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Modelling of DFIG Based Wind System Using Power Matrix Controller

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ABSTRACT

The main objective of this paper is to maintain constant active power which is developed by the wind turbine generation system. Generally, as compared with other renewable energy sources the wind generation system plays an important role. This paper proposes the concept of wind system with the help of doubly fed induction generator. The power transfer matrix is used for controlling both grid side and rotor side controllers for maintain constant active power. The performance of this controller is observed and simulated using Matlab/Simulink.

KEYWORDS: *Wind System, DFIG, Power Transfer Matrix*

I. 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.

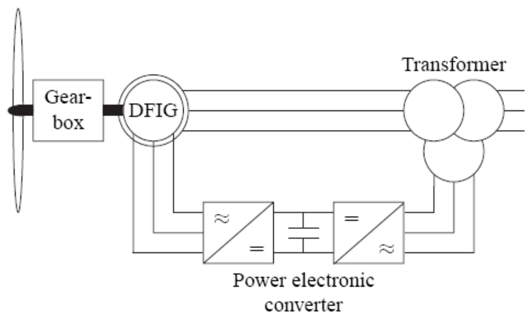

Fig 1: Schematic Diagram for DFIG based wind turbine

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.

II. MODELLING AND DESIGN OF DFIG

The doubly fed induction generator is the better solution for variable speed machines with tolerance ±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 sown in figure 2.

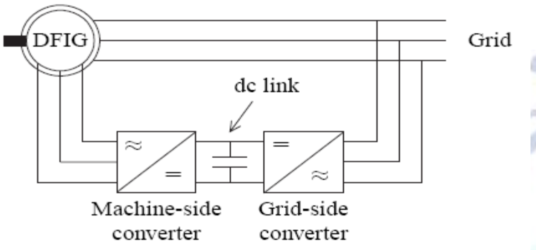

Fig 2: DFIG system with a Back to Back Converter

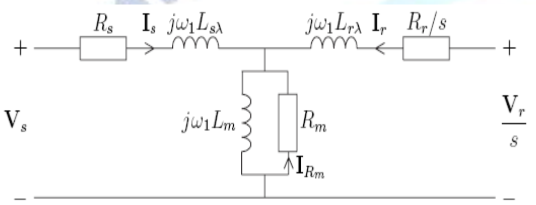

Fig 3: Equivalent circuit of DFIG

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

$V_s = j\omega_1 L_m (I_s + I_r + I_{Rm}) + j\omega_1 L_{s\lambda} I_s + R_s I_s$ (1)

$V_r/s = j\omega_1 L_m (I_s + I_r + I_{Rm}) + j\omega_1 L_{r\lambda} I_r + R_r/s{*}I_r$ (2)

$0 = j\omega_1 L_m (I_s + I_r + I_{Rm}) + R_m I_{Rm}$ (3)

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

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

$\Psi_s = L_{s\lambda} I_s + \Psi_m = L_{s\lambda} I_s + L_m (I_s + I_r + I_{Rm})$ (5)

$\Psi_r = L_{r\lambda} I_r + \Psi_m = L_{r\lambda} I_r + L_m (I_s + I_r + I_{Rm})$ (6)

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

$T_e = 3n_p I_m \Psi_r I_r^* = 3n_p I_m \Psi_m I^*_r$ (7)

Wind-Turbine based doubly fed Induction Generator:

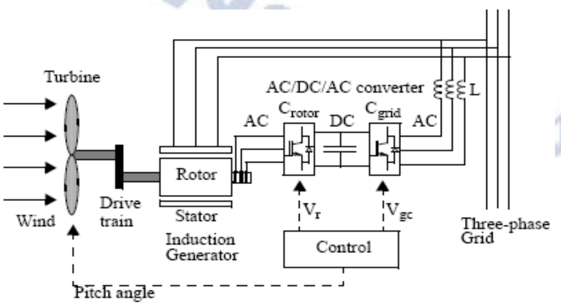

Fig 4: DFIG Connected to Wind Turbine

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.

III. 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

$$\bar{V}_r = \bar{I}_r R_r + \frac{d}{dt}(L_r \bar{I}_r + \frac{M}{L_s}\bar{\psi}_s e^{-j\epsilon} - \frac{M^2}{L_s}\bar{I}_r$$

$$= \bar{I}_r R_r + \frac{d}{dt}\left(L_r \bar{I}_r - \frac{M^2}{L_s}\bar{I}_r\right) + \frac{d}{dt}\left(\frac{M}{L_s}\psi_s e^{-j\epsilon}\right)$$

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 Idr*, quadrature axis current component Iqr* are generated. Inner-loop current regulation is the second cascaded control loop. Vdr0 and Vqr0 are the from the two regulated current controllers outputs. And these signals are used for generating Pulses to RSC converter by PWM technique.

