ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

DPC Technique for ControllingActive and Reactive Power of DFIG

Dr.Sateesh Sukhavasi[1], Kena Likassa[2]

Associate Professor, Electrical Power and Control Engineering Program, School of Electricl Engineering & Computing, Adama Science and Technology University, Adama, Ethiopia[1]

Lecturer, Electrical Power and Control Engineering Program, School of Electricl Engineering & Computing, Adama Science and Technology University, Adama, Ethiopia[2]

ABSTRACT: Wind (perhaps non-conventional)power is gaining importance these days as the conventional sources are decaying day by day. This paper presents active & reactive power control for induction generator using DPC/DTC technique. Reactive power is controlled so as to maintain the power factor optimal even with load & wind velocity variations. DFIG and its powers are controlled from rotor side using rotor side and grid side converters. Simulation is carried out using MATLAB and results are presented. The simulation design is carries out on 7.5 KW generator and its effectiveness is verified above and below synchronous speeds.

KEYWORDS: DFIG (doubly fed Induction generator), DPC(Direct Power Control), DTC(Direct Torque Control), RSC(Rotor Side Converter), GSC(Grid Side Converter).

A. NOMENCLATURE

v_s, v_r	Stator and rotor voltages
i_s, i_r	Stator and rotor currents
ψ_s, ψ_r	Stator and rotor flux linkages
L_m, X_m	Machine magnetizing inductance, Reactance
L_s, L_r	Stator and rotor per phase winding inductances
L_{ls}, L_{lr}	Stator and rotor per phase leakage inductances
R_s, R_r	Stator and rotor per phase winding resistances
σ	Leakage factor
S_s, S_r	Stator and rotor apparent power
P_s, P_r	Stator and rotor active power
Q_s, Q_r	Stator and rotor reactive power
P_n, Q_n	Wind Turbine net active & reactive powers
f_s	Grid frequency
P_{sref}	Stator side active power reference value
Q_{sref}	Stator side reactive power reference value
i_{sD}, i_{sQ}	Direct & quadrature- axis stator currentcomponents respectively, in stationary reference frame
v_{sD}, v_{sQ}	Direct & quadrature- axis stator voltage components, respectively, in stationary reference frame
ω_{sl}	Angular slip frequency
v_{rD}, v_{rQ}	Direct- and quadrature- axis rotor voltage components, respectively, in stationary reference frame
v_{as}	Stator voltage at Phase A

v_{bs}	Stator voltage at Phase B
v_{cs}	Stator voltage at Phase C

B. SUFFICES, SUPERSCRIPTS

s, r	Stator, rotor
d, q	d-q reference frame
a,b,c	Three-phase reference

P Q	Active and Reactive powers
I D	Increase and Decrease

I.INTRODUCTION

Wind energy power generation is paying great interest in the recent years. This power is prominent in some costal and hilly areas. DFIG is best suit for wind power applications for variable speeds and it will generate power below & above synchronous speeds in all four quadrant of operation. Rotor side control requires only 20 – 30 % rating of the DFIG. Conventional decoupling control of current and flux (vector control or field oriented control) is very complex [8] and parameter variation results in instability problems. Clear design and control is available in [4]. Moreover this control should be done in synchronous reference frame and it requires transformation to stationary reference frame while handling voltages and currents.

