Grid Connected Doubly Fed Induction Generator Wind Energy Conversion System using Fuzzy Controller

Pooja Dewangan, S. D. Bharti

Abstract--This paper presents the simulation and control of a grid connected doubly-fed induction generator driven by a variable speed wind turbine. Fuzzy logic control strategy is applied to doubly fed induction generator (DFIG). The Matlab/Simulink/SimPowerSystems software is used to Simulate all the components of grid connected doubly fed induction generator (DFIG)-based wind power conversion system (WPCS). DFIG consists of a common wound rotor induction generator with slip ring and a back to back voltage source convertor. Fuzzy logic controller is applied to both grid side convertor (GSC) for dc link voltage control and rotor side convertor (RSC) for active and reactive power control. Coordinated control of the grid- and rotor side converters (GSC and RSC, respectively) is presented in the positive synchronous reference. Use of DFIG in wind turbine is widely spreading due to its control over DC voltage and active and reactive power. Conventional dq axis current control using voltage source converters for both the grid side and the rotor side of the DFIG are analyzed and simulated. Simulation results prove the excellent performance of fuzzy control unit as improving power quality and stability of wind turbine.

Keywords: Doubly Fed Induction Generator (DFIG), Fuzzy Logic Controller (FLC), Wind Energy Conversion System (WECS)

I. INTRODUCTION

As the power generation demands around the world increase, the need of a renewable energy sources that will not harmful for the environment has been increased, because of the reducing availability of conventional energy sources. Wind energy is one of the most available and exploitable forms of renewable energy. Moreover, because of reducing the cost and improving techniques, the growth of wind energy in Distributed Generation (DG) units has developed rapidly. Wind turbines generation system (WPGS) based on doubly fed induction generator (DFIG), with back to back voltage source converters rated at about 25%–30% of the generator rating, have been widely used for high power application [1]. DFIG are typically used in application that requires varying speed of the machine's shaft in a limited range around the synchronous speeds, for example±30%.

Doubly fed induction generator (DFIG) is one of the most popular wind turbines which includes an induction generator with slip ring, a back to back voltage source converter and a common DC-link capacitor. Power electronic converter has two main parts; grid side converter (GSC) and rotor side converter (RSC).The three phase stator winding is directly connected to grid ,while the three-phase rotor winding is connected to grid by slip rings and brushes via a power convertor. The back to back power convertor has full controllability over the system.

The control system is an important issue for the wind energy conversion system (WECS). It maximizes the extracted power from the wind through all the components and also makes sure that the delivered power to the grid complies with the interconnection requirements. The control strategy is applied in different parts of the doubly fed induction generator based wind energy conversion system (WECS) and they have different aims. Many numbers of different control methods are developed to control wind energy conversion system. The most widely used method of controlling converter is using PI controllers. However, PI controller has same major problems: insecure conditions in the accurate model, and unpredictable behavior of some system specifications, such as wind speed, variations in reference values of required power, and simultaneous changes in these parameters, which makes the controller parameter regulation so hard [5],[10]. In this paper fuzzy controller is use to control active, reactive power and dc link voltage. Using fuzzy control, we can produce controller outputs more reliable because the effect of other parameters such as noise and events due to wide range of control area can be considered. More over without the need of a mathematical model of the system and just using the knowledge of the total operation and behavior of system, regulation of parameters can be done more simply [5].

This paper presents the operation and control of a Variable speed DFIG wind turbine using fuzzy Controller in MATLAB software. A main grid line of 120KV connected to 1.75MVA doubly fed induction generator (DFIG). Fuzzy controllers are applied to current regulation loop of both convertors (RSC and GSC). RSC and GSC are designed in the dq reference frame.

II. MODELING OF DFIG SYSTEM

Fig.1 represents the operation of DFIG and the way connected to the grid [10]. DFIG is basically a standard rotor-wounded induction machine in which stator is directly connected to the grid, and the Connection of the rotor to the grid is via a back-to-back PWM convertor.

