Optimal Tuning of Power Control for Doubly Fed Induction Generator in Wind Energy Conversion System

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Abstract

Renewable Energy Resources are best practices possible today to stand against increasingly risk of climate changes and global warming of the world and the most important sources of such types of resources of energies can be Wind and Solar energies which are most the efficient relatively. These clean power resources are used as in Distributed Generation (DGs) units technology to be defined as newer sources of power, which are in direct relation with the use of micro and smaller in capacity power generating units that are installed in distribution part of each power combined system or all the possible locations that loads and energy consumers are concentrated. Simulation of wind turbines driven double fed induction generator which fed ac power to the utility grid. For that, voltage sources converter are connected back to back between the rotor terminals and utility grid via common dc link. The size of these converters determines the speed range of the DFIG. The proper rotor excitation is provided by the machine side converter, wind power as an important and promising renewable resource is widely studied. Also, power quality problems associated with the wind turbines based distributed generation system and how the facts devices an important role in power quality improvement of distrusted generator system. Simulation study of the proposed system is carried out with MATLAB Simulink and simulation results are provided.
Keywords: Wind System, DFIG, DPC, Results of Simulink

I. INTRODUCTION

In last few year ,the environmental pollution has become a major worry in people's regular life and a possible power exigencies has lead people to develop new kind of technology for generating clean and RE (renewable energy). Also the environmental pollutions creating sources, like as coal power plant producing CO2 (carbon dioxide) ,the primary cause of global warming and other one , nuclear power plant producing radioactive substance & etc. and so that , now a days renewable energy mostly used .wind power alone with solar energy , hydro-power and Tidal energy are possible solution for an environmental friendly power production. In the power industry, wind power has been fastest growing speed (approximately 20 % annually).

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. 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. The optimum turbine speed producing maximum mechanical energy for a given wind speed is proportional to the wind speed. 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.

In conventional 3-ph generator external source makes to rotate generator. The static magnetic field created by the 3-ph AC supply fed into the generator rotor winding rotates at the same speed as the rotor. As a result, continually changing magnetic flux passes through the stator wdg as the rotor magnetic field rotates, including voltage across the stator winding. That mechanical power applied to the generator shaft (prime mover), thus converted to electrical power that is available at the stator wdg. In conventional I.G. relationship between frequency and rotor speed,

$$F_{stator} = N_{rotor} * N_{poles} / 120$$

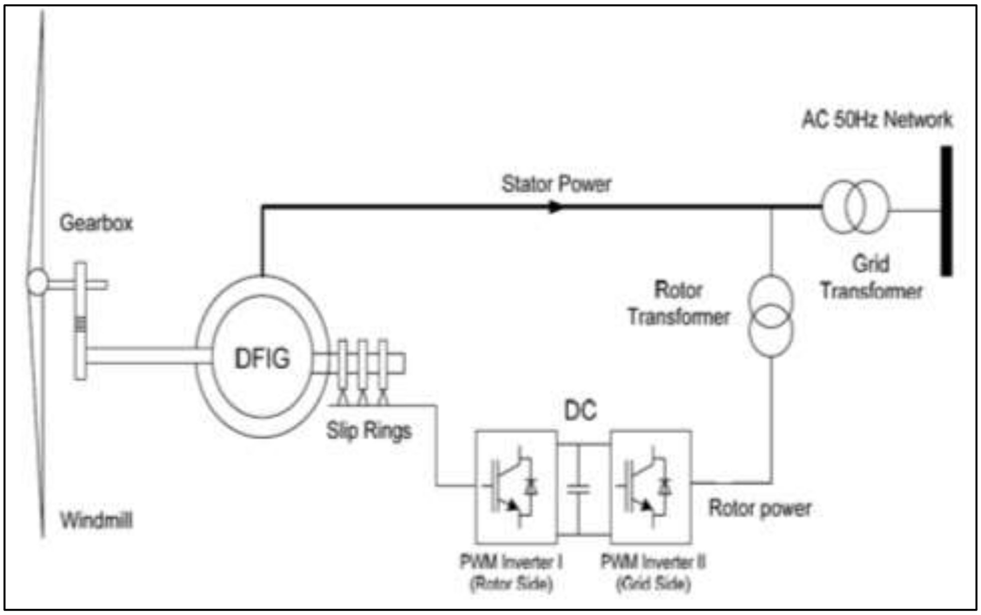

Fig. 1: Schematic diagram of proposed system.

