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Study of Characteristics of DFIG Based Wind Turbine

Shaik Naveed[1] | Muralikrishna. N[2] | Sk. Saidavali[3]

[1]PG Scholar, Department of EEE, Sri Vani School of Engineering, Chevuturu, Andhra Pradesh, India.
[2]HOD, Department of EEE, Sri Vani School of Engineering, Chevuturu, Andhra Pradesh, India.
[3]PG Scholar, Department of EEE, Sri Vani School of Engineering, Chevuturu, Andhra Pradesh, India.

ABSTRACT

In this paper the study of active power, reactive power, stator current, rotor current and grid voltage characteristics of doubly fed induction generator based wind turbine are studied. The pulses for the stator and rotor are applied by using a hysteresis current controller. The main drawback of wind energy conversion system is that it is highly nonlinear. To overcome this problem a fuzzy controller on rotor side and a discrete PID controller on stator side are applied. The active and reactive powers are controlled by this nonlinear strategy. The active power is maximized by these both controllers. The entire simulation is conducted on mat lab/simulink. The results obtained are satisfactory.

KEYWORDS: *dfig, active power, reactive power, fuzzy control, discrete PID controller*

I. Introduction

In the last century, the human activities have increased in the field of production and in development of human life quality. Among various renewable energy sources, wind energy is the one of the most important and promising renewable energy resources in the world because it is considered to be nonpolluting and economically viable[1].so far, a lot of researches concentrated on rotor current and speed controllers. Typical PID controllers and fuzzy controllers were used to satisfy the requirement [4].to study the characteristics of dfig based wind turbine these are controllers are applied on rotor and stator side in this paper.Fig.1.shown below is the block diagram of dfig based wind turbine. It consists of a doubly fed induction generator, pwm converter, discrete PID controller on stator side and a fuzzy controller on rotor side. Stator side is directly connected to three phase grid and the rotor side is connected through a pwm converter.

The hysteresis current controller for applying pulses on stator and rotor side is not shown in fig.1

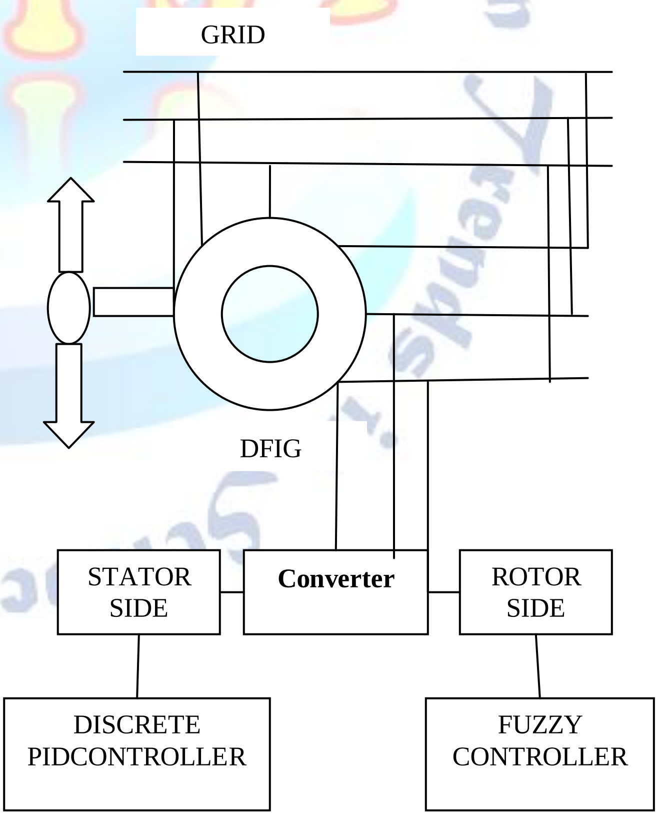

Fig.1.DFIG based wind turbine

II. Wind Turbine and Its Equations

As shown in Fig.1.the energy is transmitted directly to the grid. The control of power extracted and transmitted to the grid is done by using fuzzy and PID controller. The turbine power and torque developed are given by following relations [1]:

$$Pm = \frac{1}{2} \times \varrho \times \pi \times R^{2\times} v^3 \times \mathrm{Cp}\ (\lambda) \quad (1)$$

$$Tm = \frac{1}{2\lambda} \times \lambda \times \pi \times R^3 \times v^2 \times Cp(\lambda) \quad (2)$$

$$\lambda = \frac{\Omega \times R}{v} \quad (3)$$

The power coefficient Cp is the aerodynamic efficiency of the turbine and depends on specific speed λ and the angle of the blades.

