Modeling Analysis and Simulation of Power Converter for Doubly Fed Induction Generator

[1]YASHVANT SINGH, M.E.,
M.E. Power System Engineering,
Noble Group of institutions,
Junagadh, India,

[2]PANKAJ JADAV, M.E.,
M.E. Power System Engineering,
Noble Group of institutions,
Junagadh, India,

***Abstract*--The change in system parameters of model properties, operating points are computed and observed. The results offer a better understanding of the DFIG, which can also be useful for control design and model justification. In DFIG one winding is directly connected to the output and produces three phase ac power at desired grid frequency. The rotor winding are connected to the grid via slip ring and back to back VSC that control rotor voltage and frequency. Renewable energy source deals with the design, analysis and simulation of a wind turbine to generate a control of active and reactive power through the grid for all wind conditions.**

***Keywords*--doubly fed induction generator (DFIG), wind energy conversion system (WEGS), MATLAB for simulation of DFIG**

2. INTRODUCTION OF WECS

Renewable energy including wind, solar, tidal, hydro, and geothermal and fuel cell energies is sustainable and environmentally friendly and clean. It has become an important energy source due to increasing shortage in fossil fuels, and pollution problems. Among the other renewable energy sources wind energy has proven to be one of the most economical one [2] [5]. Earlier Constant speed wind energy

conversion system was proposed to generate constant frequency voltages from the variable wind. However, Variable speed WECS operations can be considered advantageous, because additional energy can be collected as the wind speed Increases. Variable speed wind energy conversion system must use a power electronic converter they are classified as full power handling and partial power handling WECS. In full power handling WECS, the power converter is in series with the induction or synchronous generator, in order to transform the variable frequency voltages into constant frequency voltages and the converter must handle the full power. In a partial power handling WECS, the converter processes only a portion of the total generated power which poses an advantage in terms of the reduced cost converter of the system and increased efficiency of the system [2] [1].

A dynamic steady state simulation of wind energy conversion system is essential to understand the behavior of WECS. This paper shows steady state characteristics of a typical variable speed WECS that uses DFIG using MATLAB. A Simulation analysis is performed and a variety of DFIG characteristics, and real and reactive-power over speed characteristics are analyzed.

Main aim is to Control the Reactive power for stability Improvement of power system using analysis the devices. The results given a better understanding of the DFIG. Figure 1 Shows a WECS using DFIG. A wind turbine threads the wind through its rotor blades and transfers it to the rotor hub. It is attached to a low speed shaft through a gear box. The high speed shaft drives an electric generator which converts the mechanical energy to electric energy and delivers it to the three phase line. As the wind speed varies, the power captured, converted and transmitted to the line also varies [2].

$$P_w = 0.5\ C_p.A.\rho.V_w^3$$

P_w = wind power
C_p = power coefficient of the turbine
A= sweep area in m^2
ρ = air density in Kg/m^3
V_w = wind speed

3. POWER FLOW IN DFIG

A doubly fed induction machines are basically a standard, wound rotor induction machine with its stator windings directly connected to the three phase grid and its rotor windings connected to the grid through a slip ring and power converter. The AC/DC/AC or back to back converter is divided in to two components one is the rotor side converter (RSC) and second is the grid side converter (GSC). These converters are voltage sourced converters that use force commutated power electronic devices.

A capacitor connected on the DC side acts as the DC link. A coupling inductor is used to connect directly to the grid. The three phase rotor winding is connected to the rotor side converter (RSC) by slip rings and brushes where three phase stator windings are directly connected to the grid.

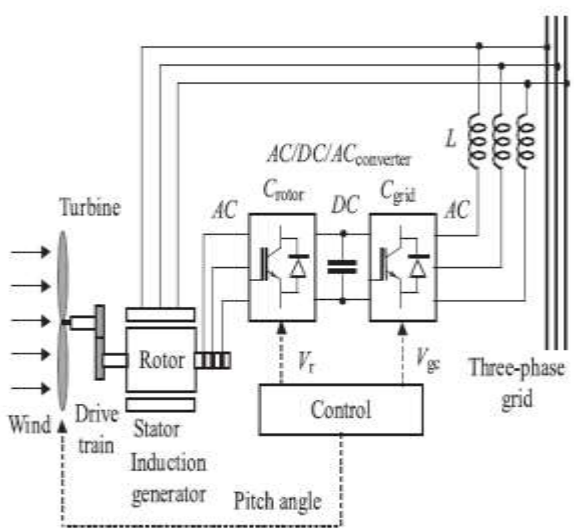

Fig. 1. Wind Energy Conversion System power output from a wind [5]

The control system generates the pitch angle command and the voltage command signals V_r and V_{gc} for the rotor and grid side converters respectively in order to control the power of the wind turbine.