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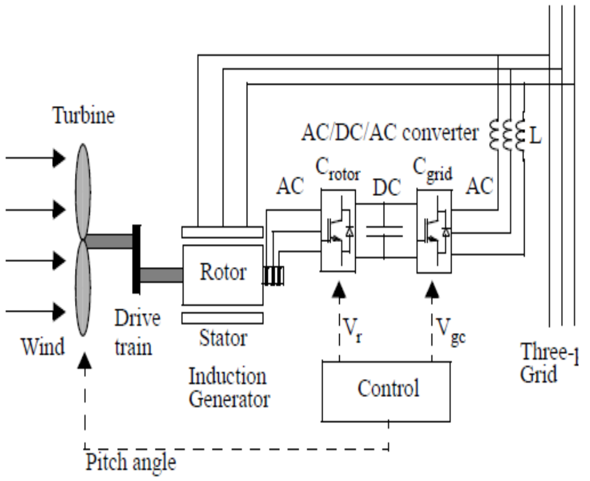


Fig. 1. The wind turbine and the doubly-fed induction generator system

A. Induction generator model

The equivalent circuit of the induction generator is shown in Fig.2. and the electric and magnetic equations of the model are described by equations (1)-(6).

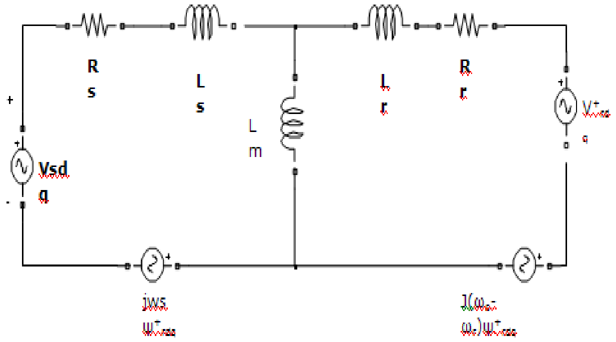


Fig. 2 .Equivalent circuit of the induction generator

Stator Voltage is given by:

$$V_{ds} = i_{ds}R_s - \omega_s\Psi_{qs} + \frac{d\Psi_{ds}}{dt} \qquad (1)$$

$$V_{qs} = i_{qs}R_s + \omega_s\Psi_{ds} + \frac{d\Psi_{qs}}{dt} \qquad (2)$$

Rotor Voltage is given by:

$$V_{dr} = i_{dr}R_r - s\omega_s\Psi_{qr} + \frac{d\Psi_{dr}}{dt} \qquad (3)$$

$$V_{qr} = i_{qr}R_s + s\omega_s\Psi_{dr} + \frac{d\Psi_{qr}}{dt} \qquad (4)$$

Flux Linkage is given by:

$$\Psi_{ds} = L_m i_{dr} - L_{sl} i_{ds}$$

$$\Psi_{qs} = L_m i_{qr} - L_{sl} i_{qs}$$

$$\Psi_{dr} = -L_m i_{ds} - L_{rl} i_{dr}$$

$$\Psi_{qr} = L_m i_{qs} - L_{rl} i_{qr} \qquad (5)$$

Electromagnetic Toque is:

$$T_{el} = \Psi_{qr} i_{dr} - \Psi_{dr} i_{qr} \qquad (6)$$

where v_s, i_s and Ψ_s are stator voltage, current and flux respectively; v_r, i_r and Ψ_r are rotor voltage, current and flux respectively; ω_s is the angular velocity of the chosen frame of reference; *d* and *q* represent *d* and *q* axis, respectively. L_m is the mutual inductance; L_{sl} and L_{rl} are the stator and rotor leakage inductances, respectively.

B. Converter model

With the assumption that the converters are lossless, the equations of converters are as follows:
The power at the rotor side (also called slip power) is given by:

$$P_r = v_{dr} i_{dr} + v_{qr}\, i_{qr}$$

$$Q_r = v_{qr} i_{dr} - v_{dr} i_{qr} \qquad (7)$$

And the power at the stator side is given by:

$$P_s = v_{ds} i_{ds} + v_{qs} i_{qs}$$

$$Q_s = v_{qs} i_{ds} - v_{ds} i_{qs} \qquad (8)$$

So the total output power is:

$$P = P_s + P_r = v_{dr} i_{dr} + v_{qr}\, i_{qr} + v_{ds} i_{ds} + v_{qs} i_{qs}$$

$$Q = Q_s + Q_r = v_{qr} i_{dr} - v_{dr} i_{qr} + v_{qs} i_{ds} - v_{ds} i_{qs} \qquad (9)$$