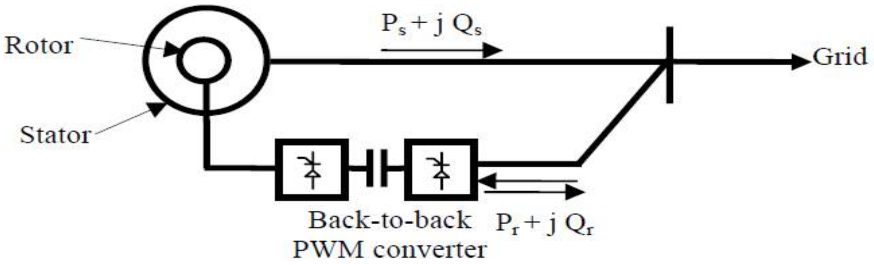

Figure 1 Schematic of DFIG

II. LITERATURE SURVEY

DTC is exciting from past several years for the control of induction motor. The same technique was extended to DFIG[5] and is called as DPC. In case of DTC torque and flux are control of interest, where as in DPC active & reactive powers are control of interest. Both DTC and DPC are same as torque variation result in power and flux variation result in reactive power variation. DTC is usually applied from stator side and DPC is usually applied from rotor side. The rotor is quantities are controlled using SVPWM inverter[1] which is known as RSC. DPC can be carried out on DFIG with fixed [2] or variable frequency [1]. There are many techniques to control the active & reactive power without DPC, one such example is vector control [9] [4][5]. DPC is does not require eliminates reference frame conversions of quantities for its control [6]. Space vector modulation is usually preferred for DPC to control the rotor field [1] [6]. It give sensor less operation with SVPM techniques. DPC can be obtained by properly selecting the voltage sectors in the converter. Only drawback this technique is that it may result in mal operation at low speeds because at low speeds zero voltage sectors are selected repeatedly. Also at low speeds, resistance drop is considerable and it is required to boost the applied voltage. Optimal switching table is developed based on active and reactive power errors. This paper proposes the modeling [7] and control [6] [7] of DPC on DFIG using MATLAB simulation. The control is based on by measuring the active power and power factor. At the end results are presented on 7.5 KW induction generator.

III.DYNAMIC MODEL OF DFIG

When the machine is rotating, the flux linkage and hence the mutual inductance change with respect to rotor position. Hence three phase stator and rotor windings are replaced with factitious two phase windings rotating at synchronous speed. The transformation matrix is used to convert three phase to two phase system [10]. This makes the mutual inductance invariant with rotor position and there will not be any displacement between stator and rotor windings in d and q axis. After converting the three phase voltages to two phase quantities, the dynamic simulation is developed from the following equations.

$$v_{sD} = R_s i_{sD} - \omega_s \psi_{sQ} + \frac{d\Psi_{sD}}{dt}$$

$$v_{sQ} = R_s i_{sQ} - \omega_s \psi_{sD} + \frac{d\Psi_{sQ}}{dt}$$

$$v_{rD} = R_r i_{rD} - \omega_r \psi_{rQ} + \frac{d\Psi_{rD}}{dt}$$

$$v_{rQ} = R_r i_{rQ} + \omega_r \psi_{rD} + \frac{d\Psi_{rQ}}{dt}$$

$$T_e = \frac{3}{2} P L_m \left(i_{sQ} i_{rD} - i_{sD} i_{rQ} \right).$$

$$\psi_{sD} = L_s i_{sD} + L_m i_{rD}$$

$$\psi_{qs} = L_s i_{ds} + L_m i_{qr}$$

$$\psi_{qs} = L_s i_{ds} + L_m i_{qr}$$

$$\psi_{dr} = L_m i_{ds} + L_r i_{dr}$$

$$\psi_{qr} = L_m i_{qs} + L_r i_{qr}$$

$$L_s = L_{ls} + L_m$$

$$L_r = L_{lr} + L_m$$

IV.WIND TURBINE MODEL

There are several methods of modeling the wind turbine. The mechanical power captured (P_{mech})by a wind turbine, depends on its power coefficient C_p, given for a wind velocity and can be represented by

$$P_{mech} = \frac{1}{2} C_p \rho \pi R^2 v^3. \ (1)$$

Where ρ and R correspond to the air density and the radius of the turbine propeller, respectively. The power coefficient can be described as the portion of mechanical power extracted from the total power available from the wind, and it is unique for each turbine. This power coefficient C_p is generally defined as a function of the tip-speed-ratio which, in turn, is given by λ

$$.\ \lambda = \frac{\omega R}{v} \ (2)$$

Where ω represents the rotational speed of the wind turbine. Figure3. Shows a typical relationship between the power coefficient C_p and the tip-speed-ratio. It should be noted that there is a value of λ to ensure a maximum of C_p . Thus, it can be stated that, for a specified wind velocity, there is a turbine rotational speed value that allows capturing the maximum mechanical power attainable from the wind, and this is, precisely, the turbine speed to be followed.

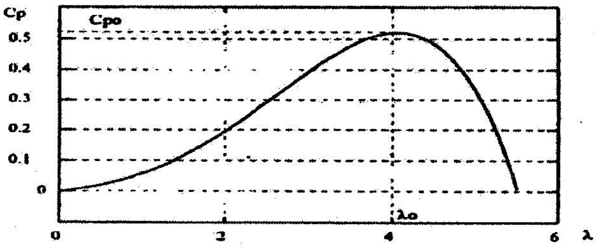

Figure 2. Typical Power Coefficient versus Tip-Speed-Ratio Curve.