Figure 1 shows the Power flow in a DFIG. The absolute value of slip is much lower than 1 and consequently the rotor electrical power output P_r is only a fraction of stator real power output P_s. Since the electromagnetic torque T_m is positive for power generation and since W_s is positive and constant frequency of grid voltage, the sign of P_r is a function of the slip sign. P_r is positive for negative slip when speed greater than Synchronous Speed and it is negative for positive slip when speed lower than synchronous speed [2] [9].

On super synchronous speed operation, Pr is transmitted to DC bus capacitor or DC link and tends to raise the DC voltage. For sub synchronous speed operation, Pr is taking out of the DC bus capacitor and tends to reduce the DC bus voltage. The three phase grid side converter is used to generate or absorb the grid electrical power Pgc in order to keep the DC voltage constant [1]. In steady state for a lossless back to back converter. By properly controlling the rotor side converter, the voltage and frequency measured at the grid terminals can be controlled by controlling the grid side converter DC bus voltage of the capacitor can be regulated [2].

4. MODE OF THE DFIG

The phase sequence of the AC voltage generated by the rotor side converter is positive for sub synchronous mode and negative for super synchronous mode. The frequency of this voltage is equal to the multiply of the grid frequency and the absolute value of the slip. The rotor side and the grid side converter have the capability of generating or absorbing reactive power and could be used to control the reactive power or the voltage at the grid terminals.

The rotor side converter is used to control the wind turbine output power and the voltage measured at the grid terminals. The grid side converter is used to regulate the voltage of the DC bus capacitor [4].

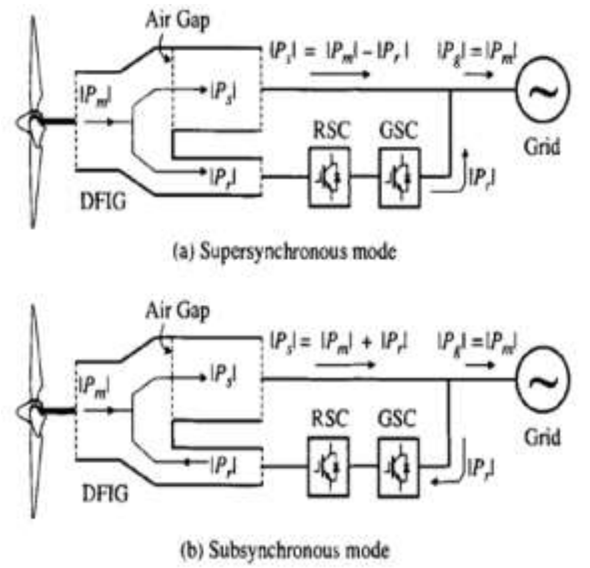

Fig.2. Modes of DFIG [4]

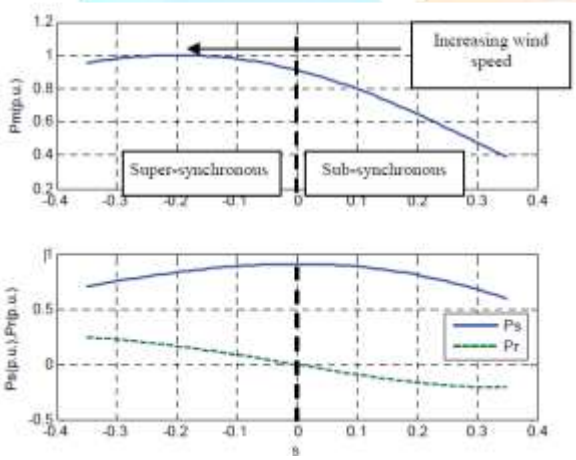

Fig.3. Equivalent Impedance of RSC[4]

5. MODELING OF THE DFIG

In complex notation, the DFIG equations are derived by park model defined in a reference frame d-q rotating at synchronous speed w_s. The electrical energy conversion system is described by equation of IMs given by

$$\overline{V}_s = R_s\overline{i}_s + \frac{d\overline{\varphi}_s}{dt} + j\omega_s\overline{\varphi}_s$$
$$\overline{V}_r = R_r\overline{i}_r + \frac{d\overline{\varphi}_r}{dt} + j\omega_r\overline{\varphi}_r$$

i being that current, V is the voltage, Rs and Rr are stator and rotor resistance, Ws angular speed of the rotating field referred to the stator which is in rad/s, Wr angular speed of the rotating field referred to the rotor which is also in rad/s. The active and reactive powers exchange between the stator and grid can defined as [3]

$$P_s = \frac{3}{2}\Re e\left(\overline{V}_s\vec{i}_s^{\,*}\right) \quad Q_s = \frac{3}{2}\Im m\left(\overline{V}_s\vec{i}_s^{\,*}\right) \quad \begin{cases} P_s = \frac{3}{2}\Re e\left(\overline{V}_s\vec{i}_s^{\,*}\right) \\ Q_s = \frac{3}{2}\Im m\left(\overline{V}_s\vec{i}_s^{\,*}\right) \end{cases}$$