III. FUZZY CONTROL SYSTEMS

The control system is based on fuzzy logic. This type of control, approaching the human reasoning that makes use of the tolerance, uncertainty, imprecision and fuzziness in the decision-making process, manages to offer a very satisfactory performance, without the need of a detailed mathematical model of the system, just by incorporating the experts' knowledge into fuzzy [5],[6].

As presented in Fig.3, the fuzzy logic control system based on mamdani fuzzy model. This system consist four main components. First, using input membership functions, inputs are fuzzified then based on rule bases and inference system, outputs are produced and finally the fuzzy outputs are defuzzified and applied to the main control system. Error of inputs from their references and error deviations in any time interval are chosen as inputs. These parts are simulated in MATLAB. The output of fuzzy controller is the value that should be added to the prior output to produce new reference output.

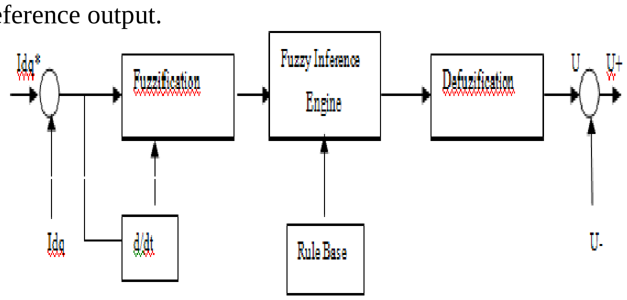


Fig.3. the fuzzy logic control blocks based on mamdani's system.

Fig.4 presents the block diagram of rotor side converter (RSC) to which fuzzy controllers are applied. The main objectives of this part of rotor side convertor (RSC) are active power control and voltage regulation of DFIG wind turbine using output reactive power control. As presented in Fig.4 rotor side converter manages to follow reference active power and voltage separately using fuzzy controllers. Based on Fig4.inputs of fuzzy controller are error in active and reactive power or voltage and the rate of changes in errors in any time interval. After the production of reference d- and q-axis rotor currents, they converted to a-b-c reference frame using Park transformation matrix.

Then they applied to a hysteresis current controller to be compared with actual currents and produce switching time intervals of converter.

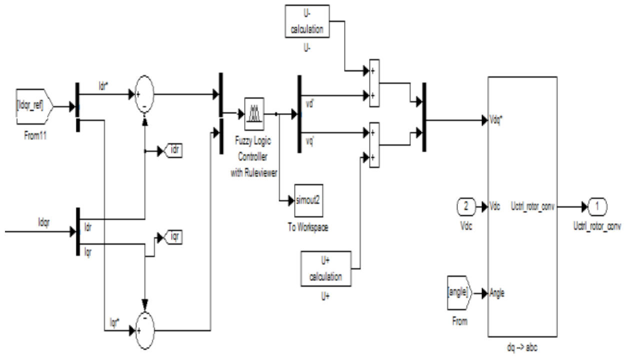
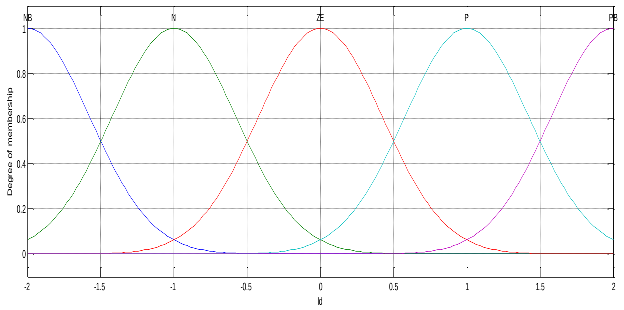
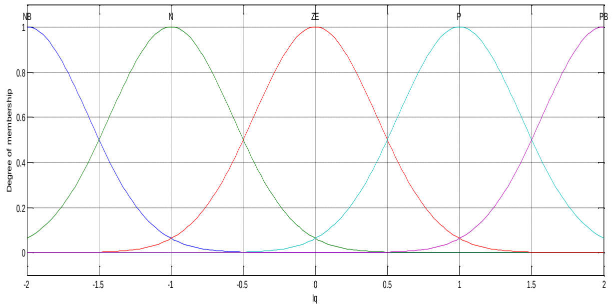