The method followed in this paper in order to reach the optimum tip-speed-ratio at each wind velocity consists in, based on the generator rotor speed, estimating and, therefore, trying to achieve the optimum active power to be generated by means of DPC.Specifically, assuming that the optimum power coefficient C_p and, as a result, the optimum λtip-speed-ratio values for the particular wind turbine employed are properly identified, the stator side active power reference $P_{s\ ref}$ value which is made equal toP_{mech} is established starting from the turbine ω angular speed through equations (1) and (2).

V.CONTROL OF ACTIVE & REACTIVE POWER

Neglecting the effect of stator resistance, stator and rotor leakage reactance, the active and reactive powers are calculated using the following equations.

$$P_s \approx \frac{3}{2}(\overrightarrow{v_s})i_{sy} = -\frac{3}{2}(\overrightarrow{v_s})\frac{L_m}{L_s}i_{ry}$$

$$Q_s \approx \frac{3}{2}(\overrightarrow{v_s})i_{s\alpha} = -\frac{3}{2}(\overrightarrow{v_s})\frac{L_m}{L_s}(|\overrightarrow{\iota_{ms}} - i_{rx}|)$$

$$\approx \frac{3}{2}(\overrightarrow{v_s})\frac{L_m}{L_s}\left(\frac{|\overrightarrow{v_s}|}{2\pi f_s L_m} - i_{rx}\right)$$

Two – level converter shown in figure 3, the output voltage in each phase is given by either $+V_d$ or 0. There are eight voltage vectors from binary 000 (V_0) to 111 (V_7), the binary digit indicates the switch position. “1” indicates the switch is connected to positive and “0” indicates for negative polarity in the circuit shown in figure. The three digits are for phase a, b and c. Depending on flux space vector, it is possible to control both active and reactive power.

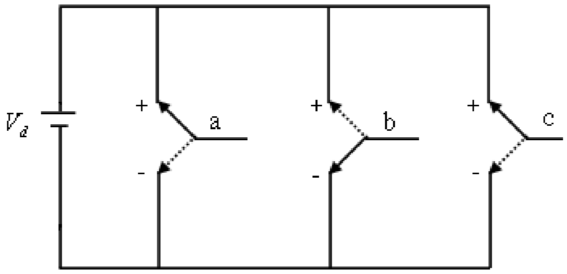

Figure 3. Two Level converter(RSC).

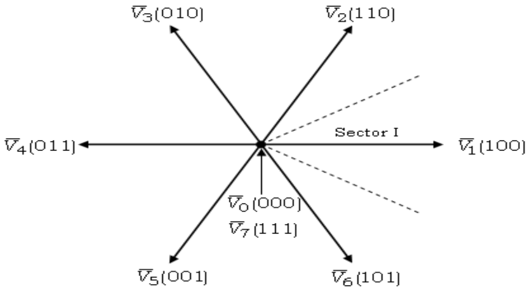

Figure 4. Voltage vectors of the converter and sector identification.

To control the active and reactive power, individual three level hysteresis comparators are used to select the voltage states in the inverter.

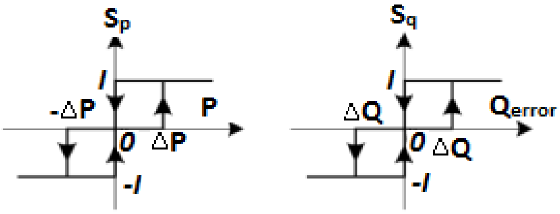

Figure 5 Active & Reactive power control using hysteresis control.

VI. OPTIMAL SWITCHING TABLE

Optimal switching table is developed [5]from the concept of DTC and is used for selecting the switching states. For different possibilities of actual and reference values, the optimal switching table is developed using the following diagram of voltage vectors in the first sector. The same logic is extended for all the sectors, by properly identifying the required voltage vector. For example, if present voltage vector is in sector 1, from the hysteresis control, if reactive power(Q) should be decreased and active power(P) should be increased means, it can be implemented using voltage vector V_3. This was shown in figure 6.