III. DFIG and Its Equation

The generator converts energy derived from the wind into electrical energy. The dfig consists of a wound rotor and an AC/DC/AC based pwm converter as shown in Fig.1.the stator winding is directly connected to the grid while the rotor winding is interfaced through a power electronic converter [2]. The stator and rotor voltages of dfig are:

$$Vds = Rs * Ids + \frac{d\varphi_{ds}}{dt} - w_s * \varphi_{qs} \quad (4)$$

$$Vqs = Rs * Iqs + \frac{d\varphi_{qs}}{dt} + w_s * \varphi_{ds} \quad (5)$$

$$Vdr = Rr * Idr + \frac{d\varphi_{dr}}{dt} - w_r * \varphi_{qr} \quad (6)$$

$$Vqr = Rr * Iqr + \frac{d\varphi_{qr}}{dt} + w_r * \varphi_{dr} \quad (7)$$

IV. Discrete PID Controller

The discrete PID controller is given on stator side as shown in Fig.1.by automatically tuning the PID controller the Kp, Ki and Kd values are assigned directly for the PID controller. The compensator formula is [3]:

$$P(b \times r - y) + \frac{1}{s}(r - y) + D \times \frac{N}{1+\frac{N}{S}}(C.r - y) \quad (8)$$

V. Fuzzy Logic Controller

Although PID controller can play an important role in stability of the power system and especially for damping of interarea oscillation, the best performance of the PID controller and accordingly, the performance of the dfig depend on a suitable choice of the PID gains. Tuning the PID gains to make optimal operation is difficult task, especially, when the process is nonlinear and may change during operation. The alternative to PID controller is FUZZY controller. Based on human experience nonlinear operations can be easily done using fuzzy controller [4].the structure of a complete fuzzy control system is composed from the following blocks:

- fuzzification
- knowledge base
- inference engine
- defuzzification

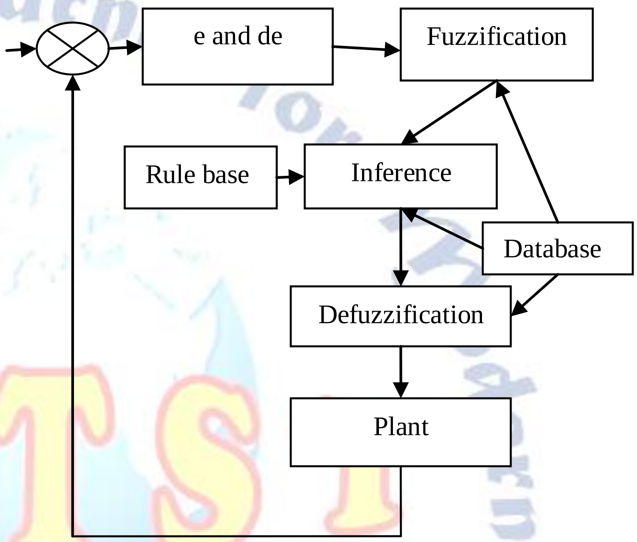

Fig.2.Basic Structure of Fuzzy Logic Control system

The fuzzification module converts the crisp values of the control inputs into fuzzy values. A fuzzy variable has values which are defined by linguistic variables such as low, medium, high, big, slow, etc.each fuzzy set is defined by a gradually varying membership function [1].

The rule base table for the fuzzy control used in this work is shown in Fig.3.

de \ e	NL	NM	EZ	PM	PL
NL	PB	PM	PM	PM	PB
NM	PB	PM	PL	PM	PB
EZ	PVB	PM	PVL	PM	PVL
PM	PB	PM	PL	PM	PB
PL	PB	PM	PM	PM	PB

Fig.3.Rule Base

VI. Hysteresis Current Controllers

The pulses on stator and rotor side of dfig are given by using hysteresis current controllers.Fig.4.shown is the simulink diagram for hysteresis current controller.

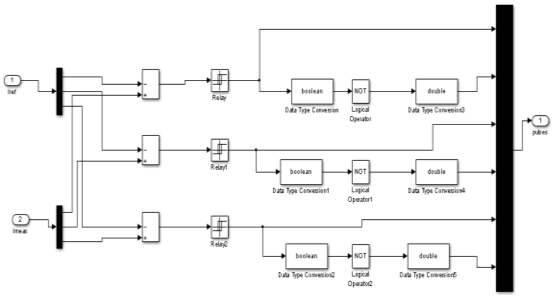

Fig.4.simulink for hysteresis current control

VII. Circuit Diagram

The circuit diagram for the developed dfig based wind model in simulink is shown in Fig.5.