Fig.4.simlation model of rotor side convertor to which fuzzy controller are applied



(a)



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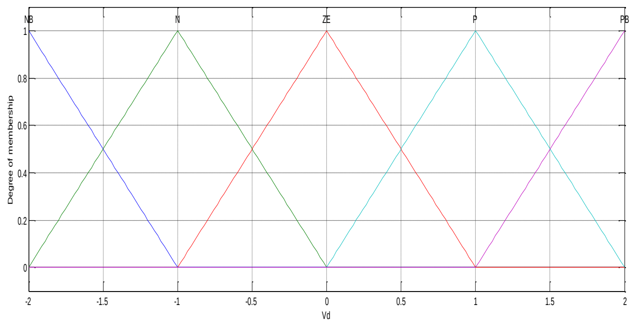

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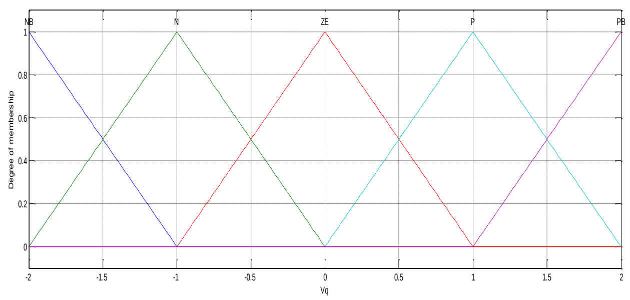
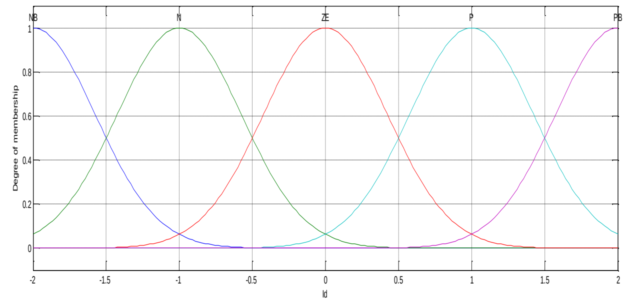
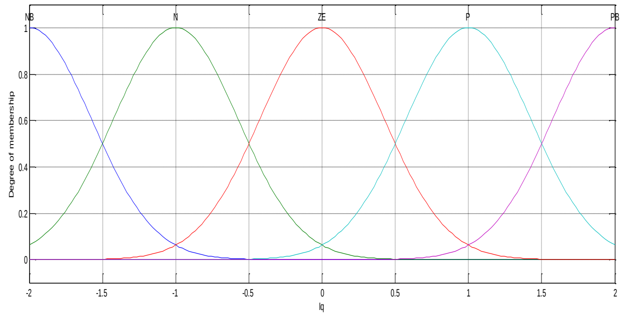


(d)

Fig.5. (a,b,c,d) Input and output membership functions of voltage controller (for RSC)



(a)



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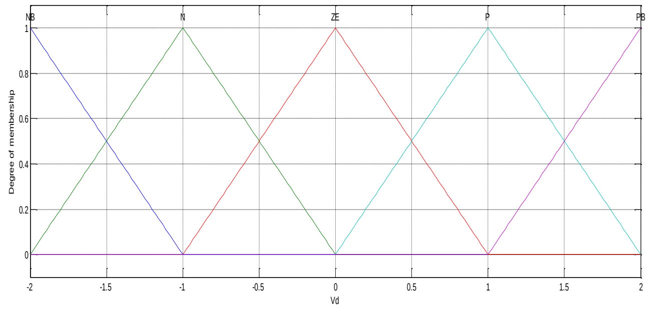