Two – level converter shown in figure 3, the output voltage in each phase is given by either $+V_d$ or 0. There are eight voltage vectors from binary 000 (V_0) to 111 (V_7), the binary digit indicates the switch position. “1” indicates the switch is connected to positive and “0” indicates for negative polarity in the circuit shown in figure. The three digits are for phase a, b and c. depending on flux space vector it is possible to control both active and reactive power

		I	II	III	IV	V	VI
S_p =1	S_q=1	101	100	110	010	011	001
	S_q=0	001	101	100	110	010	011
	S_q=-1	001	101	100	110	010	011
S_p =0	S_q=1	100	110	010	011	001	101
	S_q=0	ZV	ZV	ZV	ZV	ZV	ZV
	S_q=-1	011	001	101	100	110	010
S_p = -1	S_q=1	110	010	011	001	101	100
	S_q=0	010	011	001	101	100	110
	S_q=-1	010	011	001	101	100	110

ZV: Zero voltage state implemented by 111 or 000

Table 1 Optimal switching table.

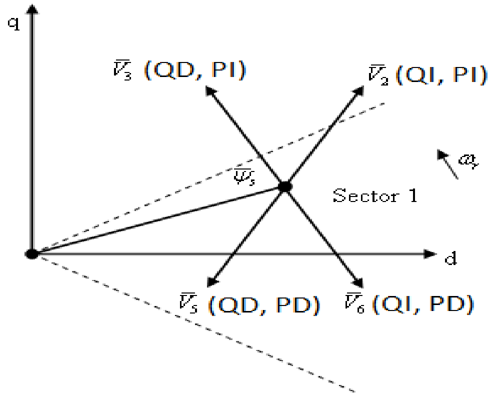

Figure 6. Voltage vector identification based on DTC

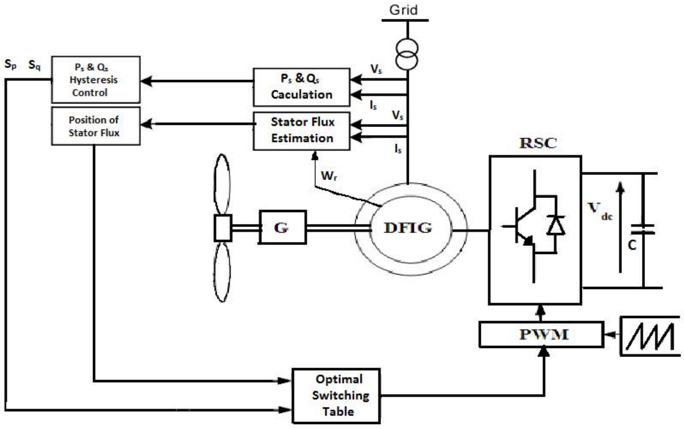

Figure 7. Schematic Diagram of Proposed system

VII SIMULATION RESULTS

After simulation using MATLAB, the model is verified, tested and results analyzed for step variation in wind velocity, active and reactive power. The results are found to be satisfactory and model is working as per the analysis.

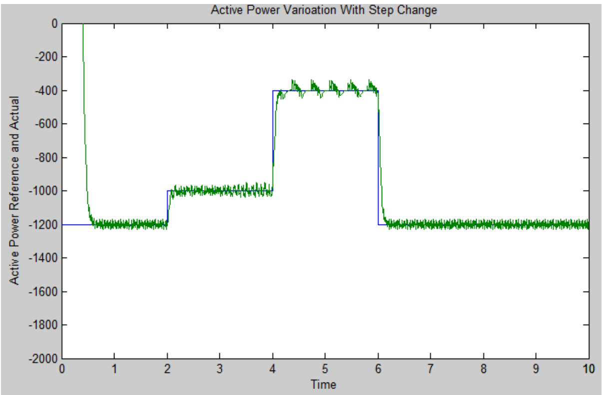

Figure 8 Variation of active power for with respect to reference

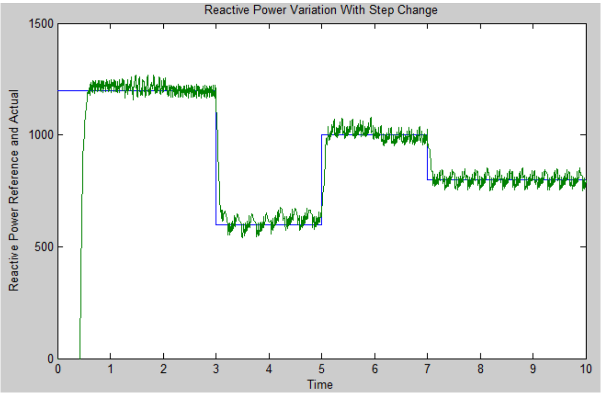

Figure 9 Variation of reactive power with respect to reference

Wind velocity is uncertain and it mainly affects the performance. Simulation is carried out with step change in wind velocity. Here in this paper results are presented when wind velocity is changed from 15 m/sec to 12 m/sec at t=0.8 Sec. Fig 10 shows stator voltage, as it is connected to the existing grid, there is no change in voltage profile. Whereas current subjected to change in the transient and returns back to original value as the active and reactive power references are remains same.

