INTERNATIONAL JOURNAL OF ENHANCED RESEARCH IN SCIENCE TECHNOLOGY & ENGINEERING
VOL. 2 ISSUE 1, JAN.-2013 ISSN NO: 2319-7463

Transient Modeling of Doubly Fed Induction Generator

Bhola Jha[1], Dr. K. R. M Rao[2]
[1]Dept. of Electrical Engg., G. B. Pant Engg. College, Pauri-Garhwal, India
[2]Dept. of Electrical Engg., M. J. College of Engg. & Tech., Hyderabad, India

Abstract: Doubly Fed Induction Generator (DFIG) finds wide applications in wind energy that keeps on changing. Also, Small disturbances refer to transients; can be modeled as the change in load to DFIG system occurs more frequently. Therefore understanding the transient operation of DFIG became very much interesting and challenging. This is desired that the system should able to digest such disturbances. In this connection, this paper presents the transient modeling of DFIG for which speed controller and power factor controller are implemented to rotor in order to take care of such disturbances. This paper also presents the transient modeling of two DFIGs connected to the power system. The operation of two DFIGs connected to power system is analyzed and addressed.

Keywords: DFIG, Transient modeling, Speed controller, Power factor controller.

I. INTRODUCTION

The power available in the wind rotates the device known as wind turbine that provides the mechanical energy to the generator for generating electricity. Wind turbines can either operate at fixed speed or variable speed. For a fixed-speed wind turbine the generator is directly connected to the electrical grid. Cage induction generator is usually employed for fixed speed wind turbine. For a variable speed wind turbine the generator is connected to grid through power electronic converter. This means that the power electronic converter decouples the generator from the grid. Synchronous generator and doubly fed induction generator are employed for variable speed wind turbine. There are several advantages of using variable-speed operation of wind turbines [1-7]. Harnessing the wind energy for variable speed wind turbines is one of the major applications of Doubly Fed Induction Generator (DFIG).Most of the wind turbine manufactures are developing larger DFIG-based variable speed wind turbines in the MW range due to many advantages. Firstly, as the rotor circuit can be controlled such that the induction generator is able to import and export reactive power. This has important consequences for power system stability and allows the machine to support the grid during severe voltage disturbances (low voltage ride through, LVRT) [5-7]. Secondly, the control of the rotor voltages and currents enable the induction machine to remain synchronized with the grid while the wind turbine speed varies. Thirdly, the fraction of the stator power, typically 25-30 %, is fed to the grid through the rotor the rest being fed to grid directly from the stator. Thus, the efficiency of the DFIG is very good. In DFIG, by controlling the rotor voltages/currents it is possible to adjust the active and reactive power fed to the grid from the stator independently of the generators turning speed [1], [7] & [8-12]. The schematic diagram of DFIG is shown in Fig.1.

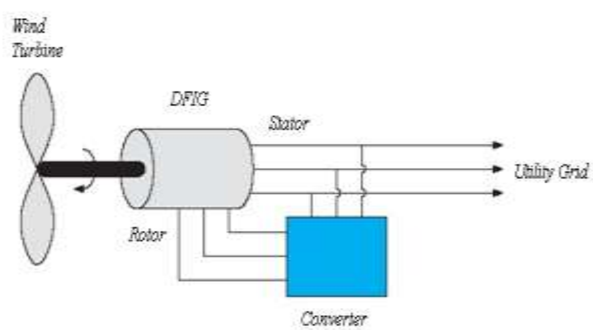

Fig.1: Schematic diagram of DFIG

Since the wind speed keeps on changing and also transients are occurring more frequently to the DFIG-based wind system. So understanding the transient operation of DFIG became very much interesting and challenging. Therefore; in this paper, speed controller and power factor controller are implemented to the rotor voltage vector in order to take care of transients. The rotor voltage vector is calculated in terms of direct and quadrature components referenced to a synchronously rotating reference frame for independent control of active power (speed) and reactive power (power factor). This paper also presents the modeling of two DFIGs connected to the power system. The operation of two DFIGs connected to power system is analyzed and addressed for different loadings. The symbols used in this paper are mentioned below:

V_{ds}	=	Stator voltage along *d* axis;	V_{qs}	=	Stator voltage along *q* axis
V_{dr}	=	Rotor voltage along *d* axis;	V_{qr}	=	Rotor voltage along *q* axis
ω_r	=	Rotor frequency;	ω_b	=	Base/rated frequency
I_{ds}	=	Stator current along *d* axis;	I_{qs}	=	Stator current along *q* axis
I_{dr}	=	Rotor current along *d* axis;	I_{qr}	=	Rotor current along *q* axis
Ψ_{ds}	=	Stator flux linkages along *d* axis;	Ψ_{qs}	=	Stator flux linkages along *q* axis
Ψ_{dr}	=	Rotor flux linkages along *d* axis;	Ψ_{qr}	=	Rotor flux linkages along *q* axis
X_{ls}	=	Magnetizing leakage reactance of stator	X_{lr}	=	Magnetizing leakage reactance of rotor
X_m	=	Mutual reactance;	R_s	=	Stator resistance
R_r	=	Rotor resistance;	$p = \frac{d}{dt}$	=	Differentiation
P	=	Pair of poles;	H	=	Inertia constant
T_m	=	Mechanical torque;	T_e	=	Electromagnetic torque
K	=	Gain of controller;	ζ	=	Time constant of controller
$\omega = \frac{d\theta}{dt}$	=	Angular frequency;	θ_r	=	Rotor angle
R	=	Transmission line resistance;	L	=	Transmission line inductance

II. MODELING OF DOUBLY FED INDUCTION GENERATOR

The mathematical modeling that describes nonlinear differential equations of DFIG [13-14] is mentioned below. It is convenient to express the voltage and flux linkages in terms reactance rather than inductances because machine and power system parameters are usually given in ohms or percentage or per unit of base impedance.