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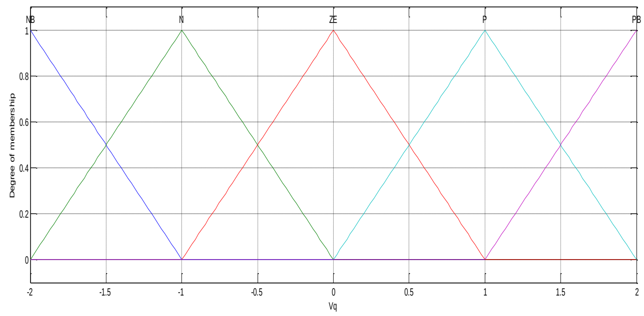

(d)

Figure 6.(a,b,c,d) Input and output membership functions power controller (for GSC)

Fig.5and6 shows inputs and output membership functions. To avoid miscalculations due to fluctuations in wind speed and the effects of noise on data, trapezoidal membership functions are chosen to have smooth and constant region in the main points.

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IV. SIMULATION ANALYSIS

A wind power generation system (WECS) based on 1.75MVA doubly fed induction generator (DFIG) connected to 120KV grid system with fuzzy control system is simulated using MATLAB/SIMULINK software. The frequency is set to 50Hz. The dc link voltage is regulated at1200V. The dc link capacitor is 10000μF

Table 1: Induction generator parameters of wind turbine (DFIG)

Rated power	1.75MW
Rated voltage	575 kV
Frequency	50Hz
Angular moment of inertia (J=2H)	5.04 p.u.
Friction factor	0.01p.u.
Stator resistance	0.00706 p.u.
Rotor resistance	0.0171 p.u.
Stator leakage inductance	0.005 p.u.
Rotor leakage inductance	0.156 p.u.
Mutual inductance	2.9 p.u.

In Fig.7. to Fig. 10 Shows different simulation results of DFIG system with wind turbine using fuzzy logic controller.

In Fig.7 voltage output is given. In Fig.8, Fig.9 and Fig.10 the active-reactive power and torque outputs are shown, it shows that as the load is applied transient state occurs and as soon as the fuzzy logic controller implemented it changes to steady state condition.

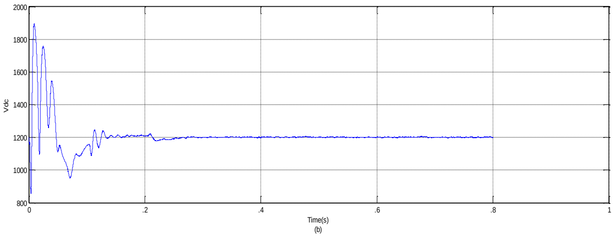

Fig.7.Simulation results with fuzzy-logic controller methods of V_{dc} under 1.2-pu rotor speed

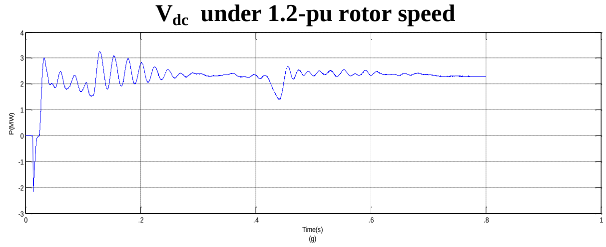

Fig.8. Simulation results with fuzzy-logic controller methods of active power under 1.2-pu rotor speed

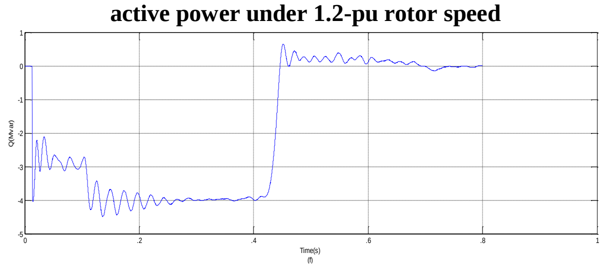

Fig.9. Simulation results with fuzzy-logic controller methods of reactive power under 1.2-pu rotor speed

