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REACTIVE POWER CONTROL OF DOUBLY FED INDUCTION GENERATOR IN WIND ENERGY CONVERSION SYSTEM USING FUZZY LOGIC CONTROLLER

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ABSTRACT

The doubly-fed induction generator (DFIG) wind turbine is a variable speed wind turbine widely used in the modern wind power industries. At present, commercial DFIG wind turbines primarily make use of the technology that was developed a decade ago. But, it is found in the paper that there is limitations conventional control method. This project presents a fuzzy-logic approach to control the DFIG. Based on which fuzzy-logic approach is controlled for real power, reactive power flow and electromagnetic torque of the wind turbine. A direct current vector control strategy is developed to control the rotor side voltage source converter. This scheme of direct current vector control strategy allows the independent control of the generated active and reactive power as well as the rotor speed. In this project, a fuzzy-logic approach is proposed to control the DFIG. The active and reactive power is controlled by rotor voltage, which goes through back-to-back voltage source converter and DC-link voltage is also maintained stable. The conventional control approach is compared with the proposed control techniques for DFIG wind turbine control under both steady and gusty wind conditions. A MATLAB based simulation system was built to validate the effectiveness of the proposed method. The proposed method waveforms of real power, reactive power, DC link voltage and generator speed are compared with conventional method. This paper shows that under the fuzzy-logic approach control techniques, a DFIG system have a superior performance in various aspects.

Key Words:DC-link voltage control, direct-current vector control, doubly-fed induction generator (DFIG) wind turbine, real and reactive power control and fuzzy logic controller (FLC).

I.INTRODUCTION

At the present time, Wind energy is one of the most important and promising renewable energy resources in the world. In the early stage of wind power development.

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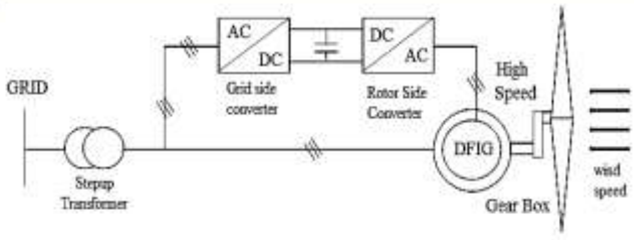


Fig .1 Schematic of a DFIG-based wind generation system

Most wind farms were equipped with fixed speed turbines and induction generators. The power efficiency of such fixed speed devices is fairly low for most wind To improve their efficiency, many modern wind generators adopt a variable speed operation in the following ways: direct ac to ac frequency converters, such as the cyclo-converter or by using back to back power converters employing generators provided that a static frequency [1], converter is used to interface the machine to the grid [2].An alternative approach of using a wound-rotor induction generator fed with variable frequency rotor voltage is receiving increasing attention for wind generation purposes. With changing wind speed, one can adjust the frequency of the injected rotor voltage of the DFIG to obtain a constant-frequency at the stator [3].

There are several reasons for using DFIG in WECS as following ways: converters about 25-30% of the generator rating increasingly popular, four quadrant active and reactive power capabilities, converter cost and power loss are reduced compared wind turbines using fixed speed generators, increase wind turbine energy capture capability, reduce stress of the mechanical structure and make the active and reactive power controllable better integration. Reduced power loss compared to wind turbines using fixed speed induction generators or fully-fed synchronous generators with full-sized converters. Schematic of a DFIG-based wind energy generation system is shown in Fig. 1. This paper develops a mechanism for improved control of a DFIG wind turbine under a fuzzy logicbased vector control configuration.

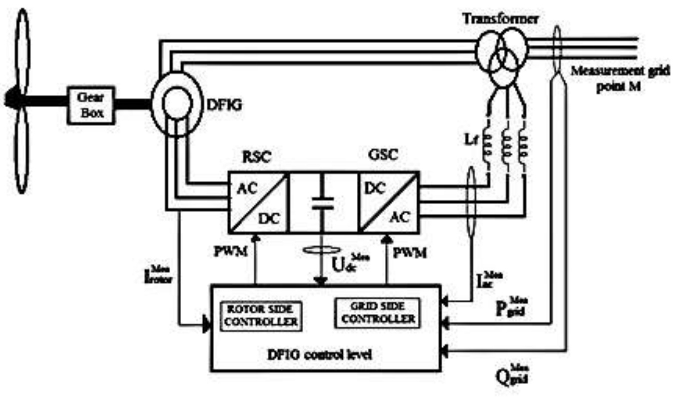


Fig.2 configuration of DFIG system

Then, based on the proposed control structure, the integrated control DFIG system control was developed. Including real power, reactive power and DC-link voltage. In the sections that follow, the paper first introduces the general configuration of a DFIG system and over all control structure in section II. Then, section III presents the active and reactive control of DFIG in WECS. Conventional and direct current vector control of GCS is presented in section IV. In section V presents the real and reactive power control of RSC. Then, the fuzzy logic controller presented in section VI. Simulation studies are conducted in section VII to compare the performance of DFIG wind turbine using the direct vector and traditional vector control configuration for steady and variable wind conditions. Finally, this paper concluded with the summary of main points.