II. LITERATURE REVIEW

In this Balasubramaniam Babypriya, Rajapalan[4] a simulation study on the operating characteristics of a doubly fed induction generator is performed using MATLAB. From the simulation analysis it is clear that the DFIG characteristics are affected by its injected rotor voltage.

In this B.Chitti Babu, K.B.Mohanty [5] paper has presented the modeling and simulation of wind turbine driven doubly-fed induction generator which feeds power to the utility grid. Wind turbine modeling has been described in order to extract maximum possible mechanical power from the wind according to the wind velocity and tip-speed ratio.

In this D.Aouzella, K.Ghedamsi, E.M.Berkouk [6] the work presented in this paper is devoted to the analysis, modeling and simulation of a variable speed wind turbine using a doubly fed induction. Stable operation of the DFIG was achieved by means of stator flux oriented control technique.

In this D. Ehlert and H. Wrede [7] the use of DFIG systems in WTG has tremendously matured over the last 20 years. It is planned to be installed in huge multi hundred megawatt off-shore wind farms simulation, analysis and solutions for improved performance in steady-state operation and during transient fault conditions of the transmission network they are connected to be required.

In this Dr. John Schonberger, Plexim Gmbh [8] report, a combined electrical-mechanical simulation model of a DFIG system has been presented. The model includes all electrical details of the rotor side converters and induction machine and the mechanical dynamics of the rotor and wind turbine. The wind turbine is modeled using a unique torque model.

III. DFIG

A. *Rotor Converter Control:*

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. This is the current component that produces the electromagnetic torque Tem. The actual Iqr component is compared to Iqr_ref and the error is reduced to zero by a current regulator (PI). The output of this current controller is the voltage Vqr generated by Crotor. The current regulator is assisted by feed forward terms which predict Vqr. The voltage at grid terminals is controlled by the reactive power generated or absorbed by the converter Crotor. The reactive power is exchanged between Crotor and the grid, through the generator. In the exchange process the generator absorbs reactive power to supply its mutual and leakage inductances. The excess of reactive power is sent to the grid or to Crotor.