$$\begin{bmatrix} V_{qs} \\ V_{ds} \\ V_{qr} \\ V_{dr} \end{bmatrix} = \begin{bmatrix} \frac{R_s X_{rr}}{D} + \frac{p}{\omega_b} & \frac{\omega}{\omega_b} & \frac{-R_s X_m}{D} & 0 \\ -\frac{\omega}{\omega_b} & \frac{R_s X_{rr}}{D} + \frac{p}{\omega_b} & 0 & \frac{-R_s X_m}{D} \\ \frac{-R_r X_m}{D} & 0 & \frac{R_r' X_{ss}}{D} + \frac{p}{\omega_b} & \frac{\omega - \omega_r}{\omega_b} \\ 0 & \frac{-R_r X_m}{D} & \frac{-(\omega - \omega_r)}{\omega_b} & \frac{R_r X_{ss}}{D} + \frac{p}{\omega_b} \end{bmatrix} \begin{bmatrix} \psi_{qs} \\ \psi_{ds} \\ \psi_{qr} \\ \psi_{dr} \end{bmatrix}$$

where, D = $X_{ss} X_{rr}$ - X_m^2

and $X_{ss} = X_{ls} + X_m X_{ss} X_{rr}$

$X_{rr} = X_{lr} + X_m$

The above matrix can also be written as

$$\begin{bmatrix} p\psi_{qs} \\ p\psi_{ds} \\ p\psi_{qr} \\ p\psi_{dr} \end{bmatrix} = \begin{bmatrix} -\frac{R_s X_{rr}}{D}\omega_b & -\omega & \frac{R_s X_m}{D}\omega_b & 0 \\ \omega & -\frac{R_s X_{rr}}{D}\omega_b & 0 & \frac{R_s X_m}{D}\omega_b \\ \frac{R_r X_m}{D}\omega_b & 0 & -\frac{R_r X_{ss}}{D}\omega_b & -(\omega - \omega_r) \\ 0 & \frac{R_r X_m}{D}\omega_b & (\omega - \omega_r) & -\frac{R_r X_{ss}}{D}\omega_b \end{bmatrix} \begin{bmatrix} \psi_{qs} \\ \psi_{ds} \\ \psi_{qr} \\ \psi_{dr} \end{bmatrix} + \begin{bmatrix} V_{qs} \\ V_{ds} \\ V_{qr} \\ V_{dr} \end{bmatrix} \quad (1)$$

The expression for electromagnetic torque of a machine is given by

$$T_e = \left(\frac{3}{2}\right)\left(\frac{P}{2}\right)\left(\frac{X_m}{D\omega_b}\right)(\psi_{qs}\psi_{dr} - \psi_{qr}\psi_{ds}) \tag{2}$$

Flux linkages per second are expressed as

$$\psi_{qs} = X_{ls}I_{qs} + X_m(I_{qs} + I_{qr})$$

$$\psi_{ds} = X_{ls}I_{ds} + X_m(I_{ds} + I_{dr})$$

$$\psi_{qr} = X_{lr}I_{qr} + X_m(I_{qs} + I_{qr})$$

$$\psi_{dr} = X_{lr}I_{dr} + X_m(I_{ds} + I_{dr})$$

If the currents are selected as independent variables then the flux linkages per second may be expressed as below.

$$\begin{bmatrix}\psi_{qs}\\ \psi_{ds}\\ \psi_{qr}\\ \psi_{dr}\end{bmatrix} = \begin{bmatrix}X_{ss} & 0 & X_m & 0\\ 0 & X_{ss} & 0 & X_m\\ X_m & 0 & X_{rr} & 0\\ 0 & X_m & 0 & X_{rr}\end{bmatrix}\begin{bmatrix}I_{qs}\\ I_{ds}\\ I_{qr}\\ I_{dr}\end{bmatrix}$$

If the flux linkages or flux linkages per second are selected as independent variables then the above matrix may be solved for currents and written as

$$\begin{bmatrix}I_{qs}\\ I_{ds}\\ I_{qr}\\ I_{dr}\end{bmatrix} = \frac{1}{D}\begin{bmatrix}X_{rr} & 0 & -X_m & 0\\ 0 & X_{rr} & 0 & -X_m\\ -X_m & 0 & X_{ss} & 0\\ 0 & -X_m & 0 & X_{ss}\end{bmatrix}\begin{bmatrix}\psi_{qs}\\ \psi_{ds}\\ \psi_{qr}\\ \psi_{dr}\end{bmatrix} \tag{3}$$

The speed equation is written as

$$p\omega_r = \frac{\omega_b}{2H}(T_m - T_e) \tag{4}$$

A change of variables that formulates a transformation of the 3-phase variables of stator circuit to the arbitrary reference frame is

$$f_{qdos} = K_s f_{abcs}$$

where, $(f_{qdos})^T = [f_{qs} \quad f_{ds} \quad f_{os}]$, $(f_{abcs})^T = [f_{as} \quad f_{bs} \quad f_{cs}]$ and

$$K_s = (2/3)\begin{bmatrix}\cos\theta & \cos(\theta - 2\pi/3) & \cos(\theta + 2\pi/3)\\ \sin\theta & \sin(\theta - 2\pi/3) & \sin(\theta + 2\pi/3)\\ 1/2 & 1/2 & 1/2\end{bmatrix} \tag{5}$$

$$\omega = \frac{d\theta}{dt}$$

$$\theta = \omega \int dt$$

But, if ω varies with time, then another relation exists, as

$$\theta(t) = \omega t + \theta(0)$$

But in this case ω is constant so the direct relation i.e.$\theta = \omega t$ is used.

For inverse transformation, we have

$$(K_s)^{-1} = \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos(\theta - {}^{2\pi}/_3) & \sin(\theta - {}^{2\pi}/_3) & 1 \\ \cos(\theta + {}^{2\pi}/_3) & \sin(\theta + {}^{2\pi}/_3) & 1 \end{bmatrix} \quad (6)$$

The three phase stator currents can be expressed as

$$\begin{bmatrix} I_{as} \\ I_{bs} \\ I_{cs} \end{bmatrix} = \begin{bmatrix} \cos\omega t & \sin\omega t & 1 \\ \cos(\omega t - {}^{2\pi}/_3) & \sin(\omega t - {}^{2\pi}/_3) & 1 \\ \cos(\omega t + {}^{2\pi}/_3) & \sin(\omega t + {}^{2\pi}/_3) & 1 \end{bmatrix} \begin{bmatrix} I_{qs} \\ I_{ds} \\ 0 \end{bmatrix}$$