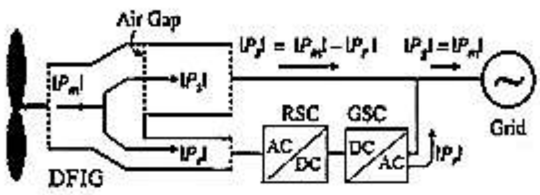
II.DFIG MECHANICAL SYSTEMAND POWER FLOW OPERATION

(a) DFIG mechanical system

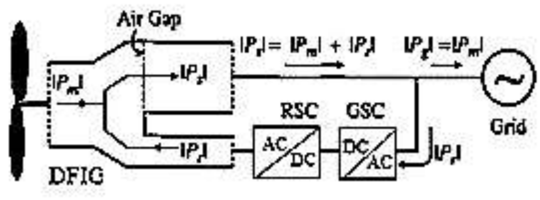
A DFIG wind turbine primarily consists of three parts: a wind turbine drive train, an induction generator and power electronic converter (Fig. 2) [2], [4]. In the wind turbine drive train, the blades of the rotor turbine catch wind energy that is then transferred to the induction generator via gearbox. The induction generator is a standard wound rotor induction machine with its stator windings directly connected to the grid and its rotor winding connected to the grid through a voltage source converter. The voltage source converter is built by two self-commutated voltage source converters, the RSC and the GSCwith intermediate dc voltage link.

(b) Power flow in DFIG

The DFIG can be operated in two modes of operation namely;sub-synchronous and super-synchronous mode depending on the rotor speed below and above the synchronous speed. Figure.2 shows the basic scheme adopted in the majority of systems. The stator winding is directly connected to the AC mains, whilst the rotor winding is fed from the Power Electronics Converter via slip rings to allow DIFG to operate at different speeds in response to changing the wind speed. Indeed, the basic concept is to interpose a frequency converter between the variable frequency induction generator and fixed frequency grid. The DC capacitor linking [5]stator- side and rotor-side converters allows the storage of power from inductiongenerator for further power generation. To achieve full control of grid current and DC-link voltage.



(a) Sub synchronous speed



(b) Super synchronous speed

Fig.3 Power flow in DFIG wind energy conversion system

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The slip power can flow in both directions grid to rotor as well as rotor to grid in, i.e. to the rotor from the supply and from supply to the rotor and hence the speed of the machine can be controlled from either rotor-side or stator-side converter in both above and below-synchronous speed ranges. The wound rotor induction machine can be controlled as a generator at or a motor in both super and sub-synchronous operating modes. [6] The sub synchronous speed in the motoring mode and super synchronous speed in the generating mode, RSC operates as a rectifier and GSC as an inverter at that time the slip power is returned to the stator. RSC operates as an inverter and GSC as a rectifier at that time where slip power is supplied to the rotor winding. At the synchronous speed, slip power is taken from supply to excite the rotor windings and in this case machine behaves as a synchronous machine.

III.ACTIVE AND REACTIVE POWER CONTROL OF DFIG

The per phase equivalent for a DFIG is shown in the figure 4.Variables with the 'notation denote rotor quantities as seen from stator side. By neglecting the effects of Rs, jXls and jXlr the per phase stator power Ss and rotor power Sr Can be expressed as

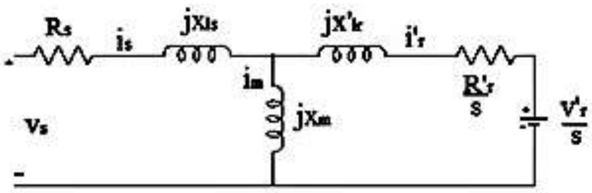

Fig.4 per Phase Equivalent Circuit of a DFIG.

$$S_S = P_S + jQ_S = V_S\, I^*_S \qquad (1)$$

$$S_r = P_r + jQ_r = V_r\, I^*_r \quad (2)$$

The active and reactive powers are found by using the Equations as below.

$$p_S \approx \frac{3}{2}(\overrightarrow{v_S}) i_{sy} = -\frac{3}{2}(\overrightarrow{v_S}) \frac{L_m}{L_S} i_{ry} \quad (3)$$

$$Q_S \approx \frac{3}{2}(\overrightarrow{v_S}) i_{s\alpha} = -\frac{3}{2}(\overrightarrow{v_S}) \frac{L_m}{L_S} \left(\left| \overrightarrow{l_{ms}} - i_{rx} \right| \right)$$

$$\approx \frac{3}{2}(\overrightarrow{v_S}) \frac{L_m}{L_S} \left(\frac{\left|\overrightarrow{v_S}\right|}{2\Pi\Pi_s Lm} - i_{rx} \right) \qquad (4)$$

V.CONVENTIONAL AND DIRECT CURRENT VECTOR CONTROL OF DFIG

Fig. 4 shows the schematic of the GSC, in which a dc-link capacitor is on the left and a three-phase voltage source, representing the voltage at the point of common coupling (PCC) of the AC system.

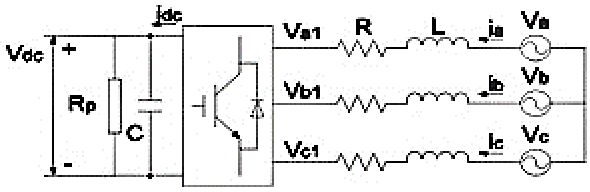

Fig.4 Grid-connected converter schematic.