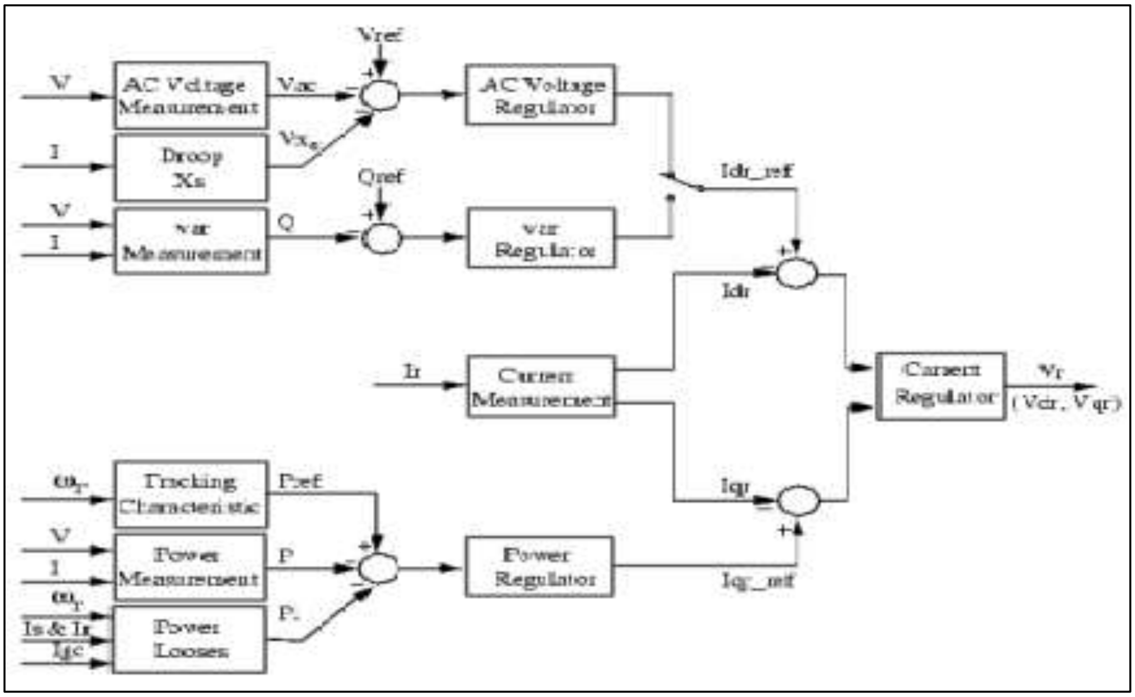

Fig. 2: Rotor converter control block diagram

B. Grid side converter control system

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. A measurement system measuring the d and q components of AC currents to be controlled as well as the DC voltage Vdc.

- An outer regulation loop consisting of a DC voltage Regulator.
- An inner current regulation loop consisting of a current Regulator.

The current regulatory controls the magnitude and phase of the voltage generated by converter Cgrid (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 Cgrid output voltage.

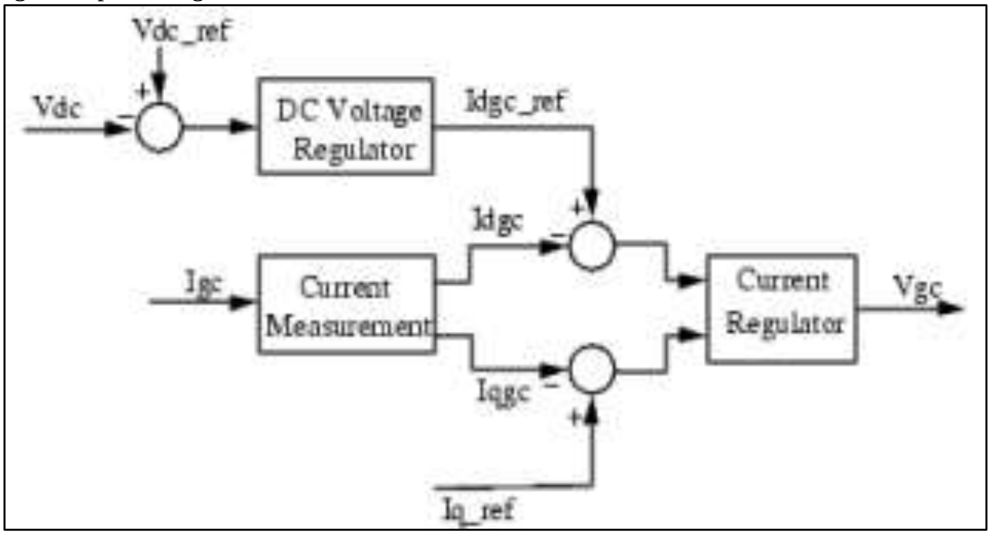

Fig. 3: grid converter control block diagram

C. Pitch Angle Control System:

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.

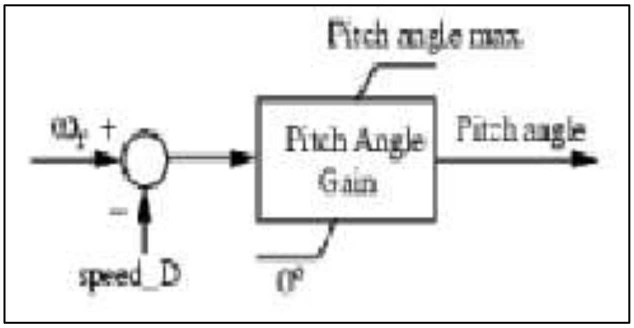

Fig. 4: Pitch angle control system

IV. WIND TURBINE SYSTEM

Wind turbine is applied to convert the wind Energy to mechanical torque. The mechanical torque of turbine can be calculated from mechanical power at the turbine extracted from wind power. This fact of the wind speed after the turbine isn't zero. Then, the power coefficient of the turbine (C_p) is used. The power coefficient is function of pitch angle (β) and tip speed (λ), pitch angle is angle of turbine blade whereas tip speed is the ratio of rotational speed and wind speed. The power coefficient maximum of (C_p) is known as the limit of Betz.