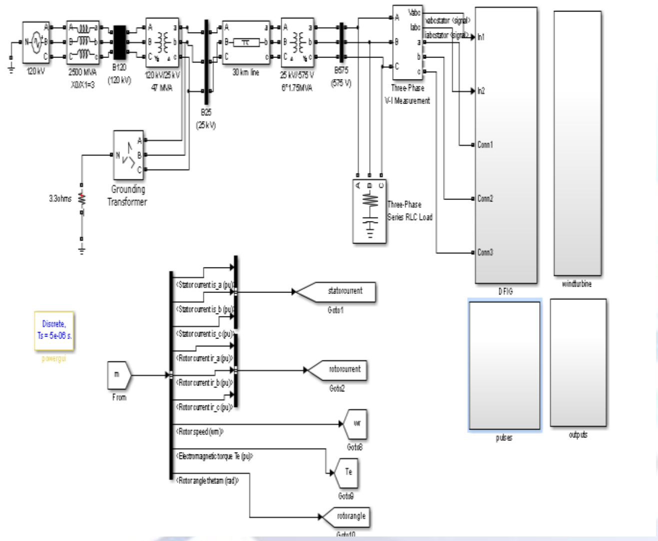

Fig.5.simulink diagram

As shown in Fig.5.the figure consists of a three phase grid, dfig, wind turbine, pulses and outputs. It is a 9MW wind farm with wound rotor induction generator whose parameter values are [5]:
Rs=0.023; Rr=0.62; Ls=0.084; Lr=0.081; M=0.078; inertia constant=0.3125; friction factor=0.00673; p=2;
These values are obtained by using the following relations [5]:
Rs=R1;
Ls=(X1+Xm)/w;
M=n (2/3) Xm/w;
Rr=n2*R2;
Lr=n2*(X2+Xm)/w;

VIII. Results and Discussion

The characteristics of active power, reactive power, stator voltage and currents, grid current and dclink voltages are shown from Fig (6)-Fig (12):

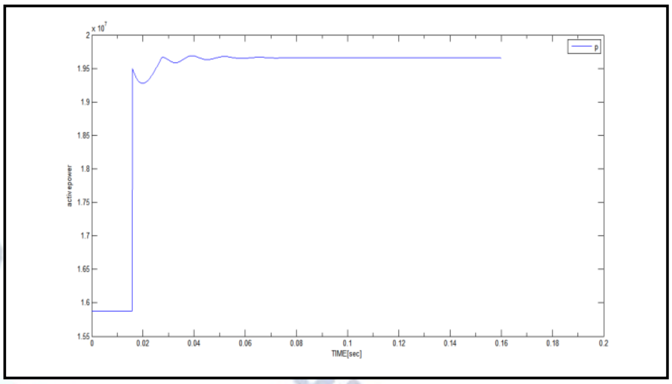

Fig.6.ACTIVE POWER

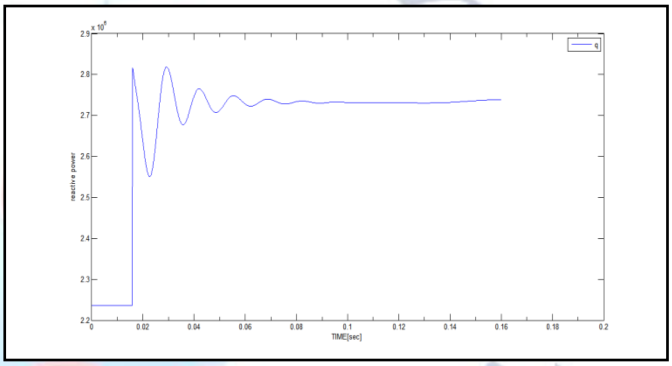

Fig.7.REACTIVE POWER

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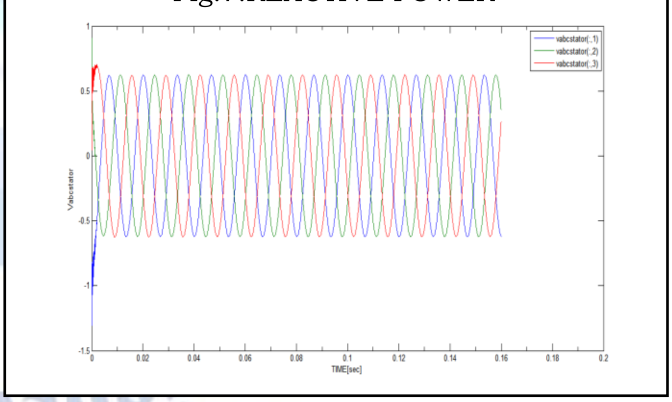

Fig.8.THREE PHASE STATOR VOLTAGE

The active power obtained is maximized to 20MW using the controllers fuzzy and PID compared without controllers.