In the d-q reference frame, the voltage balance across the grid filter is

$$\begin{bmatrix} v_d \\ v_q \end{bmatrix} = R_f \begin{bmatrix} i_d \\ i_q \end{bmatrix} + L_f \frac{d}{dt}\begin{bmatrix} i_d \\ i_q \end{bmatrix} + \omega_s L_f \begin{bmatrix} -i_q \\ i_d \end{bmatrix} + \begin{bmatrix} v_{d1} \\ v_{q1} \end{bmatrix} \quad (5)$$

Where ω_s is the angular frequency of the PCC voltage and L_f and R_f are the inductance and resistance of the grid filter. Using space vectors, (9) is expressed by a complex (8) in which $v_{dq,}$ $i_{dq}$and v_{dq1} are instantaneous space vectors of the PCC voltage, line current, and converter output voltage. In the steady-state condition, (8) becomes (9), where $V_{dq,}$ $I_{dq}$and V_{dq1} stand for the steady-state space vectors of PCC voltage, grid current, and converter output voltage .

$$v_d = R_f i_d + L_f \frac{di_d}{dt} - \omega_s L_f i_q + v_{d1} \quad (6)$$

$$v_q = R_f i_q + L_f \frac{di_q}{dt} + \omega_s L_f i_d + v_{q1} \quad (7)$$

The (6) and (7) is an d-q axis voltage can be expressed from the d-q reference frame (1)

$$v_{dq} = R_f i_{dq} + L_f \frac{di_{dq}}{dt} + j\omega_s L_f i_{dq} + v_{dq1} \quad (8)$$

$$V_{dq} = R_f I_{dq} + j\omega_s L_f I_{dq} + V_{dq1} \quad (9)$$

In the PCC voltage oriented frame [3], [11], the instant active and reactive powers absorbed by the GSC from the grid are proportional to grid d-and q-axis currents, respectively, as shown by (10) and (11)

$$p(t) = v_d i_d + v_q i_q = v_d i_d \quad (10)$$

$$p(t) = v_q i_d - v_d i_q = -v_d i_q \quad (11)$$

(a) Direct current vector control of GSC

The conventional vector control method for the GSC has anested-loop structure consistingofafasterinnercurrentloopand a slower outer loop, as shown by Fig.5 and fig.6 shows that the standard GSC dc vector control structure .

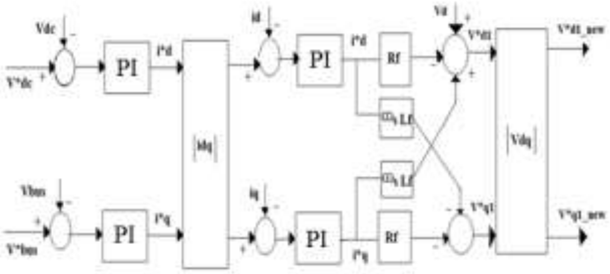

Fig.5 Conventional standard GSC dc vector controlstructure

which the -axis loop is used for dc-link voltage control and the -axis loop is used for reactive power or grid voltage support control. The control strategy of the inner current loop is developed by rewriting (6) and (7) as

$$v_{d1} = -(R_f i_d + L_f \frac{di_d}{dt}) + \omega_s L_f i_q + v_d \qquad (12)$$

$$v_{q1} = -(R_f i_q + L_f \frac{di_q}{dt}) - \omega_s L_f i_d + v_q \qquad (13)$$

in which the item in the bracket of (12) and (13) is treated as the transfer function between input voltage and output current for d and q loops. The direct-current vector controlstructure outputs a current signal at or current loop controller. In other words, the output of the controller is a d or q tuning current while the input error signal tells the controllerhow much the tuning current should be adjusted during the dynamic control process.The development of the tuning currentcontrol strategy has adopted FLC concepts, the error between the desired and actual d-andq-axis currents through an adaptive tuning mechanism [15]. This tuningcurrent is different from the actual measured d or q current. d-and q-axis currents to prevent the high orderharmonics from entering the controllers the current loop controller by FLC to improve the dynamic performance of the GSCFor example, for a d-axis current reference, the adaptive tuningprocess would continue until the actual d axis current reachesthe d-axis reference current. It is necessary to point out that afast current-loop controller is critical to assure the highest powerquality in terms of harmonics and unbalance for the GSCBut, due to the nature of a voltage-source converter, the d–and q-axis tuning current signals i'_dandi'_qgeneratedbythe current-loop controllers must be transferred to d-and q-axis voltagesignals v^*_{d1} and v^*_{q1} to control the GSC. This is realized through (104and (15), which is equivalent to the transient d-q (1) after being processed by a low passfilter for the purpose of reducing the high oscillation and reference voltages applied directly tothe converter.

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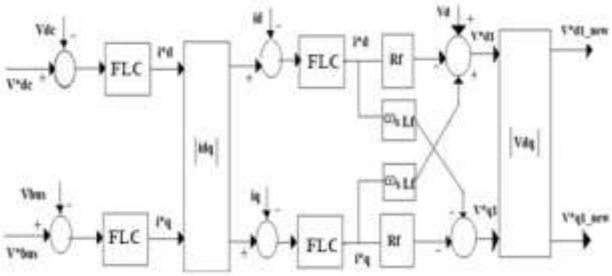

Fig .6 standard GSC dc vector control structure

$$v^*_{d1} = -R_f i'_d + \omega_s L_f i'_q + v_d \quad (14)$$

$$v^*_{q1} = -R_f i'_q - \omega_s L_f i'_d \quad (15)$$

The reactive power controller is actually decided by the constraint of the converter linear modulation requirement but not the control rule.

$$v^*_{d1\_new} = \text{sign}(v^*_{d1})$$

$$\sqrt{(v^*_{d1\_max})^2 - (v^*_{q1})^2}\, v^*_{q1\_new} = v^*_{q1} \quad (16)$$

VI.REAL AND REACTIVE POWER CONTROL OF RSC IN DFIG

The RSC controls the induction generator of a DFIG wind turbine for energy extraction from the wind and coordinates with the GSC for reactive power or grid voltage support control ofthe overall DFIG system as well. The control is implementedthrough a nested-loop structure consisting of an inner currentloop and an outerspeed and reactive power loop [3], [4].Similar to the GSC, the importance of the RSC current controlloop is to assurethat the highest power quality in terms of harmonicsand unbalance for the DFIG.