A change of variables which formulates a transformation of the 3-phase variables of rotor circuits to the arbitrary reference frame is:

$$f_{qdor} = k_r f_{abcr}$$

Where, $(f_{qdor})^T = [f_{qr}\ f_{dr}\ f_{or}]$, $(f_{abcr})^T = [f_{ar}\ f_{br}\ f_{cr}]$ and

$$K_r = ({}^2/_3) \begin{bmatrix} \cos\beta & \cos(\beta - {}^{2\pi}/_3) & \cos(\beta + {}^{2\pi}/_3) \\ \sin\beta & \sin(\beta - {}^{2\pi}/_3) & \sin(\beta + {}^{2\pi}/_3) \\ {}^1/_2 & {}^1/_2 & {}^1/_2 \end{bmatrix} \quad (7)$$

Where, $\beta = (\theta - \theta_r)$

The angular displacement θ is defined as above and θ_r is the rotor angle defined by,

$$\omega_r = \frac{d}{dt}(\theta_r)$$

$$[k_r]^{-1} = \begin{bmatrix} \cos\beta & \sin\beta & 1 \\ \cos(\beta - {}^{2\pi}/_3) & \sin(\beta - {}^{2\pi}/_3) & 1 \\ \cos(\beta + {}^{2\pi}/_3) & \sin(\beta + {}^{2\pi}/_3) & 1 \end{bmatrix} \quad (8)$$

$$V_{qdor} = k_r V_{abcr}$$

The rotor voltages with respect to stator side can be expressed as

$$V_{abcr} = [k_r]^{-1} V_{qdor}$$

The rotor currents with respect to stator side can be expressed as

$$I_{abcr} = [k_r]^{-1} I_{qdor}$$

III. CONTROL OF DOUBLY FED INDUCTION GENERATOR

The control of DFIG is done so as to achieve suitable torque and speed with an impressed slip. The control is done on speed and p.f to attain best slip power recovery. The speed and power factor is improved by changing the rotor voltage i. e., rotor voltage control. The p.f control near to unity is attained by changing the V_{dr} and speed control to a value much greater than synchronous speed of the machine is attained by changing the V_{qr}. The rotor voltage vector is calculated in terms of direct and quadrature (d and q) components referenced to a synchronously rotating reference frame. The d axis of the frame can be arranged to coincide with the stator flux vector. The d component of the rotor voltage vector is used to exercise control over the stator terminal voltage magnitude or the power factor. The power factor defines the phase relationship between the stator terminal voltage and the stator current. The d axis rotor current error is processed to provide the demanded value of the d axis component of the rotor voltage vector. The q axis component of rotor voltage is used to exercise control over the generator torque via control over the q axis value of the rotor current. The q axis rotor current error is processed to provide the demanded value of the q axis component of the rotor voltage vector. However, this control strategy gives rise to interaction between the control loops. In process control today, more than 95% of the control loops are of PID type, most loops are actually series PID control which is found in all areas. Here also, the same series controller is used.

A. *Speed Control of Doubly Fed Induction Generator*

As already mentioned that speed can be varied by varying the V_{qr}. There is an inverse relationship between speeds and V_{qr}. So, we take the negative gain for the speed controller. The speed control block diagram is shown in Fig.2.

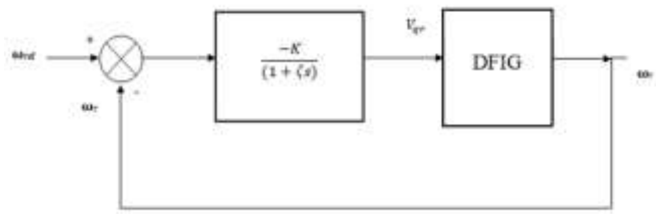

Fig.2: Speed control block diagram of DFIG

$$V_{qr} = \frac{-K}{1+s\zeta}.error$$

$$V_{qr} + \zeta.\frac{dV_{qr}}{dt} = -K.error$$

$$\frac{dV_{qr}}{dt} = -\frac{V_{qr}}{\zeta} - \frac{K.error}{\zeta}$$

$$V_{qr} = V_{qr} + \frac{dV_{qr}}{dt}$$

$$V_{qr} = V_{qr} + \left(-\frac{V_{qr}}{\zeta} - \frac{K.error}{\zeta}\right)$$

B. *Power Factor Control of Doubly Fed Induction Generator*

The power factor of a DFIG system can be varied by varying the V_{dr}. The Block diagram for power factor control of DFIG is shown in Fig.3.

$$V_{dr} = \frac{K}{1+s\zeta}.error$$

$$V_{dr} + \zeta.\frac{dV_{dr}}{dt} = K.error$$

$$\frac{dV_{dr}}{dt} = -\frac{V_{dr}}{\zeta} + \frac{K.error}{\zeta}$$

$$V_{dr} = V_{dr} + \frac{dV_{dr}}{dt}$$

$$V_{dr} = V_{dr} + \left(-\frac{V_{dr}}{\zeta} + \frac{K.error}{\zeta}\right)$$

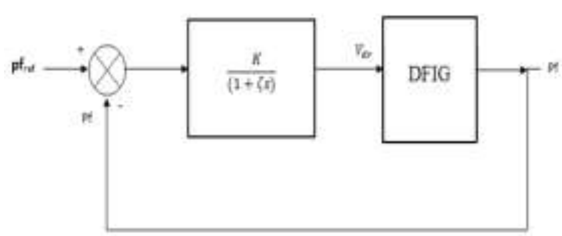

Fig.3: Power factor control block diagram of DFIG

IV. FLOW CHART OF SIMULATION PROCEDURE

The procedural steps to simulate the generator are shown in Fig.4. Fluxes are calculated first using equation (1). Once we know the fluxes then toque and currents can be calculated using equations (2) and (3) respectively. Rotor speed can be computed using equation (4). For the transformation of variables (*a-b-c* to *d-q* and vice-versa), equations (5), (6), (7) and (8) are used. In motoring mode, the electromagnetic torque equals the mechanical torque or load torque for zero frictional torque. In generating mode, for zero frictional torque, the mechanical torque/load torque equals the electromagnetic torque which is reversed (negative) as compared to motor.