6. RSC CONVERTER OF DFIG

The rotor-side converter (RSC) applies the voltage to the rotor windings of the DFIG. The purpose of the rotor side converter is to control the rotor currents such that the rotor flux position is optimally oriented with respect to the stator flux in order that the desired torque is developed at the shaft of the machine [5].

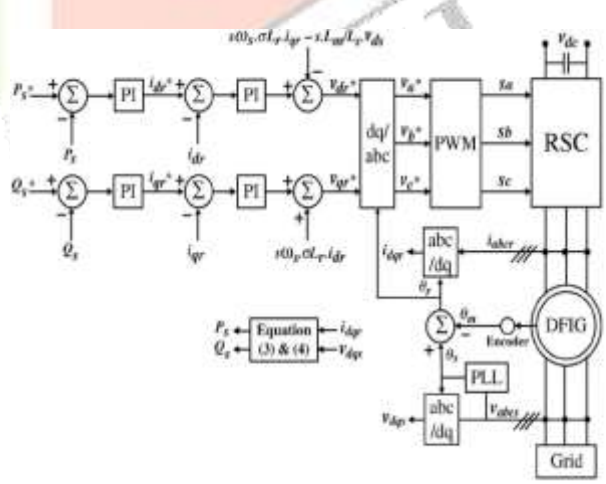

Fig.4. Diagram of stator voltage oriented Control [9]

SR NO.	Parameters	Value
01	Nominal Power –Pn	3730 W
02	Nominal Voltage (Line-Line)-Vn	460 V
03	Frequency-f	50 Hz
04	Stator Resistance –Rs (pu)	0.01965 ohm
05	Stator Inductance – Ls (pu)	0.0397 H
06	Rotor Resistance - Rr' (pu)	0.01909 ohm
07	Rotor Inductance - Lr' (pu)	0.230 H
08	Mutual Inductance – Lm (pu)	1.354 H
09	Inertia Constant - Hs	0.09526
10	Friction Factor –F (pu)	0.05479
11	Pole pairs- P	4 pole
12	Cut in Speed	3.5 m/s
13	Maximum output Speed	14 m/s