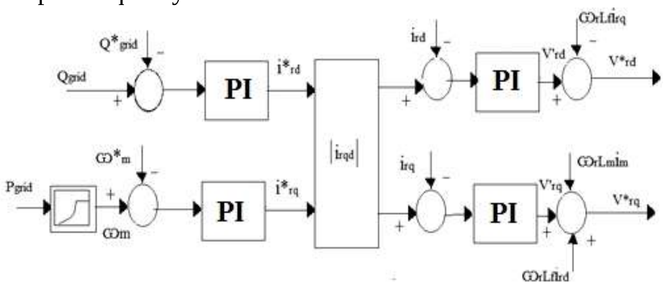

Fig .7 conventional real and reactive power controlStructure of RSC.

Fig. 7 shows the standard RSC control structure using thestator-flux oriented frame [2]–[4]. The direct-current vectorcontrol mechanism is not used because the rotor electricalfrequency is near zero around the synchronous speed. In thefigure, the speed reference is generated according to the maximum power extraction principle [4], [19] while the reactivepower reference is generated based on a wind plant reactivepower demand as well as the

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coordination of the reactivepower control with the GSC (Section V). The reactive powerreference is transferred to rotor -axis current referencethrough a reactive-power controller and the torque reference,generated by the speed controller, is transferred to rotor d–axiscurrent reference. The current-loop controllers generate -and -axis voltages, and , based on the error signalsbetween the reference and actual rotor q-and d-axis currents.Thefinal d- and q-axis control voltage, and, consists ofthe q-and d -axis voltage from the current-loop controllers, or plus the compensation items as shown by Fig. 7.

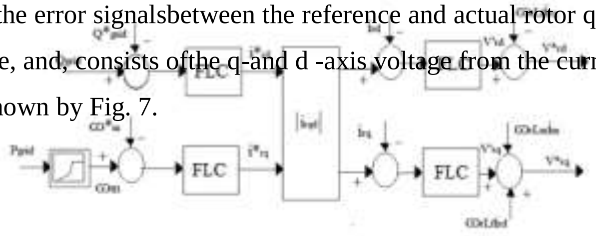

Fig .8 standard real and reactive power control Structure of RSC.

$$i^*_{rd\_new} = \text{sign}(i^*_{rd}) \sqrt{(i^*_{rdq})^2 - (i^*_{rq})^2} \quad i^*_{rq\_new} = i^*_{rq} \qquad (17)$$

VII.DESIGN OF FUZZY LOGIC CONTROLLER

The fuzzy controllers used in this scheme assist theConventional PI controllers in providing more reliable controller outputs for the grid side and rotor side converter control as shown in Fig. 6 and Fig. 8. The main objectives of the fuzzy controllers are to achieve more accurate active and reactive power control of the wind turbine driven DFIG.

The design of a fuzzy logic system (FLS) includes the design of a rule base, the design of the membership functions [7][8]. Here, the inputs of fuzzy controllers are the error in active/ reactive power and the rate of change of this error at any time interval. The output of the fuzzy controller is the change in the reference current that is the value added to the prior output [4] obtained using only conventional PI controller, to produce a new reference output. Here, five fuzzy sets (NB, N, Z, P, and PB) are adopted for each input and output variables. The character NB, N Z, P, PB represents Negative big, NegativeZero, Positive, Positive Big. The membershipfunctions of the two input variables and the one output variable has normalized universe of discourse over the interval [- 1, 1]

The active and reactive power fuzzy controller outputs

are evaluated considering the above mentioned rule-base Table I and Table II using Matlab-functions in S-function code. For instance, when E (P) the error of the active power and ΔE(P) the rate of change of active power error in a time interval are 'NB', that means the active power output is very high as compared to the reference value and is increasing dramatically. Therefore reference quadrature axis rotor current which controls active power should decrease rapidly, that represents the change in the reference current as NB.

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Table I

RULE BASE FOR REAL AND REACTIVE POWER FUZZY CONTROLLER

Δ_{pq}			**ΔE(P)**			
		NB	N	Z	P	PB
	NB	NB	NB	N	N	Z
E(P)	N	NB	N	N	Z	P
	Z	N	N	N	P	P
	P	N	Z	P	P	PB
	PB	Z	P	P	PB	PB

Table II

RULE BASE FOR DC LINK VOLTAGE AND BUS VOLTAGE FUZZY CONTROLLER

Δvdc			**ΔE(P)**			
		NB	N	Z	P	PB
	NB	NB	NB	N	N	Z
E(P)	N	NB	N	N	Z	P
	Z	N	N	N	P	P
	P	N	Z	P	P	PB
	PB	Z	P	P	PB	PB

For the implementation of FLC, firstly the universes of discourse of input and output variables of FLC are determined. Each universe is restricted to an interval that is related to the maximal and minimal possible values of the respective variables, i.e., the operating range of the variables. The universe of discourse of the input and output variables of the Mamdani type FLC can be determined as follows:

The universe of the error e (K)=P_{sref}(K)–P_s(K) is defined by the maximal and minimal values of the variables in the interval [e_{max},e_{min}], where:

$$e_{max} = psref_{max} - ps_{min}$$
$$e_{min} = psref_{min} - ps_{max}$$

Analogously, the change in error $\Delta e(K)= e(K)-e(K-1)$ and the change of output variables $\Delta u(K)= u(K)-u(k-1)$ have operating ranges$[\Delta e_{min,}\Delta e_{max}]$and $[\Delta u_{min,}\Delta u_{max}]$, where:

$$\Delta e_{max} = e_{max} - e_{min}$$
$$\Delta e_{min} = e_{min} - e_{max}$$
$$\Delta u_{max} = u_{max} - u_{min}$$
$$\Delta u_{min} = u_{min} - u_{max}$$

For simplification and unification of the design of the FLC and its computer implementation, it is operated with normalized universe of discourse of the input variables of
the FLC with an interval [-1 1] by multiplying a scaling factor i.e., reciprocal of $e_{max}$and $\Delta e_{max.}$

The scaling factors are one of the main parameters for tuning the FLC. It has a dramatic effect on the performance of the controlled object. The scaling also changes all the rules on the rule base of the FLC. Changing of scaling factor, changes the normalized values of input variables E(P), Δ E(P) and hence the domain of membership functions of the fuzzy values of normalized input/output variables of FLC, i.e., NB, N etc depending upon the normalized values and hence changes the rule-base.
The defuzzified value of output variable obtained by application of FLC algorithm also belongs to the normalized universe of discourse. It is then related to the real change of controlled output variables Δu(K)through output scaling factor.Thus the scaling of the normalized output variables is effectively de-normalization, i.e. bringing the output of FLC from the normalized universe to its actual operating range.Tuning of the output $\Delta Iry_{ref}$and $\Delta_{IX\ ref}$ isdone manually by changing the output scaling factor till actual values of P, Q approaches the reference values.

However, the effectiveness of tuning based on the scaling factors is bounded by different performance measures. Solution to this problem which improves the responsiveness and the stability of the system has been achieved again through tuning manually the peaks of membership functions i.e., by shifting the peaks of the membership function and the limits of the triangular membership functions of the fuzzy values without affecting the responsiveness of the system.

IX.CONTROL EVALUATION AND COMPARISON

To control evaluation and compare the real power, reactive power and dc-link voltage control using conventional and proposed direct current vector control approaches, an integrated simulation of an DFIG system is developed by using power converter average and detailed switching models in Matlabsimpower systems. In which both steady and variable wind speed condition are considered. The DFIG is rated power as the 2000KVA and system parameters are show in appendix I and II. The RSC and GSC switching frequency is considered as the 1980HZ, all the results presented in this based on the switching model simulation.
(a)Real Reactive power control under steady wind condition.

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Fig.9 and 10 presents the RSC and GSC real power, reactive power and DC link voltage control using both conventional and proposed direct current vector control approach, respectively. The wind speed 10m/s generator speed gradually increased before t=3.5s after t=3.5s generator speed get constant up to an t=5s, and the desired