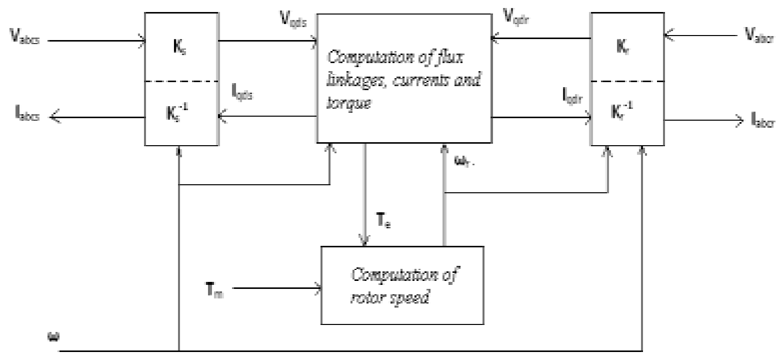

Fig.4: Simulation block diagram of Doubly Fed Induction Generator

V. MODELING OF TWO DFIGS CONNECTED TO POWER SYSTEM

The representation of two DFIGs connected to the power system is shown in Fig.5.

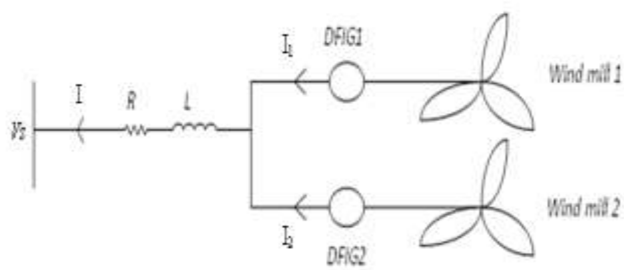

Fig.5: Representation of two DFIGs connected to power systems

Applying KCL, we have

$$I = I_1 + I_2$$

$$I = \frac{\Psi}{\omega_b L}$$

Considering the transmission line drop, the voltage drop between the two points are written as

$$V_{bus} - V_s = R(I_1 + I_2) + L\left(\frac{dI_1}{dt} + \frac{dI_2}{dt}\right)$$

$$V_{qbus} - V_{qs} = \frac{R\psi_q}{\omega_b L} + \frac{1}{\omega_b}\frac{d\psi_q}{dt}$$

$$V_{dbus} - V_{ds} = \frac{R\psi_d}{\omega_b L} + \frac{1}{\omega_b}\frac{d\psi_q}{dt}$$

From the above equations, we can write

$$\frac{d\psi_q}{dt} = -\frac{R}{L}\psi_q + \omega_b(V_{qbus} - V_{qs})$$

$$\frac{d\psi_d}{dt} = -\frac{R}{L}\psi_d + \omega_b(V_{dbus} - V_{ds})$$

The above equations can be written in matrix form

$$\begin{bmatrix} p\psi_{qsys} \\ p\psi_{dsys} \end{bmatrix} = \begin{bmatrix} -\frac{R}{L} & 0 \\ 0 & -\frac{R}{L} \end{bmatrix} \begin{bmatrix} \psi_q \\ \psi_d \end{bmatrix} + \omega_b \begin{bmatrix} V_{qbus} - V_{qs} \\ V_{dbus} - V_{ds} \end{bmatrix}$$

Here, V_{qbus} and V_{dbus} are the stator voltage of DFIG whereas V_{qs} and V_{ds} are the grid voltage and there is a transmission line in between stator and grid. No more description is required regarding simulation procedure, speed control, power factor control, calculation of flux, current and torque in case of two DFIGs connected to power system because they are same which is already described in earlier sections.

VI. SIMULATION RESULTS

The Fig.6 shows the electromagnetic torque Vs time characteristics and Fig.7 represents speed Vs time characteristics of a 3-hp induction machine in generating mode. The electromagnetic torque (Te) is negative in generating condition and it reaches to a steady value of -11.87 N-m due to speed controlling action. At the zero electromagnetic torque machine runs at synchronous speed of 1800 rpm. As the load torque increases in negative direction, speed increases beyond the synchronous speed to validate the generating action.