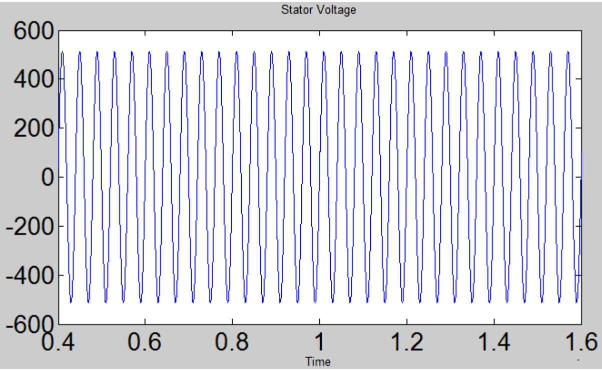

Figure 10 Stator voltage

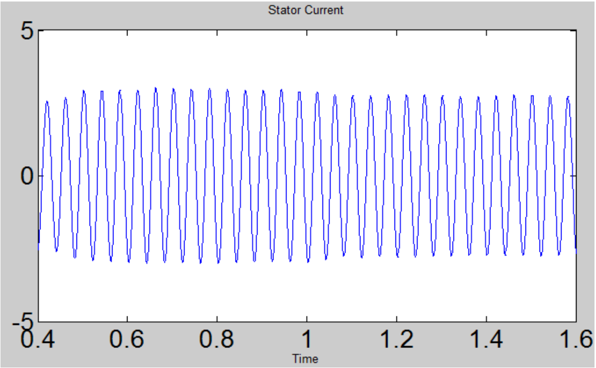

Figure 11 Stator current

As the wind velocity is decreased from 15 m/sec to 12 m/sec, the power available in the wind decreases, momentarily the power injected from the rotor side increases as shown in figure 12. The command wind velocity is show in figure 13.

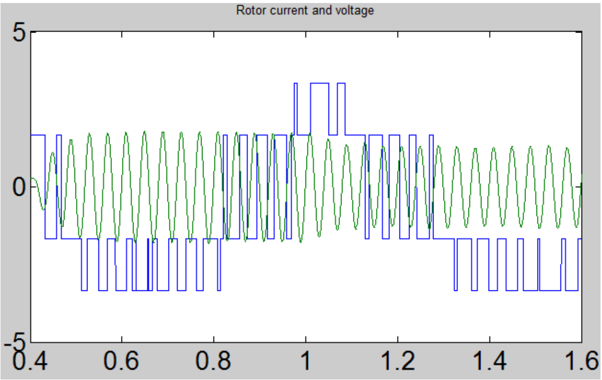

Figure 12 Rotor current and voltage

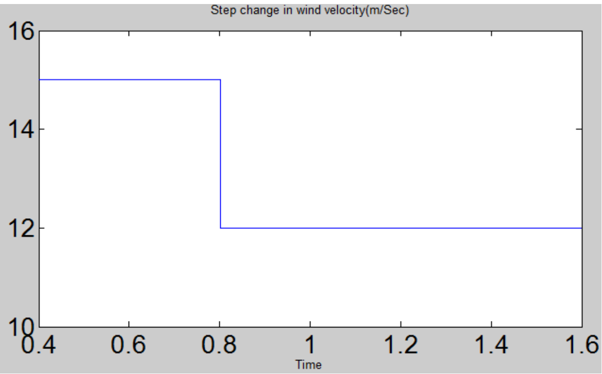

Figure 13 Wind velocity

Response of active and reactive powers are shown in figure 14 and 15 respectively. It is found that response is within acceptable range but still it is subjected to little fluctuations in the steady state. These can be tightened by increasing the DC link capacitance and decreasing the step size in simulation.