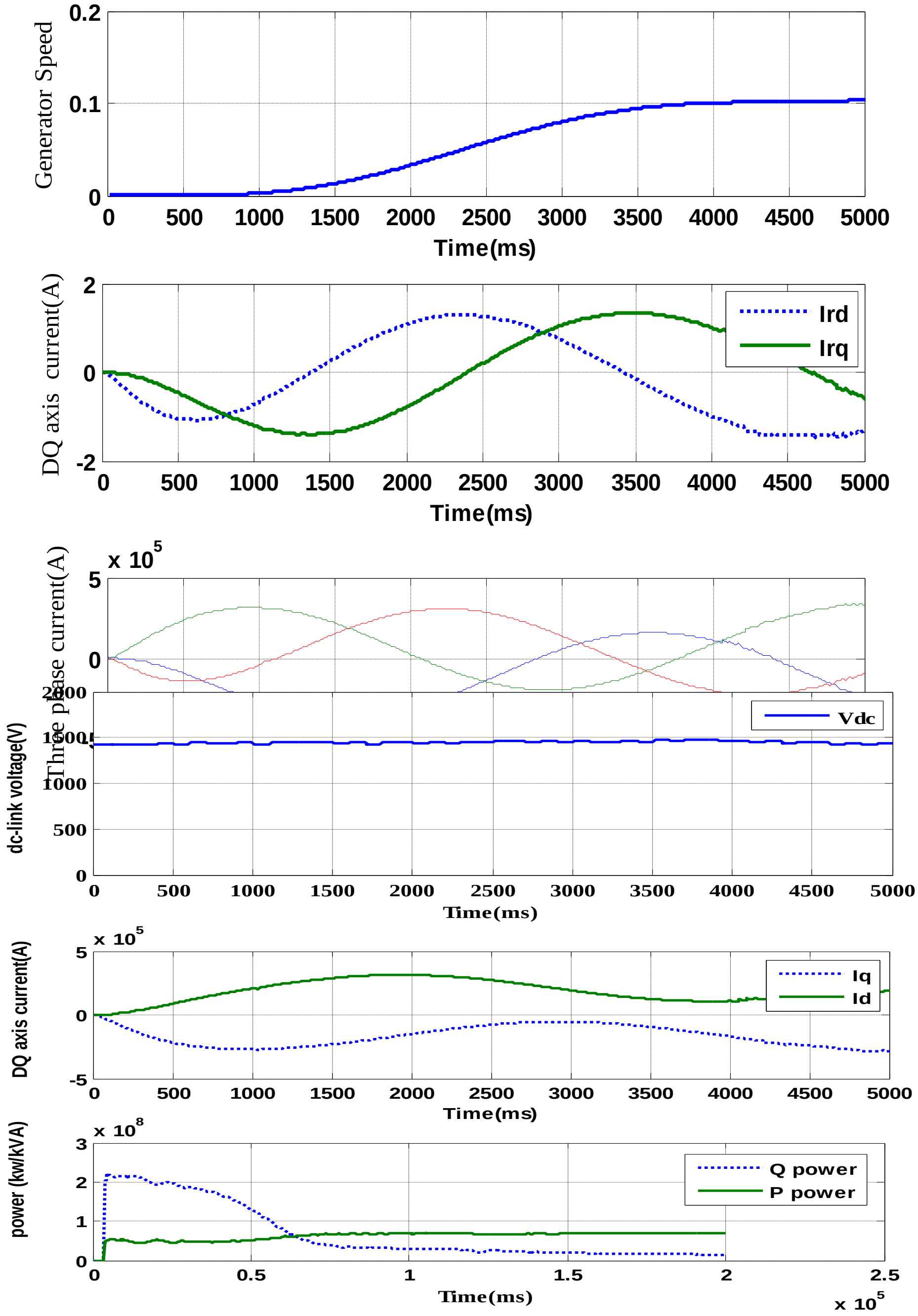

Fig. 9 GSC and RSC real, reactive power and DC linkVoltage using conventional control method

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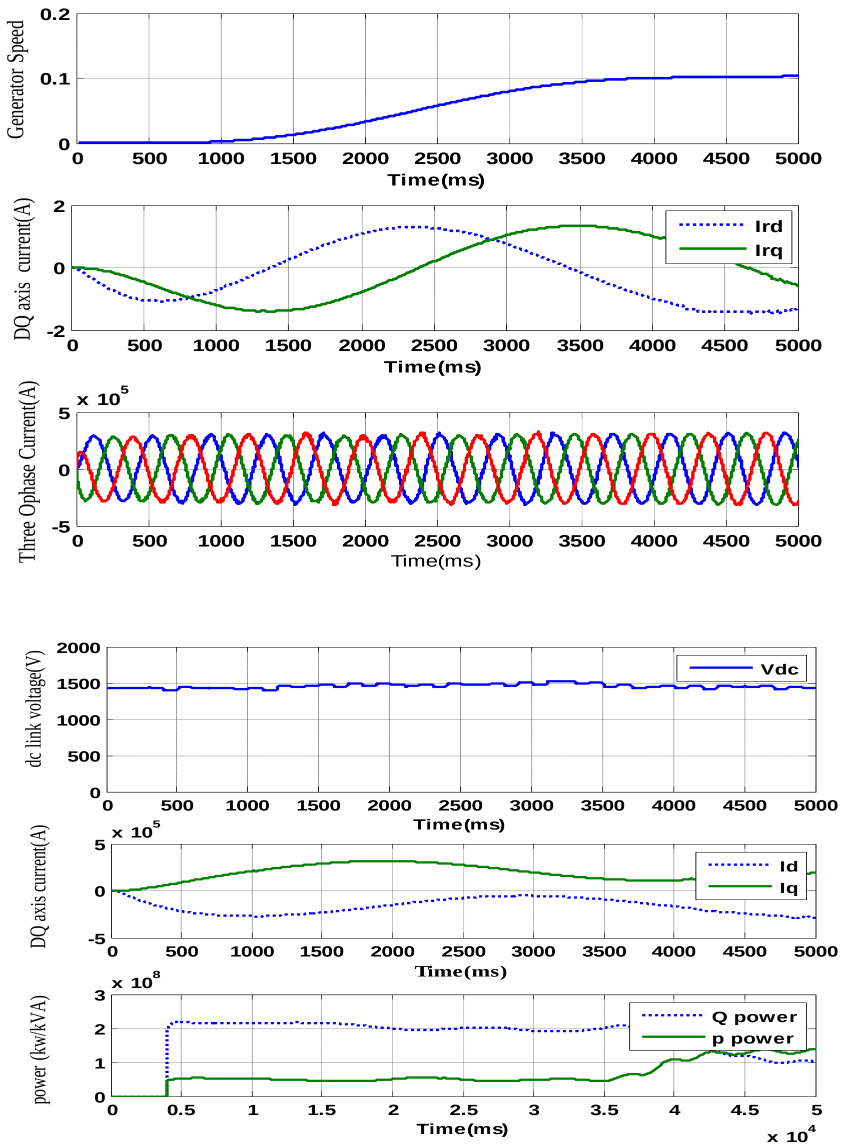

Fig. 10 GSC and RSC real, reactive power and DC linkVoltage using proposed control method

Dc link voltage maintained at 1500v in conventional method but in proposed method dc link voltage maintained as the 1550v.the rotor d and q axis current increased up to 2A at constant wind speed. In conventional method real and reactive power stabled after the t=5s but in proposed method real and reactive power stabled after the t=2s. At t=1.5s three phase current waveform produced an unbalanced current in conventional method but in proposed method their was an no unbalanced current as show in fig 10

(b)Real Reactive power control under variable wind condition.