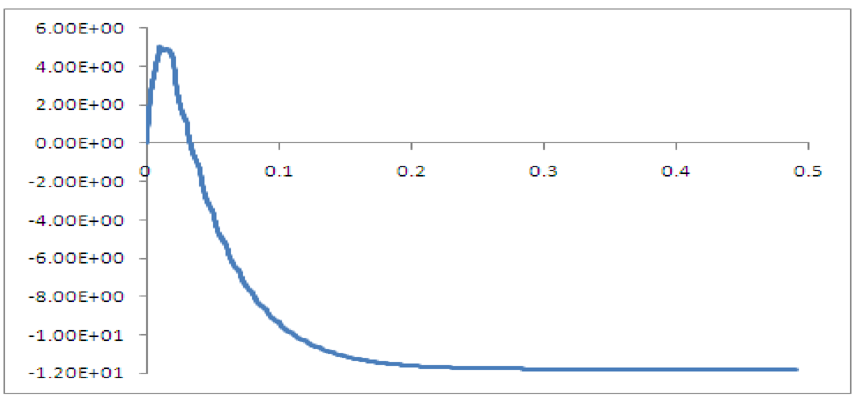

Fig.6:Transient performance of DFIG with torque 11.8N-m

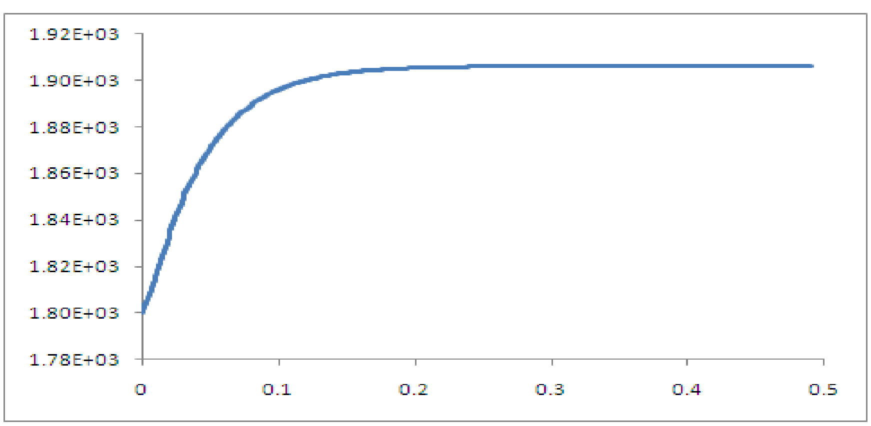

Fig.7: Transient performance of speed control

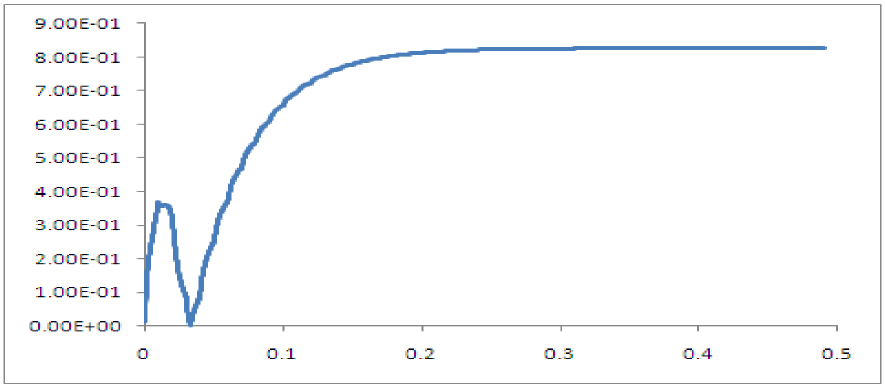

Fig.8: Transient performance of power factor control

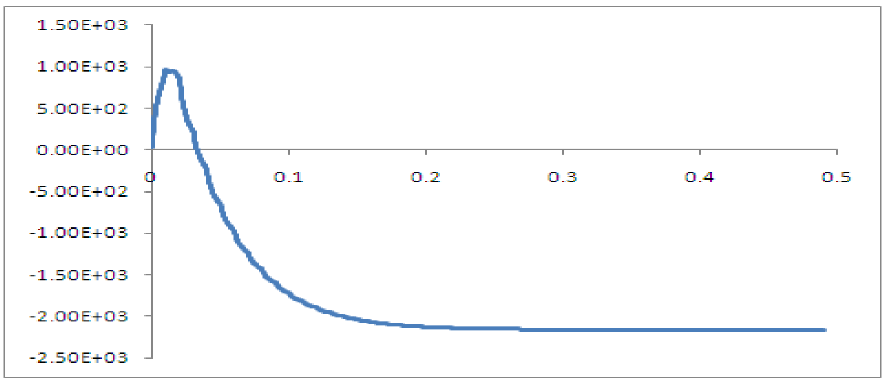

Fig.9: Transient performance of active power

The Fig.8 shows the power factor Vs time characteristics and Fig.9 shows the power Vs time characteristics of DFIG. The induction machine comes into generating mode for the negative load torque. Therefore, the power generated $(p = \omega_r T_e)$is indicated with negative sign and reaches to steady state value. The power factor also shoots up to approximately 0.8 due to power factor controlling action.

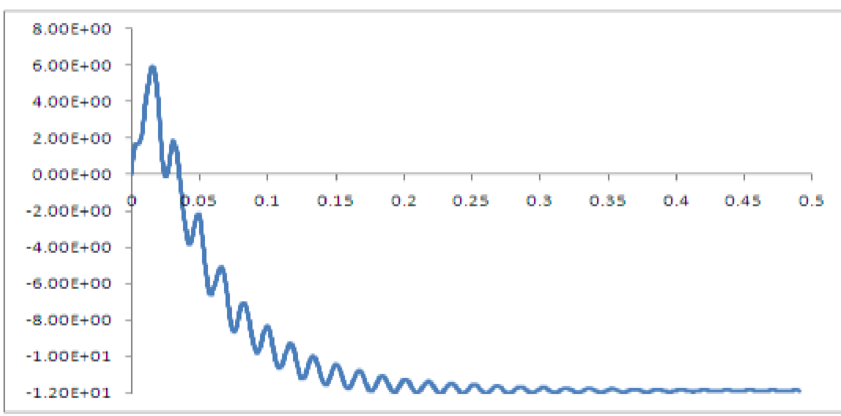

Fig.10: Performance with load torque of 11.87 N-m

The performances of two interconnected DFIGs to the power system are shown below. The torque, speed, power factor and power of DFIG are shown in Fig.10, Fig.11, Fig.12 and Fig.13 for equally loaded of 11.87 N-m. This is to be noted that the parameters of both the machines are same.