The power coefficient is given by

$$C_P(\lambda,\beta) = C_1\left(\frac{C_2}{\lambda_i} - c_3\beta - c_4\right)e^{-\frac{c_5}{\lambda_i}} + c_6\lambda$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1}$$

The power coefficient is given by

$$c_p = \frac{p_m}{p_w} \quad ;\ c_p < 1$$

$$p_m = c_p(\lambda,\beta)\frac{\rho S}{2}v_w^3$$

Where

P_m = the mechanical output power of the turbine
C_p = the performance coefficient of the turbine
ρ = the air density
S = the turbine swept area
V_w = the wind speed
K_p = gain power
λ = the tip speed ratio
β = the blade pitch angle

The mechanical torque is given by

$$T_m = \frac{P_m}{w}$$

The WECS is presented with two-mass drive train model. The mathematical model are given by [12]

$$2H_t\frac{dw_t}{dt} = T_m - T_s$$

$$\frac{1}{W_{ebs}}\frac{d\theta_{sta}}{dt} = w_t - w_r$$

$$T_s = K_{ss}\theta_{sta} + D_t\frac{d\theta_{sta}}{dt}$$

Where

H_t = the inertia constant of the turbine
θ_{sta} = the shaft twist angle
w_t = the angular speed of the wind turbine
w_r= the rotor speed of generator
w_{ebs} = the electrical base speed
T_s = Shaft torque
K_{ss} = the shaft stiffness
D_t = the damping coefficient