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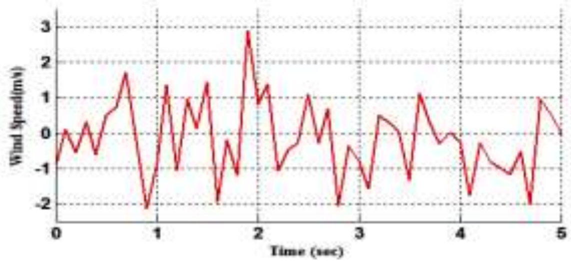

Fig.11 illustration of variable wind speed

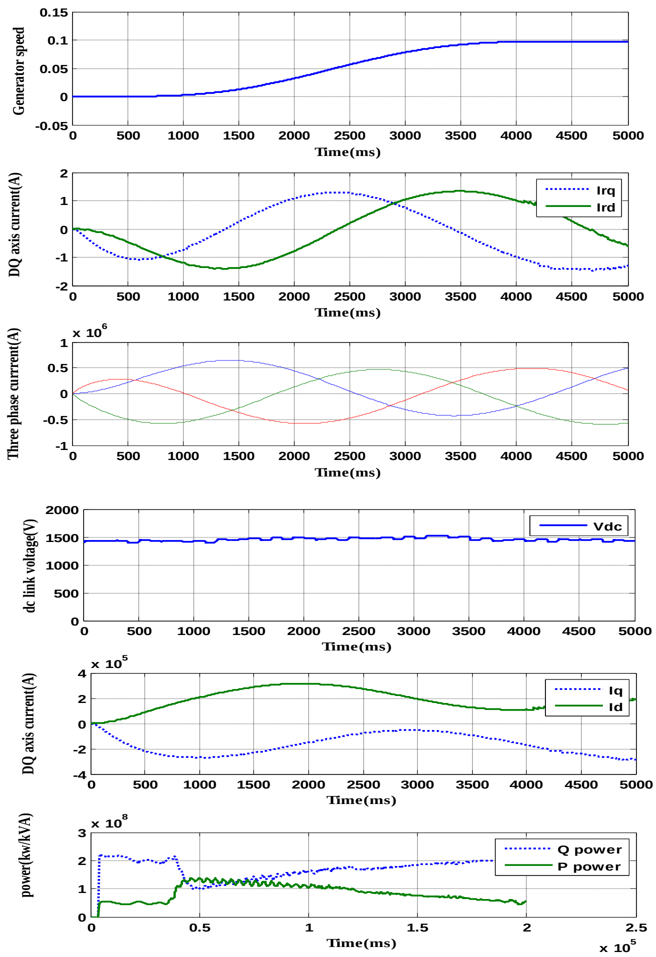

Fig. 12 GSC and RSC real, reactive power and DC link Voltage using conventional control method

The fig 11 shows that illustration of variable speed. fig 12 & 13 shows that simulation result for GSC and RSC real, reactive power and DC link Voltage both conventional and proposed control method. In variable wind speed the DC-link voltage maintained as an 1500V. In variable wind speed operating condition the generator operated at variable speed before the t=4s after the time t-4s the generator operated as an constant speed to get an constant output voltage in conventional method but in proposed method generator speed settled at time t=3.5s.

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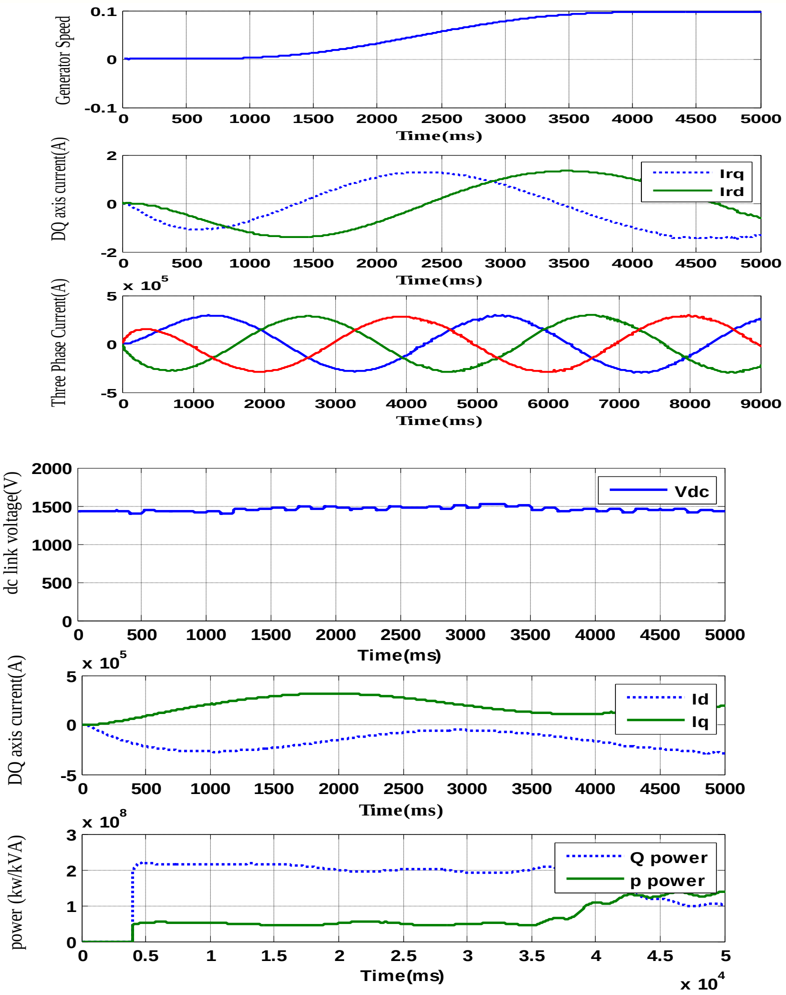

