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. 6, Special Issue 2, March 2017

Control of PMSG Based Variable Speed Wind Turbines for Voltage Regulation

S.Kumaravel[1], R.Sundaravel[2]

Assistant Professor, Dept. of EEE, Sri Venkateswara College of Engineering, Chennai, Tamilnadu, India[1]

PG Student [PED], Dept. of EEE, Sri Venkateswara College of Engineering, Chennai, Tamilnadu, India[2]

ABSTRACT: This project investigates the Fuzzy Logic based control scheme of the Permanent Magnet Synchronous Generator (PMSG)-based wind turbines to improve the Voltage regulation and power system damping. Based on the characteristics and control scheme of the PMSG-based wind turbines, the relationship between the DC side voltage fluctuation of the full scale power converter and the voltage regulation of the PMSG is discussed, which ensures the wind turbine provide the power support quickly and smoothly, and then the system damping is also improved using the reactive power additional control scheme of the PMSG-based wind turbines. The simulation results show that the PMSG-based wind turbines with improved voltage regulation.

KEYWORDS: Voltage regulation, Permanent Magnet Synchronous Generator, Power oscillation damping, Variable speed wind turbine.

I.INTRODUCTION

The wind energy is a pollution-free resource, in inexhaustible potential. The main drawback is the energy production irregularity. In the recent years, because global warming and because the effects of carbon emissions had an important impact over the entire world, a demand for clean and sustainable energy sources like wind, sea, sun and biomass have become an considerable alternative to the conventional resources. The utilization of wind energy was used in the past mainly in the agriculture sector for pumping water and for grinding. The research for wind power industry started to be improved in the last century, mainly due to the oil crisis and natural resources. The increasing the wind turbine size leads to the increase electrical power production is also increased.

The purpose of this study is to investigate new system control to simultaneously provide voltage regulation and positive damping during voltage and oscillation events. Smooth recovery of wind turbine operation after voltage regulation can also be achieved. Due to the increase popularity of PMSG-based wind turbine for applications in large wind farms, the proposed integrated control scheme is performed on the PMSG-based wind turbine. This project is organized as follows. The basic control of the PMSG is briefly introduced first. The concept of the PI and fuzzy controlled PMSG-based variable speed wind turbine is presented, and the design of the PI and fuzzy controller for voltage regulation is described . The damping capability of the proposed controller is analyzed to ensure positive damping.

II. BASIC CONTROL OF PMSG

Permanent magnet electric machine is a synchronous machine which is magnetized from permanent magnets placed on the rotor instead of using a DC excitation circuit. In this case having the magnets on the rotor the electrical losses of the machine are reduced and the absence of the field losses improves. The electromagnetic power of the generator can be controlled using either the generator-side converter or the grid-side converter. The grid-side converter directly controls the generated active power, whereas the generator-side converter is used to maintain a constant dc-link voltage since the grid-side converter can fall into current limit during ac voltage dip with reduced power transmission, the generator side converter as the dc voltage control station automatically reduces power generation in order to maintain a constant dc voltage. The conventional PI controllers are fixed-gain feedback controllers. Therefore they cannot compensate the parameter variations in the process and cannot adapt changes in the environment. PI-controlled system is less responsive to real and relatively fast alterations in state and so the system will be slower to reach the set point.

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. 6, Special Issue 2, March 2017

III. MATHEMATICAL MODELLING OF PMSG

In order to design the PM machine in MATLAB/Simulink it is necessary to develop the mathematical model of the generator that is derived from the space vector form of the stator voltage equation. The mathematical model is the

$$\overrightarrow{V_{abc}^{s}} = R_s\overrightarrow{J_{abc}^{s}} + \frac{d}{dt}\overrightarrow{\lambda_{abc}^{s}} \quad (1)$$

Where R_s=Stator winding resistance, J_{abc}^{s}=Stator phase current, λ_{abc}^{s}=Flux linkage. Based on the reference frame theory, stator voltage equations in dq synchronous reference frame the equations are,

$$V_d^s = R_s i_d^s + \frac{d}{dt}\lambda_d^s - \omega_e\lambda_q^s \quad (2)$$

$$V_q^s = R_s i_q^s + \frac{d}{dt}\lambda_q^s - \omega_e\lambda_d^s \quad (3)$$

The electromagnetic torque expressed in equation 4

$$P_e = \omega_m T_e = 3/2\left[\omega_e\lambda_d^s i_q^s - \omega_e\lambda_q^s i_d^s\right]. \quad (4)$$