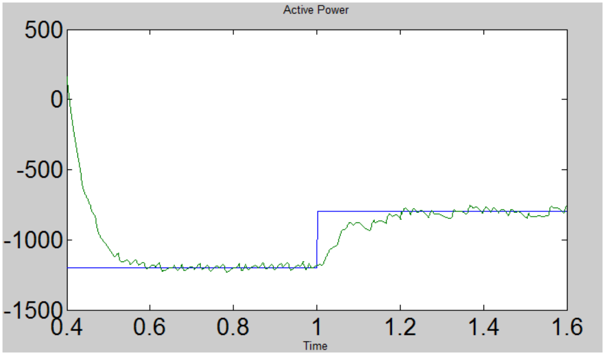

Figure 14 Active power

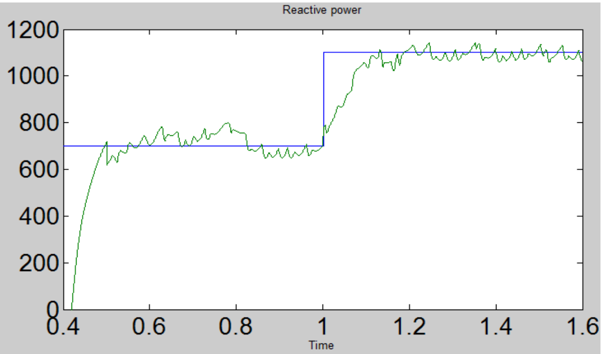

Figure 15 Reactive power

VIII. CONCLUSION

This paper presents modeling and simulation of DFIG. Active and reactive powers are controlled using DPC. SVPWM technique is used to control RSC. Simulation is carried out using MATLAB/Simulink software and the results are verified. The results are satisfied for active and reactive power control.

APPENDIX A: INDUCITON MACHINIE DATA

Wound Rotor Induction Machine Parameters:-
Nominal Power $P_n = 7.5$ Kw
Stator Voltage $V_s = 415$ V
Stator Frequency $f_s = 50$ Hz
Stator Resistance $R_s = 7.83\ \Omega$
Stator Inductance $L_s = 0.4751$ H

Rotor Resistance $R_r = 7.55\ \Omega$
Rotor Inductance $L_r = 0.4751$ H
Mutual Inductance $L_m = 0.4535$ H
Inertia Constant $J = 0.06$ Kg-m^2
Number of Pair of Poles P =2

REFERENCES

[1]. JafarSoltani, Gholam Reza Arab Markadeh,NR Abjadi, HW Ping, "*A new adaptive direct torque control (DTC) scheme based – on SVM for adjustable speedsensorless induction motor drive*" Proceeding of International Conference on Electrical Machines and Systems 2007, Oct. 8~11, Seoul, Korea
[2]. Won-Sang Kim, Sung-TakJou, Kyo-Beum Lee, "*Direct power control of doubly fed induction generator with fixed switching frequency*" IEEE 2008.
[3]. Xianyong Zhang, JieShu, Changhong Wu, "*A novel maximum wind power capture strategy for the doubly fed induction generator*" IEEE 2009
[3]. NishadMendis, Kashem M. Muttaqi, SaadSayeef and SarathPerera, "*Power Generation in Isolated and Regional Communities: Application of aoubly-fedInduction Generator based Wind Turbine*" IEEE 2009.
[4]. BrahimNait-kaci, Mamadou L. Doumbia, *Member IEEE*, KodjoAgbossou, "*Active and reactive power control of a doubly fed induction generator for wind applications*" IEEE 2009
[5]. Lie Xu, and Phillip Cartwright, "*Direct Active and Reactive Power Control of DFIGfor Wind Energy Generation*" IEEE Transactions on Energy Conversion, Vol 21,No 3 September 2006.
[6]. Mohammad VerijKazemi, Ahmad SadeghiYazdankhah, HosseinMadadiKojabadi "*Direct power control of DFIG based on discrete space vector modulation*" Elsevier, renewable energy 35 (2010) Pg 1033-1042.
[7]. AdriàJunyent-Ferré, OriolGomis-Bellmunt, Andreas Sumper, Marc Sala d, Montserrat Mata, "*Modeling and control of the doubly fed induction generator wind turbine*" Elsevier, Simulation modeling practice and theory18(2010), Pg 1365-1381.
[8]. Y.W. Liao, E. Levi "*Modelling and simulation of a stand-alone induction generator*" Elsevier, Electrical power system research 46 (1998) Pg 141152.
[9]. SateeshSukhavasi and SrinathVanukuru "*Active & Reactive Power Control Of A Doubly Fed Induction Generator Driven By A Wind Turbine*" International Journal of Power System Operation and Energy Management, ISSN (PRINT): 2231– 4407, Volume -1, Issue - 2, 2011, pp. 83 – 90
[10]. BK Bose "*Modern power electronics and AC Drives*"Prentice Hall.