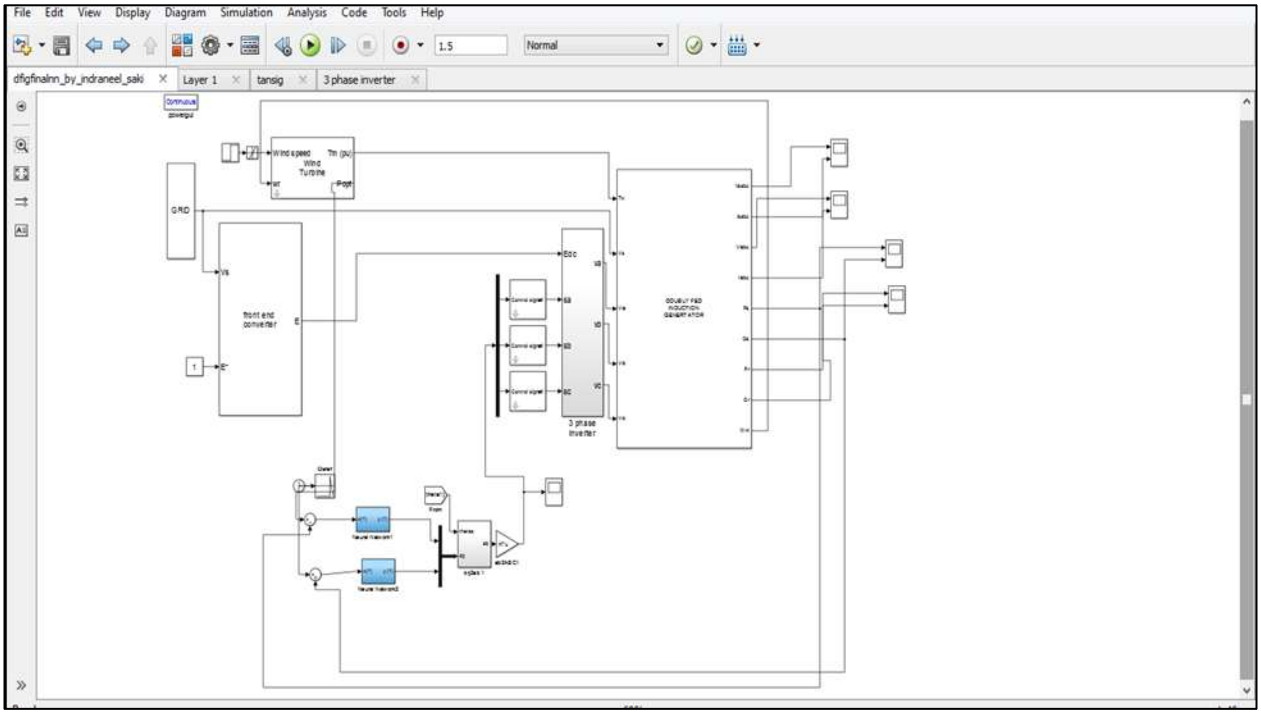

Fig. 5: Simulation model of DFIG

A. DPC Method:

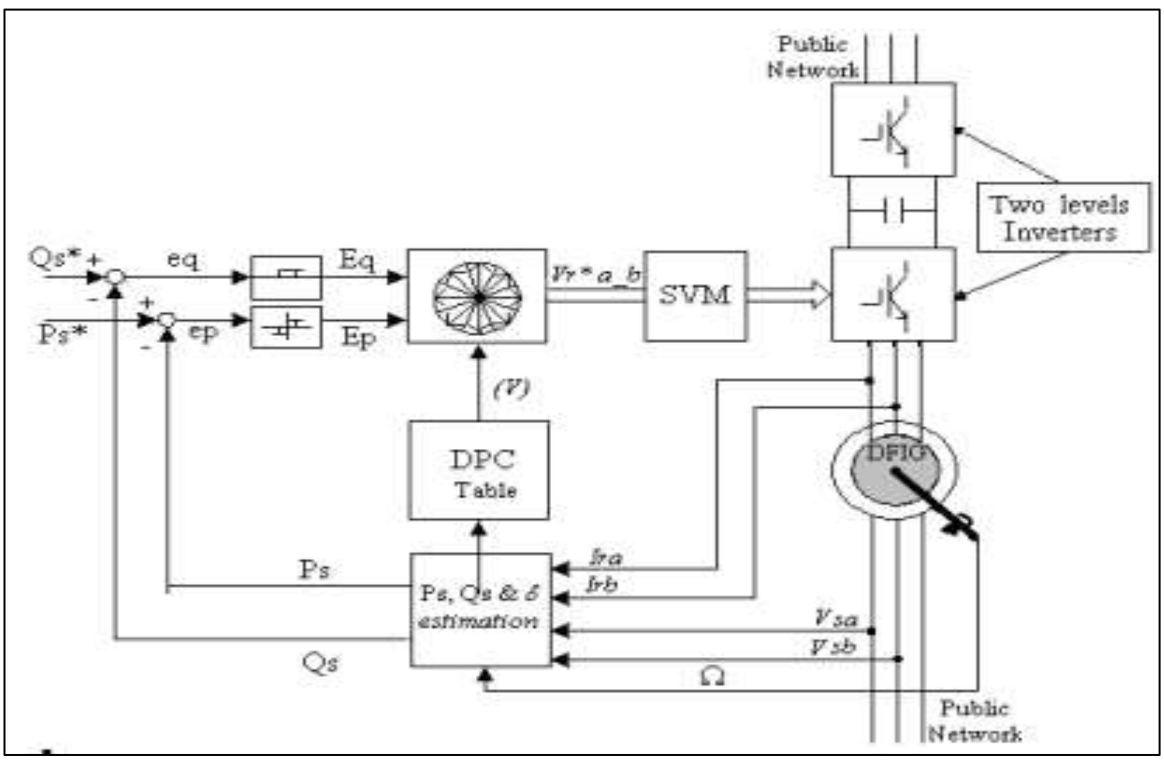

Fig. 6: Direct Power Control Strategy

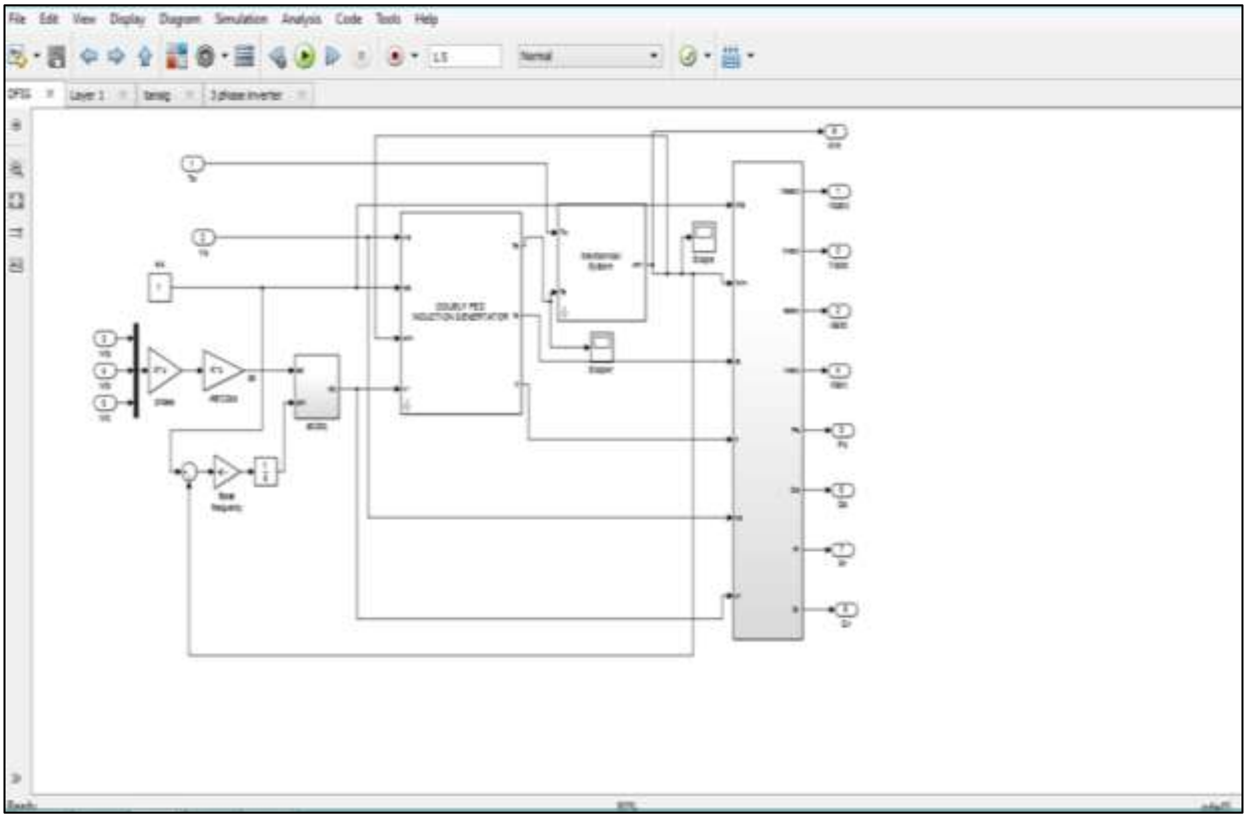

Fig. 7: Simulation model of Wind System

V. SIMULATION RESULT

For the simulation, solar irradiance and wind speed are used. The data is the input Wind energy system. The waveforms of the Wind energy generation system are shown and also the waveform of grid voltage and current is obtained.

Table – 1
Parameters of Wind Turbine

Parameter	*Value*
Rated Power	*5.3 KW*
Rated Wind Speed	*10 m/s*
Blade Radius	*2.5 m*
Blade Pitch Angle	*0 degree*
Air Density	*1.225 kg/m3*
Rated Rotor Speed	*21.09 rad/s*