By substituting the values of λ_d^s, λ_q^s

3/2npp*$\omega_m(L_d - L_q)\ i_q^s i_d^s$ = It is the reluctance torque and represents the torque produced by the difference of the inductances in dq reference frame. Hence the final expression is

$$T_e = T_l + B\omega_m + J\frac{d}{dt}\omega_m \quad (5)$$

IV.PERFORMANCE OF PMSG WITH PI CONTROLLER AND FUZZY CONTROLLERS

Under normal operation, the generated power of the wind turbine is controlled under the Proportional integral controller according to its rotor speed. The reactive power of the PMSG can be controlled to zero or be regulated to maintain the stator voltage or minimize the power loss of the generator In order to emulate the dynamic response of synchronous generators using PMSG-based wind turbines, advanced control schemes considering voltage regulation.

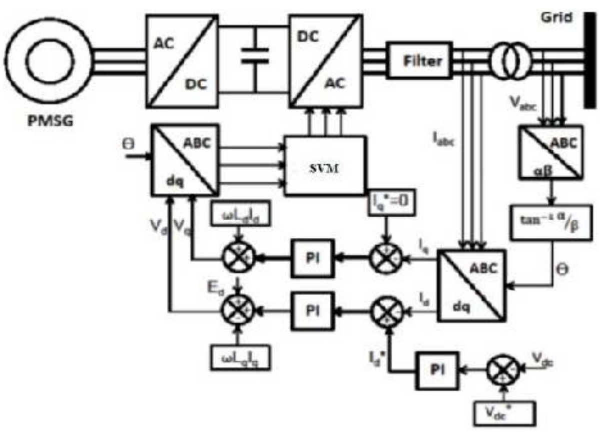

Fig. 1 Control of grid side converter for voltage regulation

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. 6, Special Issue 2, March 2017

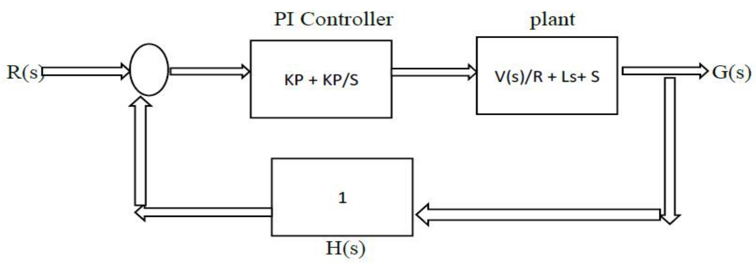

Fig. 2 Block diagram of PI controller

P-I controller is mainly used to eliminate the steady state error resulting from P controller. However, in terms of the speed of the response and overall stability of the system, it has a negative impact. This controller is mostly used in areas where speed of the system is not an issue.

KP' = (2εωn – Rc/Lc)*Lc/Vg (6)
= 2 * 0.707 *2 *3.14 *50 – (20/15) * (15/150)
= 44.2
KP = KP'* 0.04*20/f (7)
= 0.45
KI' = Lc/Vg * 2 *3.14 *50 (8)
= 15/150* 2 *3.14 *50 = 31.2
KI = KI' * 0.04 *20/f (9)
= 0.68

IV. FUZZY CONTROLLERS

This section employs the technique of fuzzy-logic control theorem to design the FLC based on the data collected from the responses of the studied system with PI controller. The rotor-speed deviation and active-power deviation of the wind PMSG are fed to the FLC in order to generate a damping signal. To design the FLC controller, the following fundamental design steps for a FLC are employed: (a) fuzzification (FI), (b) Decision-making logic (DML), (c) defuzzification (DFI), and (d) knowledge base (KB).

This paper uses Sugeno-type fuzzy inference since it works well with linear, optimization. And adaptive techniques. Seven linguistic variables for each input variable are used: NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZR (Zero), PS (positive Small), PM (Positive Medium), and PB (Positive Big). Seven linguistic variables are also employed for the output variable: IE (Increase Big), 1M (Increase Medium), IS (Increase Small), KV (Keep Value), DS (Decrease Small), DM (Decrease Medium), and DB (Decrease Big). The membership functions for input variables are Gaussian curve and the weighted average method for defuzzification is employed.