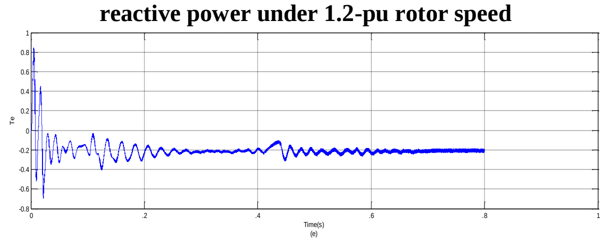

Fig.10. Simulation results with fuzzy-logic controller methods of torque under 1.2-pu rotor speed

The result shows fuzzy logic controllers for RSC and GSC are both enabled. This is the proposed coordinated control strategy. V_{dc} pulsation (V) is ±6, P pulsation (%) is ±1.2, Q pulsation (%) is±3.8 and T_e pulsation (%) is ±0.2.It shows that fuzzy logic controller gives better results.

V. CONCLUSION

Control and operation of a DFIG-based wind power generation system under unbalanced supply voltage conditions have been investigated in this thesis. A new coordinated control strategy for the RSC and GSC has been proposed. The RSC is controlled to eliminate the electromagnetic torque oscillation while the GSC compensates for the oscillation of the DFIG stator output active power to eliminate the oscillation in the total active power generated from the overall system. Fuzzy-logic controller is used as according to user defined rules. This paper presents a study of Fuzzy Logic Controller in a DFIG system. Simulation results prove that Fuzzy Logic Controller gives improved performance. Fuzzy Logic Controller exhibits the best steady-state accuracy and robustness to parameters variations, but its implementation is complicated. With fuzzy controller the power quality and voltage stability are improved.

REFERENCES

1. J. Hu, Y. He, Lie Xu and B. W. Williams, "Improved Control of DFIG Systems During Network Unbalance Using PI–R Current Regulators" *IEEE Trans. Ind. Electron.*, vol. 56, no. 2, pp. 439-451, Feb. 2009.
2. Dimitrios, G.Giaourakis, N.Safacas, and Savvas Tsotoulidis, "Dynamic Behaviour of 1.5 M Doubly-Fed Induction Generator based Wind Energy Conversion System" International Symposium on Power Electronics, Electrical Drives, Automation and Motion, IEEE 2012.
3. Yu Fang,Liu Qihui1,Hou Guixin Zhang Jianhua, "Study of The Reactive Power Characteristics in the Double Fed Variable Speed Constant Frequency Wind Turbine" IEEE 2012.
4. Chengyuan Yu, Dongdong Li , "Fuzzy-PI and Feedforward control strategy of DFIG wind turbine" IEEE PES ISGT ASIA 2012 1569537679.
5. H. K.-Davijani, A. Sheikholeslami, H. Livani and M. K.-Davijani, " Fuzzy Logic Control of Doubly Fed Induction Generator Wind Turbine," *World Applied Sciences Journal*, vol.6, no. 4, pp.499-508, 2009.
6. Mohamed Hilal, Youssef Errami, Mohamed Benchagra,Mohamed Maaroufi, "Fuzzy Power Control for Doubly Fed Induction Generator based Wind Farm" Journal of Theoretical and Applied Information Technology ,vol. 43 no.2, pp.321-330 September 2012.
7. Christina N. Papadimitriou and Nicholas A. Vovos, "Fuzzy Control of WT with DFIG for Integration into Micro-grids" Fundamental and Advanced Topics in Wind Power, ISBN 978-953-307-508-2, June 2011.
8. B. Babypriya, N. Devarajan, "Simulation and Analysis of a DFIG Wind Energy Conversion System with Genetic Fuzzy Controller" International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-2, Issue-2, May 2012.
9. Furat Abdal Rassul Abbas and Mohammed Abdulla Abdulsada, "Simulation of Wind-Turbine Speed Control by MATLAB" International Journal of Computer and Electrical Engineering, vol. 2, No. 5, October, 2010.
10. Arash Abedi, Mojtaba Pishvaei, Ali Madadi and Homayoun Meshgin Kelk, "Analyzing Vector Control of a Grid-Connected DFIG under Simultaneous Changes of Two Inputs of Control System" European Journal of Scientific Research, ISSN 1450-216X ,vol.45 No.2, pp.221-231 (2010).

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