Fig.5. DFIG Ratings

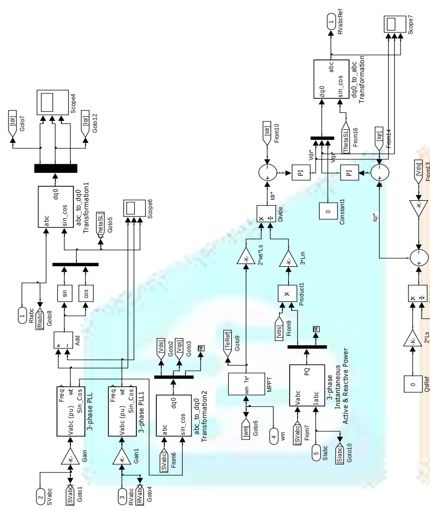

Fig.6. MATLAB Simulation RSC

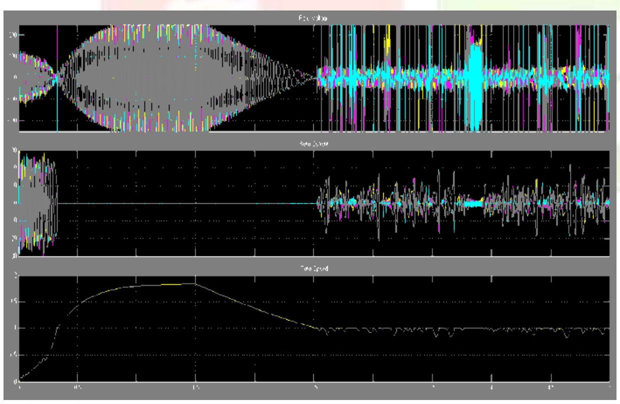

Fig.7. Rotor voltage-current-speed

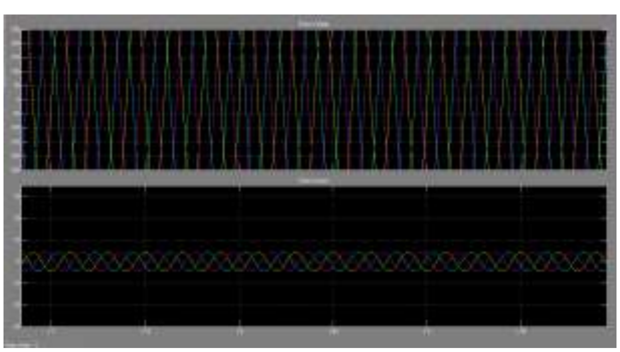

Fig.8. Stator voltage and stator current

7. GSC CONVERTER OF DFIG

The grid side converter tries to regulate the voltage of the dc bus capacitor. Moreover, it is allowed to generate or absorb reactive power for voltage support requirements. The function is realized with two control loops as well an outer regulation loop consisting of a dc voltage regulator. The output of the dc voltage regulator is the reference current icdref for the current regulator. The inner current regulation loop consists of a current regulator controlling the magnitude and phase of the voltage generated by converter from the icdref produced by the dc voltage regulator and specified q-axis icqref reference [9].

Active and reactive power control of the DFIG is based on the feedback method by using the suitable voltage vectors on the rotor side. The rotor flux has no impact on the changes of the stator active and reactive power. The proposed controller is based on the feedback method in order to reduce the oscillation of the generator. The control approach is estimated through the simulation result of the feedback controller assembled with DFIG wind turbines. It is applied by the feedback control based techniques in order to control the power flowing of DFIG and the power grid [9].

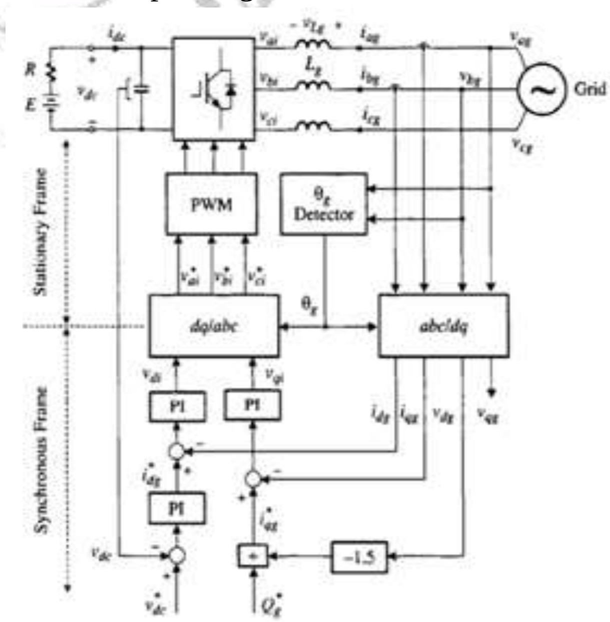

Fig.9. Block diagram of GSC [9]