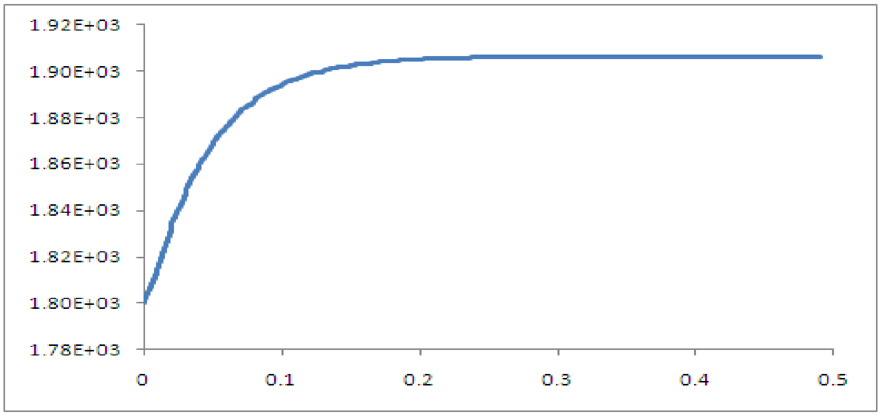

Fig.11: Performance of speed control

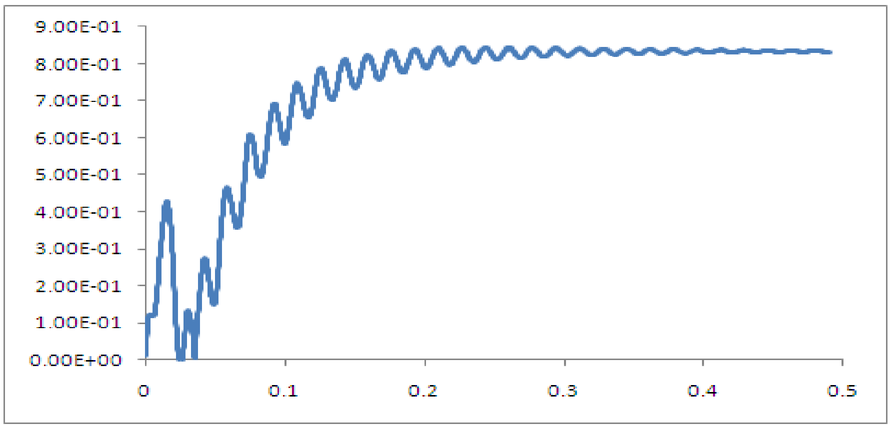

Fig.12: Performance of power factor control

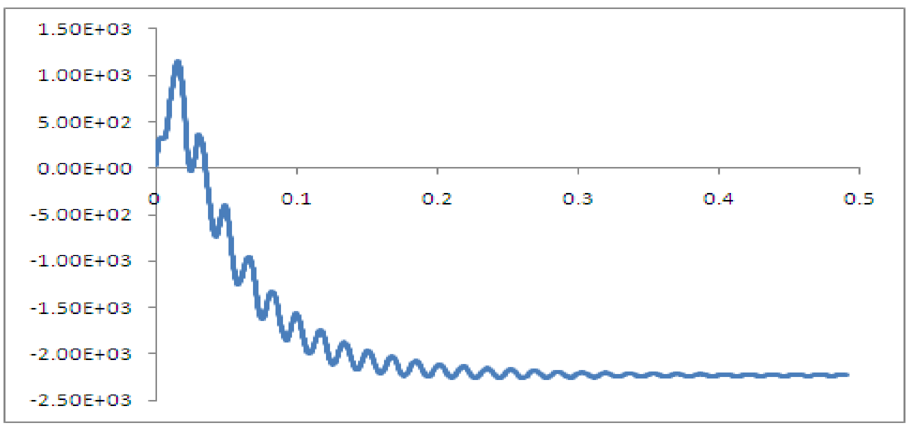

Fig.13: Performance of power

The performances in terms of torque, speed, power factor and power of interconnected DFIGs system for the load on second DFIG is reduced to zero are shown in Fig.14, Fig.15, Fig.16 and Fig.17 respectively. Similarly the waveforms of interconnected system in terms of torque, speed, power factor and power are shown in Fig.18, Fig.19, Fig.20 and Fig.21 respectively for the load on second generator is reduced to half i.e. 5.9 N-m. This is observed from the waveforms that the speed of second generator remains same whether it is fully load, partially loaded and not loaded. If speed changes then the frequency of grid will also change, which is not acceptable at all.