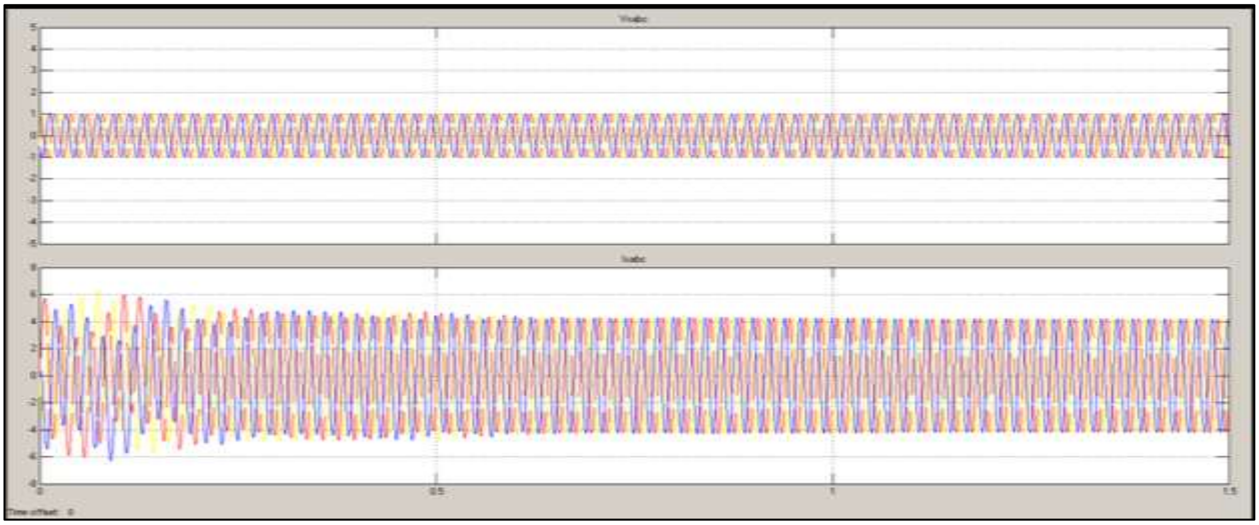

Fig. 8: Waveform of Output VRABC & IRABC

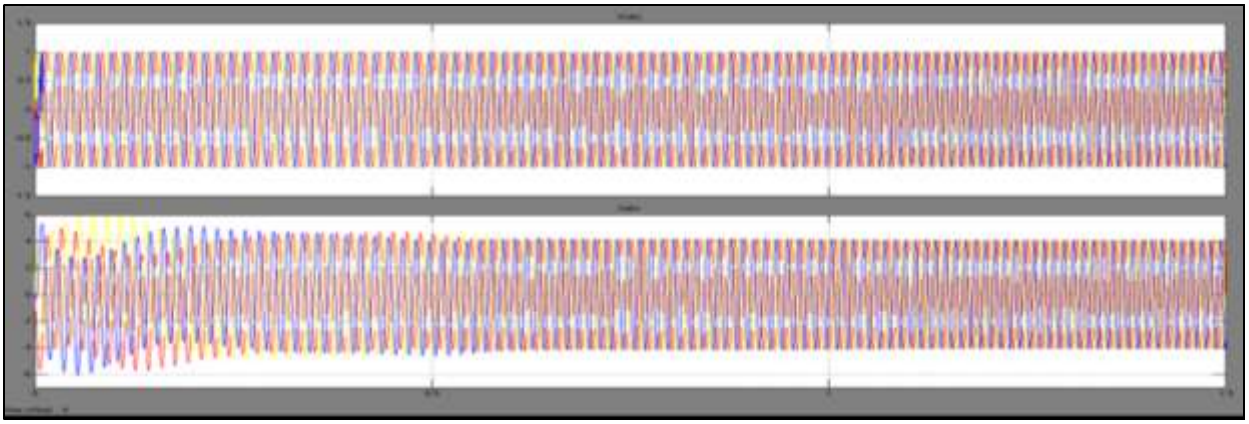

Fig. 9: Waveform of Output Vsabc & Isabc

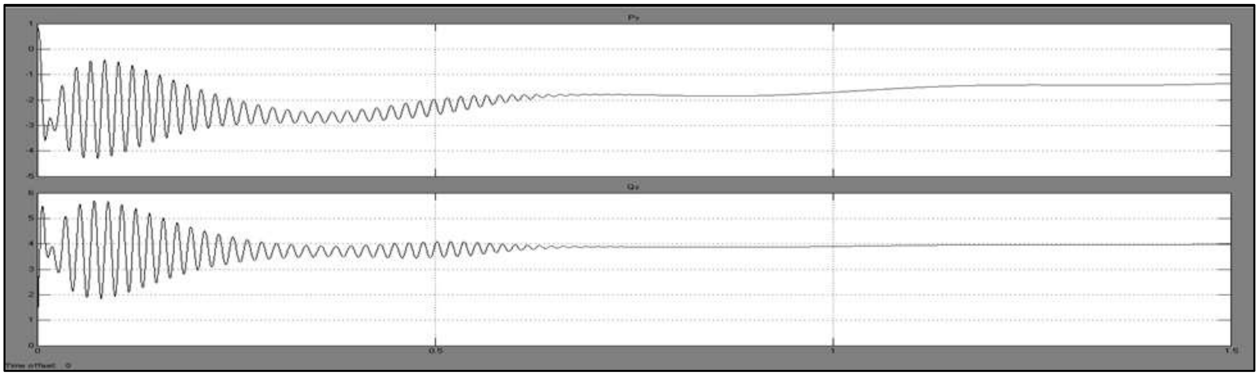

Fig. 10: Waveform of Output Ps & Qs

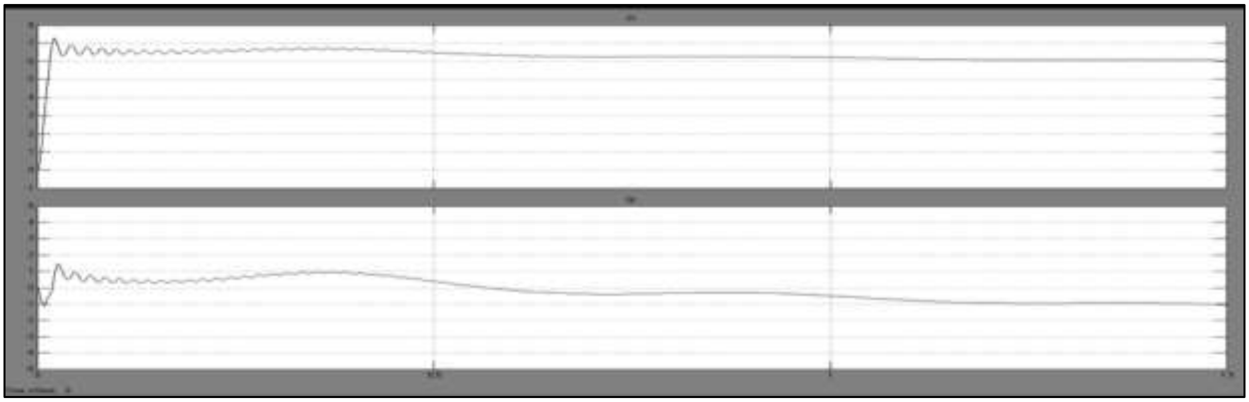

Fig. 11: Waveform of Output Pr & Qr

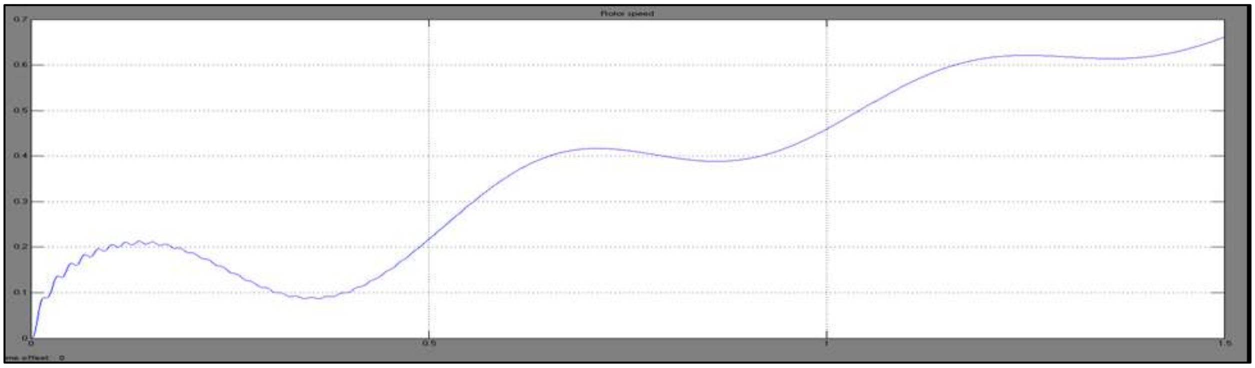

Fig. 12: Rotor speed

VI. CONCLUSION

We have discussed here the basic operation of DFIG and its controls using AC/DC/AC converter. First we simulated a wind turbine driven isolated (not connected to grid) induction generator. But for best efficiency the DFIG system is used which is connected to grid side and has better control. The rotor side converter (RSC) usually provides active and reactive power control of the machine while the grid-side converter (GSC) keeps the voltage of the DC-link constant. So finally we simulated grid side and wind turbine side parameters and the corresponding results have been displayed. The model is a discrete-time version of the Wind Turbine Doubly-Fed Induction Generator (Pharos Type) of Matlab/SimPowerSystems. Here we also took the protection system in consideration which gives a trip signal to the system when there is a fault (single phase to ground fault) on the system. The faults can occur when wind speed decreases to a low value or it has persistent fluctuations. The DFIG is able to provide a considerable contribution to grid voltage support during short circuit periods. Considering the results it can be said that doubly fed induction generator proved to be more reliable and stable system when connected to grid side with the proper converter control systems.

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