Fig. 13 GSC and RSC real, reactive power and DC linkVoltage using proposed control method

X.CONCLUSION

This paper presents a DFIG wind turbine control study using a direct-current vector control design. The project compares the proposed control scheme with the conventional standard DFIG control method. The project shows that under the direct-current vector control configuration, how the integrated GSC and RSC control is designed to implement the dc-link voltage, real power, reactive power, and grid voltage support control functions. Comprehensive simulation studies demonstrate that the proposed DFIG wind turbine control structure can effectively accomplish wind turbine control objectives with superior performance under both steady and variable wind conditions within physical constraints of a DFIG system. Beyond physical constraints of a DFIG system, the proposed control approach operates the system by regulating the RSC for real and reactive power control and by controlling the GSC to stabilize the dc-link voltage as the main concern. The direct-current vector current structure is also effective for peak power tracking, power factor improvement and grid voltage support control under a low voltage sag condition.

APPENDIX

TABLE I

POWER FACTOR AND DC-LINK VOLTAGE

Method	Power factor	Dc link voltage
Conventional Method	0.72	1480
Proposed Method	0.83	1550

TABLE II

PARAMETER OF DFIG WIND TURBINE

PAPRAMETER	**VALUE**	**UNITS**
S_g (Generator rated power)	2000	KVA
F(frequency)	50	HZ
V_g(Generator rated voltage)	690	V
R_s(Stator resistance)	0.0043	P.U
X_{ls}(Stator reactance)	0.0809	P.U
R_r (Rotor resistance referred to stator side)	0.0048	P.U
X_{lr} (Rotor reactance referred to stator side)	0.0871	P.U
X_m(Magnetizing reactance)	3.459	P.U
C (dc-link capacitor)	16000	µF
R_f (Grid filter resistance)	0.012	Ω
L_f(Grid filter reactance)	2	mH

REFERENCES

[1]shuhui li, timothy a. haskew, keith a.(2012) williams and richard p. swatloski "control of dfig wind turbine with direct-current vector control configuration," IEEE transactions on sustainable energy, vol. 3, no. 1, january.

[2] shuhuili , timothy a. haskew, yang-kihong and ling xu (2011) "direct-current vector control of three-phase grid-connected rectifier–inverter," electric power systems research 81 357–366.

[3] Ahmed G and Abo-Khalil (2012) "Synchronization of DFIG output voltage to utility grid in wind power system" Renewable Energy 44 193e198.

[4] DaweiZhiand Lie Xu (2007) "Direct Power Control of DFIG with Constant Switching Frequency and Improved Transient Performance" IEEE transactions on energy conversion, vol. 22.

[5] Gaillard A. P. Poure and S. Saadate(2009) "Variable speed DFIG wind energy system for power generation and harmonic current mitigation" Renewable Energy 34 1545–1553.

[6] Hany M. Jabr, Dongyun Lu and Narayan C. Kar (2011) "Design and Implementation of Neuro-Fuzzy Vector Control for Wind-Driven Doubly-Fed Induction Generator" IEEE transactions on sustainable energy, vol. 2, no. 4, october.

[7] Hee-Sang Ko, Gi-Gab Yoon and Nam-Ho Kyung (2009) "Variable speed DFIG wind energy system for power generation and harmonic current mitigation" Renewable Energy 34 1545–1553.

[8] Jingjing Zhao, Xin Li ,Jutao Hao and Jiping Lu (2010) "Reactive power control of wind farm made up with doubly fed induction generators in distribution system" Electric Power Systems Research 80 698–706.

[9]JeanPatric da Costa, Humberto Pinheiro and Thomas Degner (2011) "Robust Controller f9o r DFIGs of Grid-Connected Wind Turbines" IEEE transactions on industrial electronics, vol. 58, no. 9, september.

[10] Mansour Mohseni, Syed M. Islam and Mohammad A. S (2011) "Enhanced Hysteresis-Based Current Regulators in Vector Control of DFIG Wind Turbines" IEEE transactions on power electronics, vol. 26, no. 1, january.

[11] Mustafa Kayıkc¸ı and Jovica (2007) "Reactive Power Control Strategies for DFIG-Based Plants" ieee transactions on energy conversion, vol. 22, no. 2, june.

[12] Orlando Soares, Henrique Gonçalves, Anto´ nioMartins,and Adriano Carvalho (2010) "Nonlinear control of the doubly-fed induction generator in wind power systems" Renewable Energy 35 1662–1670.

[13] Rahim. A.H.M.A, I.O. Habiballah (2011) "DFIG rotor voltage control for system dynamic performance enhancement"Electric Power Systems Research 81 503–509.

[14] Shuhui Li, Timothy A. Haskew, and Ling Xu (2010)"Control of HVDC Light System Using Conventional and Direct Current Vector Control Approaches" IEEE transactions on power electronics, vol. 25, no. 12, december.

[15] Van-Tung Phan,, and Hong-Hee Lee (2012) "Performance Enhancement of Stand-Alone DFIG Systems With Control of Rotor and Load Side Converters Using Resonant Controllers" IEEE transactions on industry applications, vol. 48, no. 1, january/february.