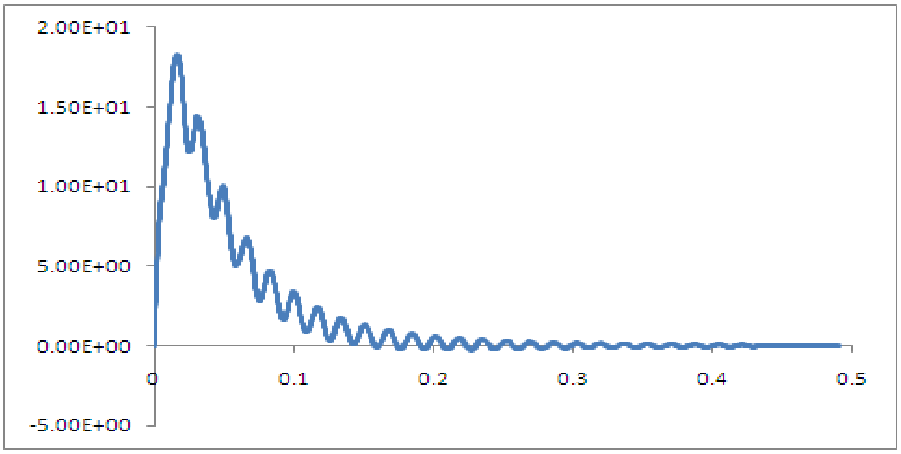

Fig.14: Performance with load torque 0 N-m

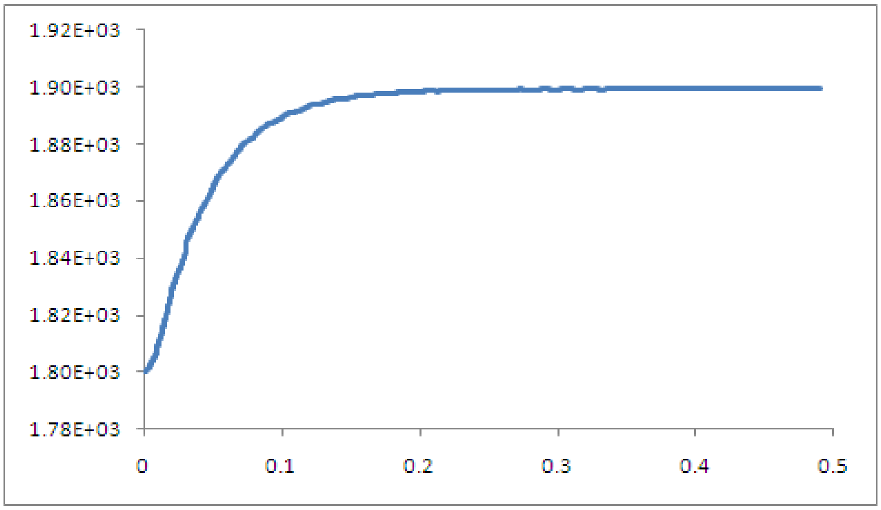

Fig.15: Speed control of DFIG with no load

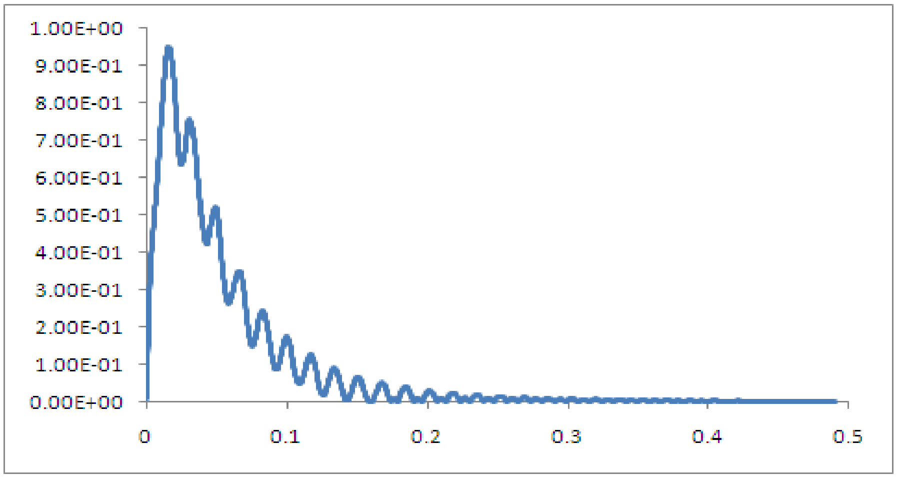

Fig.16: Power factor control of DFIG with no load

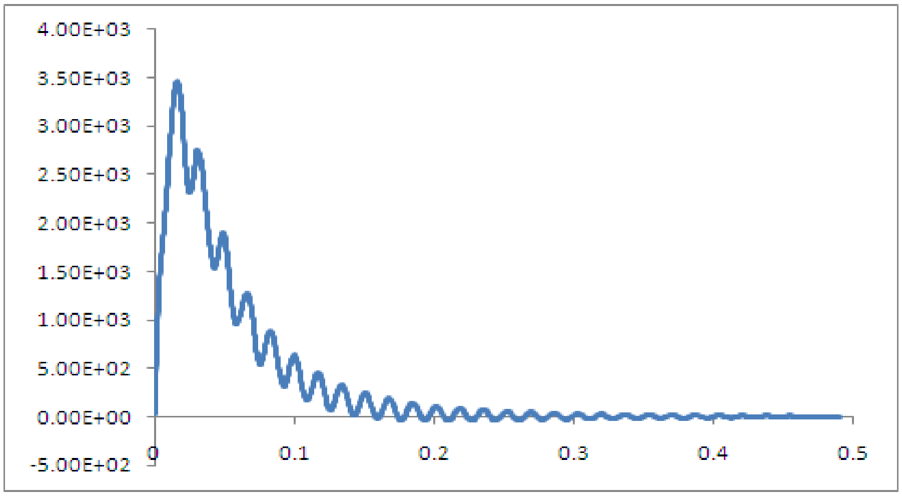

Fig.17: Power of DFIG with no load

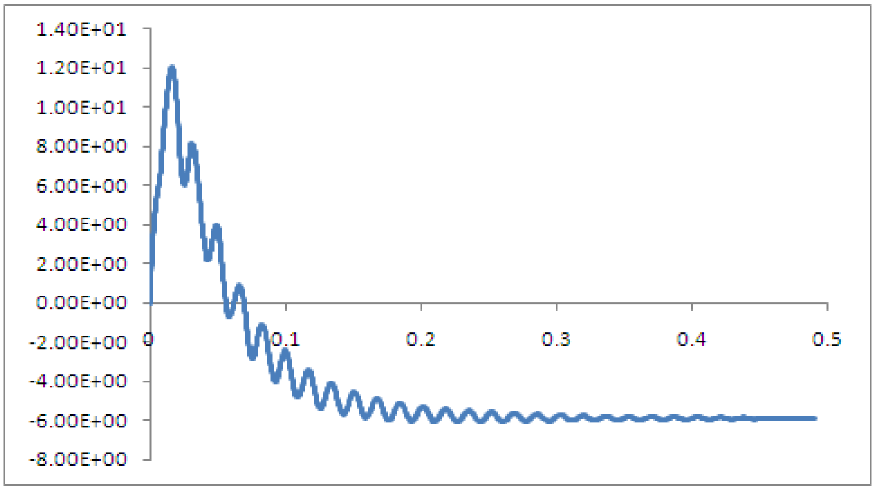

Fig.18: Performance of DFIG with half load 5.9 N-m

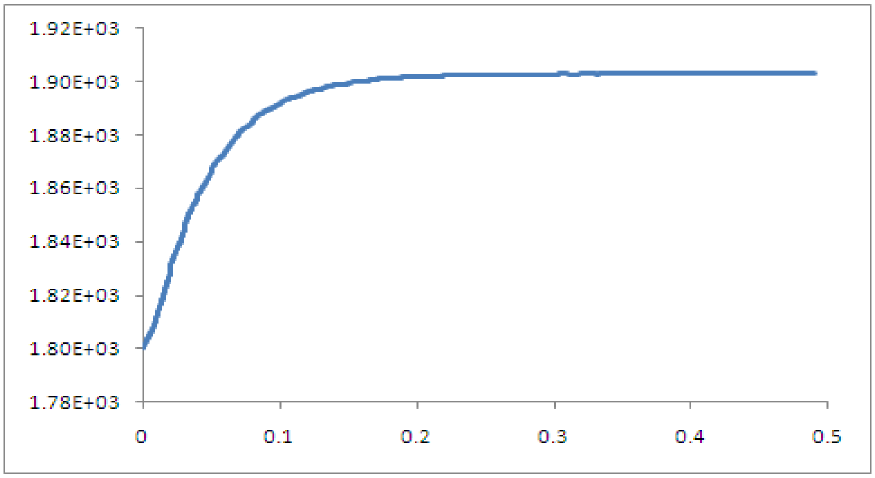

Fig.19: Speed control of DFIG with half load

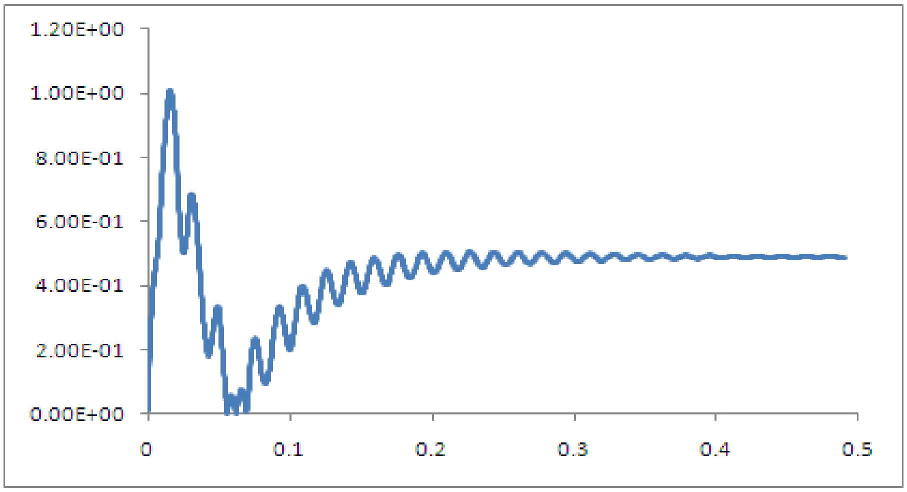

Fig.20: Power factor control of DFIG with half load

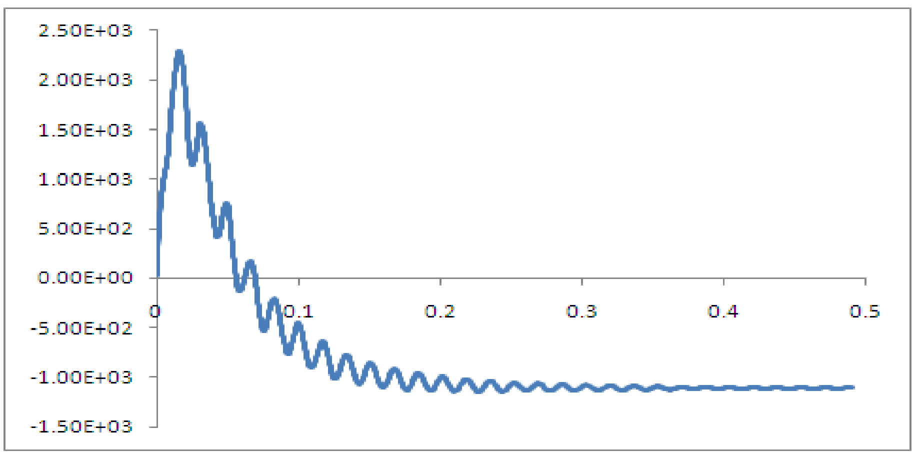

Fig.21: Power of DFIG with half load

This is clearly observed that torque, power factor and power all are zero for the load on DFIG2 is reduced to zero and their values will change in accordance with load.

CONCLUSION

Modeling of DFIG is presented. Performance of speed controller and power factor controller are validated. Mathematical modeling of interconnected DFIGs to the power system is presented. Combined (speed & power factor) control of interconnected system are verified with different loadings.

ACKNOWLEDGMENT

Authors are very much thankful to S. V. N. L. Lalitha, R. Punyavathi and K. Santhi for their cooperation and support.

REFERENCES

[1]. Bhandra, Banerjee and Kastha "Wind Electrical Systems" Oxford University Press, 2007.

[2]. A. Petersson "Analysis, Modeling and Control of Doubly Fed Induction Generators for Wind Turbines" Ph.D dissertation, Electr. Power Engg, Chalmers Univ. Tech., Sweden, 2005.

[3]. Nicholas W. Miller "Dynamic Modeling of GE 1.5 MW and 3.6 MW Wind Turbine-Generators" General Electric Power System Energy Consulting, New York, USA 2003.

[4]. Lars Gertman "Power Electronics and Wind Power" ABB Corporate Research, Sweden, EPE-2003-Toulouse, ISBN: 90-75815-07-7.