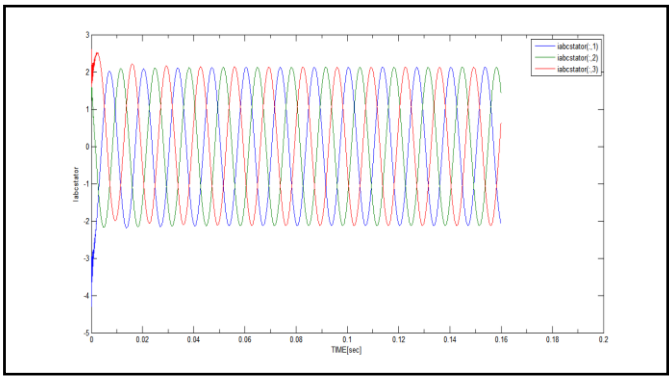

Fig.9.THREE PHASE STATOR CURRENT

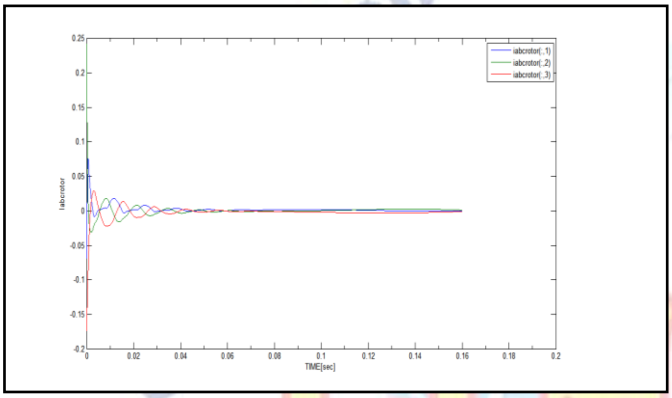

Fig.10.THREE PHASE ROTOR CURRENT

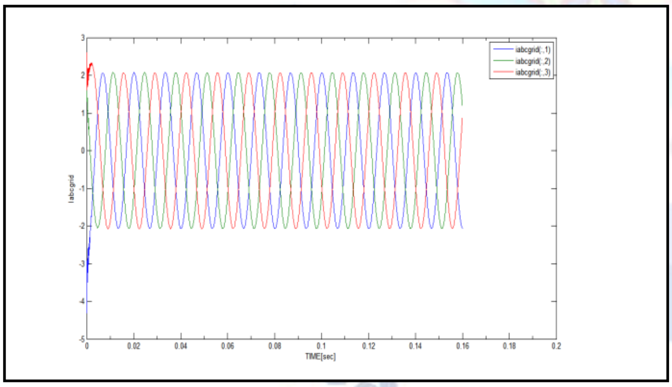

Fig.11.THREE PHASE GRID CURRENT

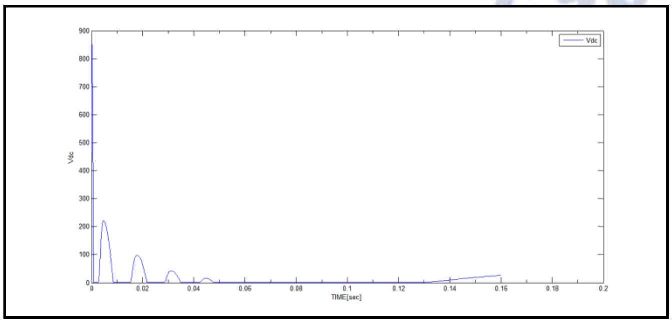

Fig.12.DCLINK VOLTAGE

IX. Conclusion

The characteristics of DFIG based wind turbine are studied in this paper. The active power is maximized to 20MW using fuzzy and PID controllers on rotor and stator sides. The results obtained were satisfactory. The entire simulation is conducted on mat lab/simulink environment.

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