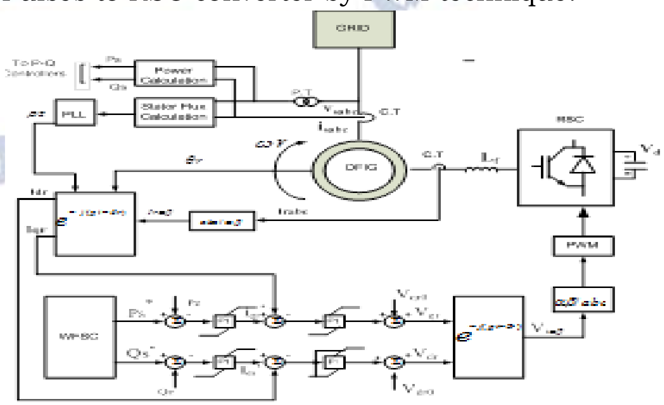

Fig 5 Control Diagram for the rotor side controller

IV. 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

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

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

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

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

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

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

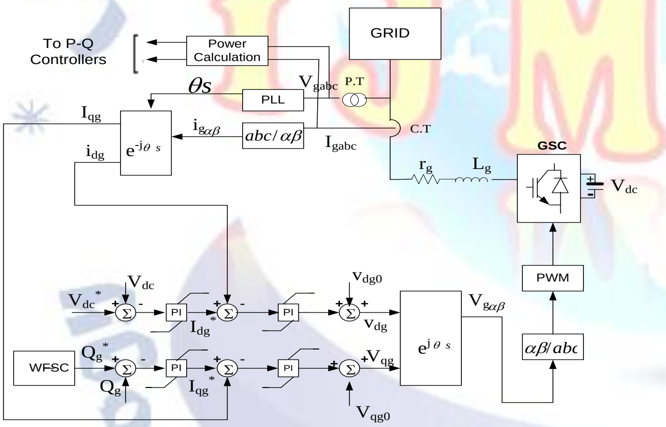

Fig 6: Grid side controller (GSC) scheme

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 idg* and q-axis current component iqg* 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 Ps 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

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

V. 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 Pref 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 figure7.

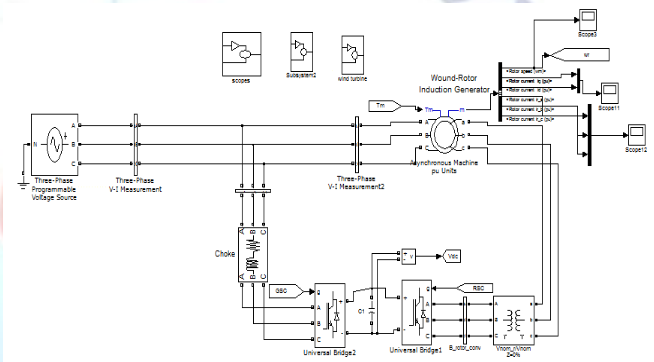

Fig 7: Simulation Diagram for DFIG WIND turbine

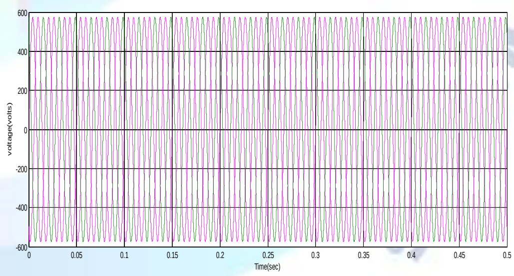

Fig 8: DFIG Stator Voltage

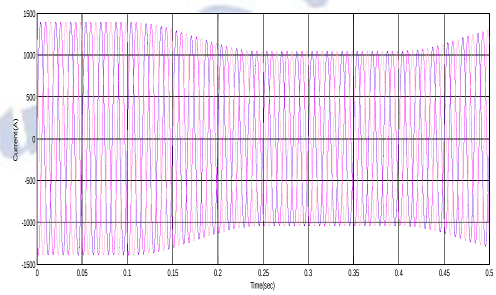

Fig 9: DFIG Stator Current

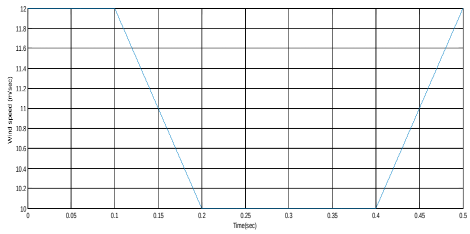

Fig 10: Wind turbine Speed

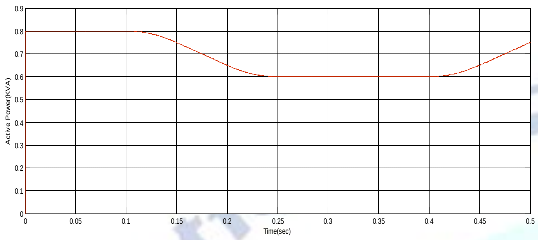

Fig 11: Active power at grid side

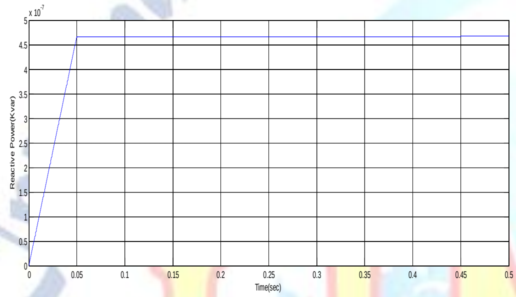

Fig 12: Grid Reactive Power

VI. 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 succefully 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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