[5]. G. Tsourakis and C. D. Vournas "Simulation of Low Voltage Ride through Capability of Wind Turbines with Doubly Fed Induction Generator" European Wind Energy Conference (EWEC), Athens, March 2006.

[6]. Tao Sun *et. al.* "Transient Analysis of Grid Connected Wind Turbines with DFIG after an External Short-Circuit Fault" Nordic Wind Power Conference, 1-2 March, 2004, Chalmers University of Technology.

[7]. M. Godoy Simoes and Fellix A. Ferret "Alternate Energy Systems: Design and Analysis with Induction Generator" 2nd edition, CRC Press-Taylor and Francis Group.

[8]. S. Muller *et. al* "Doubly Fed Induction generator for Wind Turbines" IEEE Industry Application Magazine, May/June, 2002, pp. 26-33.

[9]. B. Rabelo *et. al*. "Power Flow Optimization and Grid Integration of Wind Turbines with DFIG, 0-7803-9033-4/05/2005/IEEE, pp.2930-2936.

[10]. Hofmann. W. *et. al.* "Doubly Fed Full Controlled Induction Wind Generator for Optimal Power Utilization "PEDES'01 Conference, Germany.

[11]. Jeferson Marques and Hunberto Pinheiro "Dynamic Behavior of DFIG in Stator Flux Vector Reference Frame" 0-7803-9033-4/05/2005/IEEE, pp.2104-2110.

[12]. M. Becherif and R. Oretega *et. al*. "Passivity-Based Control of DFIG Interconnected with an Induction Motor" 42nd IEEE Conference on Decision and Control, Maui, Hawaii, USA, Dec. 2003, pp.5657-5662.

[13]. P .C. Kraus, O. Wasynczuk, Scott. D. Sudhoff, Analysis of Electric Machinery, 2nd Edition, 2004, John Wilely and Sons.

[14]. R. Krishnan "Electric Motor Drives-Modeling, Analysis & Control" Prentice-Hall, 2001.

APPENDIX

SPECIFICATION OF MACHINE AND PARAMETERS OF CONTROLLER

S. N	Parameters	Values
1	Power	3 H.P
2	Voltage	220 Volt
3	Current	5.8 Amp.
4	Stator resistance	0.435 Ω
5	Stator leakage reactance	0.754 Ω
6	Magnetizing reactance	26.13 Ω
7	Rotor leakage reactance referred to stator	0.754 Ω
8	Rotor resistance referred to stator	0.816 Ω
9	Moment of inertia	0.089 Kg-m^2
10	Frequency	60 Hz
Parameter of Controller		
11	Constant (K)	1
12	Integral Constant (ζ)	5