

$$v_{sq} = I_{sq}R_f + L_f \frac{dI_{sq}}{dt} - \omega_s L_f I_{sd} \quad (16)$$

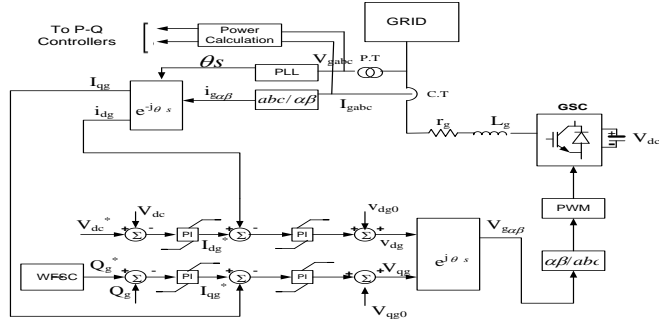


Fig -6: Grid side controller (GSC) scheme

Fig 6 shows the complete closed loop control diagram for the grid side converter and it having two cascaded control loops. The reactive power is indirectly controlled by the dc link voltage controlling done by the outer control loop for generating the reference signals of the d-axis current component i_{dg}^* and q-axis current component i_{qg}^* for the inner-loop current regulation. Then these signals are used for generating pulses with the help of PWM technique

$$P_{ei,max} = P_{mi,max} - P_{Li} = P_{si,max} + P_{ri,max}$$

The stator active power P_s can be written as

$$P_s = \frac{3}{2} (v_{ds}i_{ds} + v_{qs}i_{qs}) = \frac{3}{2} [\omega_s L_m (i_{qs}i_{dr} - i_{ds}i_{qr}) + r_s (i_{ds}^2 + i_{qs}^2)]$$

The rotor side active power can be expressed as:

$$P_r = \frac{3}{2} (v_{dr}i_{dr} + v_{qr}i_{qr}) = \frac{3}{2} [-s\omega_s L_m (i_{qs}i_{dr} - i_{ds}i_{qr}) + r_r (i_{dr}^2 + i_{qr}^2)] \quad (17)$$

5. SIMULATION DIAGRAM AND RESULTS

Here the simulation is done for maintaining the real power supplied by the wind farm is to be maintained constant. The constant real power is given as P_{ref} to the wind turbines under different conditions like wind turbines operating without any energy storage system, operating with energy storage system with two layer conventional controllers. The amount of real power that has to be maintained constant. The simulation diagram is shown in figure 7.

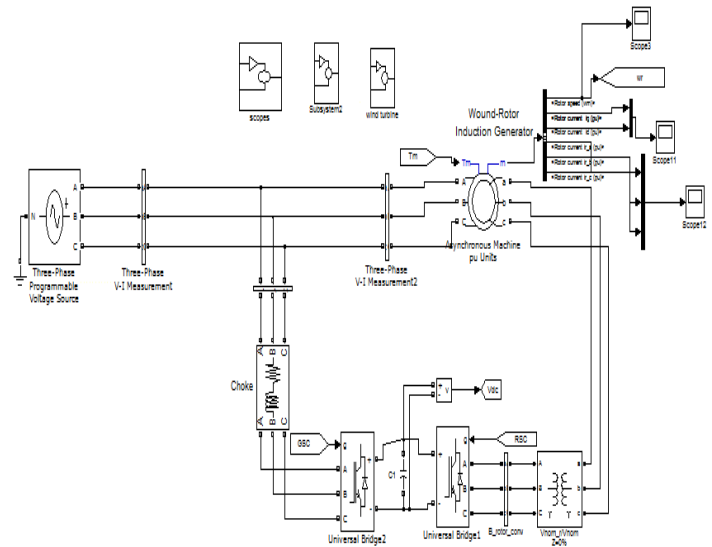


Fig -7: Simulation Diagram for DFIG WIND turbine

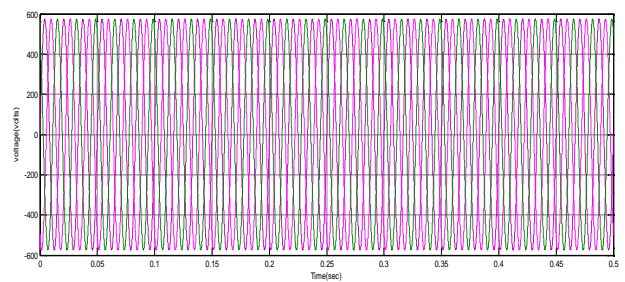


Fig -8: DFIG Stator Voltage

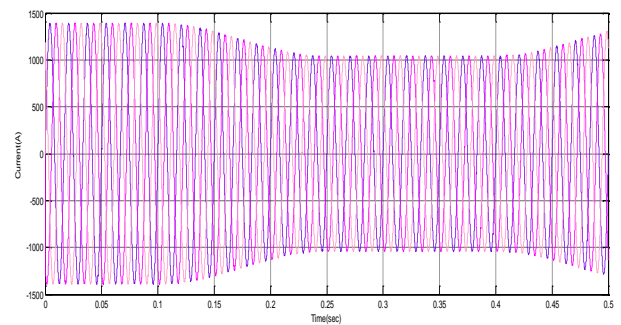


Fig -9: DFIG Stator Current

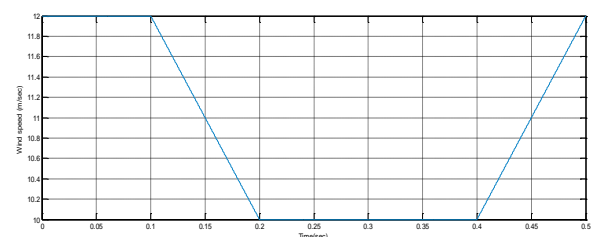


Fig -10: Wind turbine Speed

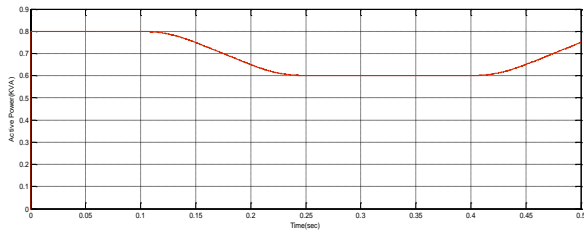


Fig -11: Active power at grid side

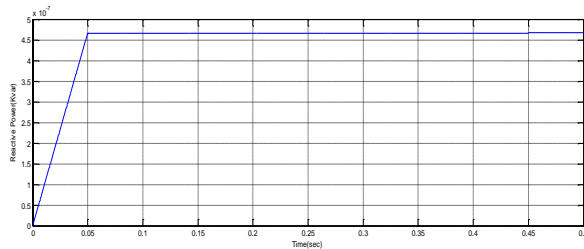


Fig -12: Grid Reactive Power

6. CONCLUSION

This paper proposed a concept of power matrix technique for controlling the doubly-fed induction generator based wind turbine energy generation units. These power components have different reference frame quantitative and can be obtained with the help of voltage and currents. Therefore, this controller improves the performance and robustness of the DFIG system. This proposed approach is verified through time based analysis of a DFIG based wind energy systems. Then the simulation results show that the proposed control diagram of a power matrix technique has successfully control the rotor speed for obtaining the constant value of dc link voltage and control of powers with their reference values.

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