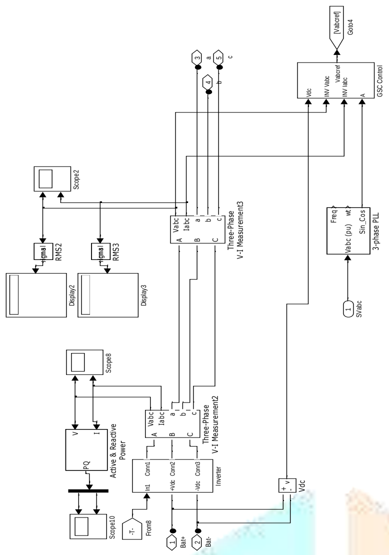

Fig.10. MATLAB simulation of GSC

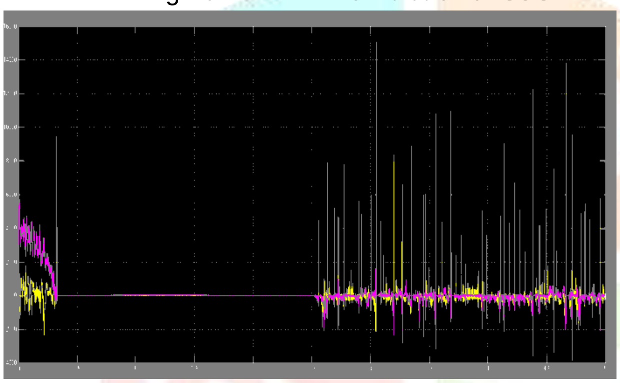

Fig.11. Active and reactive power - rotor side

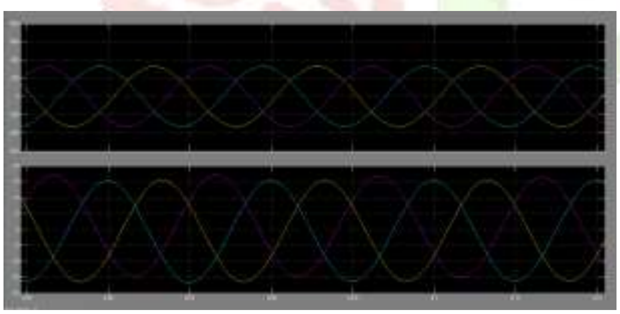

Fig.12. source voltage and source current

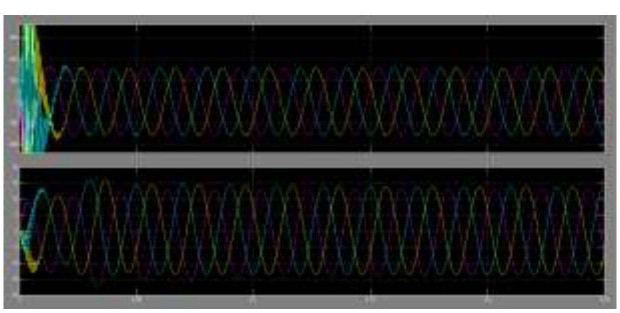

Fig.13. Inverter output voltage and current

8. CONCLUSION

To analysis of active and reactive power of waveform of rotor side converter and grid side converter. On mathematical equation and diagram of power converter simulate rotor side converter (RSC) and grid side converter (GSC). In rotor side converter 600 DC volt generated which is given to input of grid side converter and load connected at receiving end.

9. REFERENCES

[1] Francoise Mei and Bikash Pal, "Modal Analysis of Grid-Connected Doubly Fed Induction Generators". IEEE, VOL. 22, NO. 3, SEPTEMBER 2007.

[2] Balasubramaniam Babypriya and Rajapalan Anita, "MODELLING, SIMULATION AND ANALYSIS OF DOUBLY FED INDUCTION GENERATOR FOR WIND TURBINES", Journal of ELECTRICAL ENGINEERING, VOL. 60, NO. 2, 2009.

[3] Yazhou Lei, Alan Mullane, Gordon Lightbody, and Robert Yacamini "Modeling of the Wind Turbine with a Doubly Fed Induction Generator for Grid Integration Studies" IEEE, VOL. 21, NO. 1, MARCH 2006

[4] Dr John Fletcher and Jin Yang, "Introduction to Doubly-Fed Induction Generator for Wind Power Applications", Ju1.2013.

[5] Arantxa Tapia, Gerardo Tapia, J. XabierOstolaza, and José Ramón Sáenz "Modeling and Control of a Wind Turbine Driven Doubly Fed Induction Generator"IEEE, VOL. 18, NO. 2, JUNE 2003.

[6] Tran, Q.V., Chun, T.-W., Ahn, J.-R., Lee, H.-II, "Modal Analysis of Grid- connected Doubly Fed Induction Generators", IEEE Trans. Power Electron., pp. 2745-2750,2010..

[7] Johan Morren and Sjoerd W. H. de Haan, "Ridethrough of Wind Turbines with Doubly-Fed Induction Generator During a Voltage Dip" IEEE, VOL. 20, NO. 2, JUNE 2005.

[8] Yufei Tang, HaiboHe,Zhen Ni, Jinyu Wen, Xianchao Sui"Reactive power control of grid-

connected wind farm based on adaptive dynamic programming" Y. Tang et al. / Neurocomputing 125 (2014) 125–133,2013

[9] Bin Wu, Yongqiang Lang, Navid Zargari, Samir kouro, "Power Conversion and control of wind energy systems", IEEE PRESS ON POWER ENGINEERING, WILEY.

Yashvant Singh received B.E degree in Electrical Engineering from Sanjaybhai Rajyaguru College of Engineering, Rajkot in 2013. He is currently pursuing his M.E degree in Noble Group of Institutions, Junagadh. His area of interests includes renewable energy system, Wind Energy Conversion System.

Pankaj Jadav received B.E degree in Electrical Engineering from Sanjaybhai Rajyaguru College of Engineering, Rajkot in 2012. He is received of his M.E degree in V.V.P Engineering College, Rajkot. His area of interest is including renewable energy system, Hybrid renewable system, and power quality.