TABLE I RULE BASE MATRIX

VOLTAGE AND SPEED	CHANGE IN VOLTAGE AND SPEED				
	NB	NS	ZE	PS	PB
NB	NB	NB	NB	NS	ZE
NS	NB	NB	NS	ZE	PS
ZE	NB	NS	ZE	PS	PB
PS	NS	ZE	PS	PB	PB
PB	ZE	PS	PB	PB	PB

Fig. 3 Membership functions

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. 6, Special Issue 2, March 2017

The Fig.4 describes the Simulink model of the open loop wind system and there are no controller used it leads to voltage instability and oscillation.

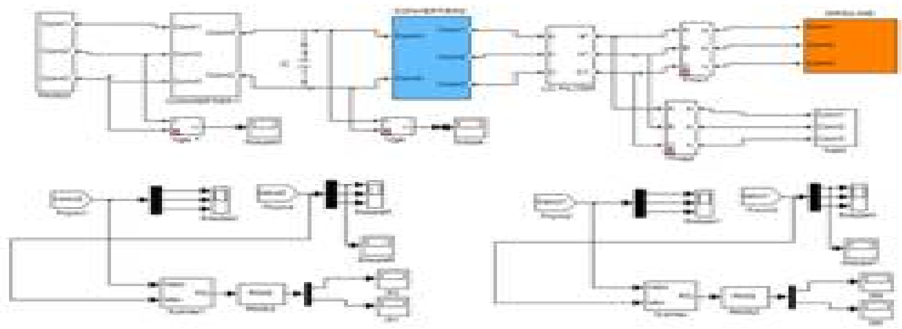

Fig. 4 Simulink diagram of open loop wind turbine

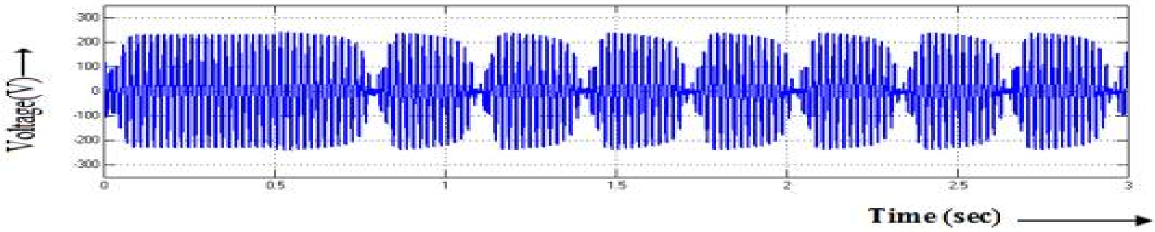

Fig. 5 Output voltage of wind

The Fig.5 describes about the output voltage of wind generator and its value is 230V and the wind output voltage consists of fluctuations and they cause losses.

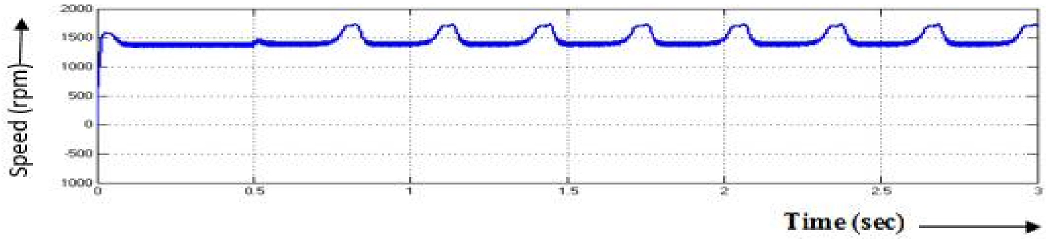

Fig. 6 Rotor speed of wind generator

The Fig.6 describes about the rotor speed of wind is 1500rpm turbine and its value is the rotor speed is having oscillations.

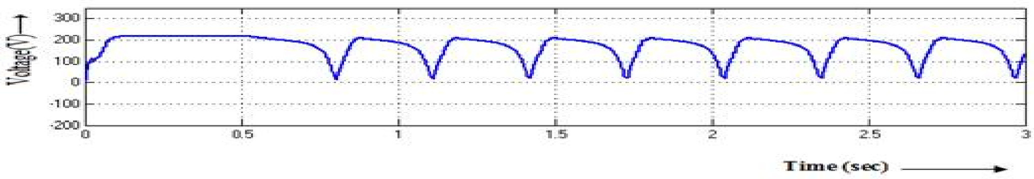

Fig. 7 Output voltage of converter

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. 6, Special Issue 2, March 2017

The Fig.7 describes about the output voltage of converter and its value is 230V and the converter output voltage consists of ripple and they cause problems.

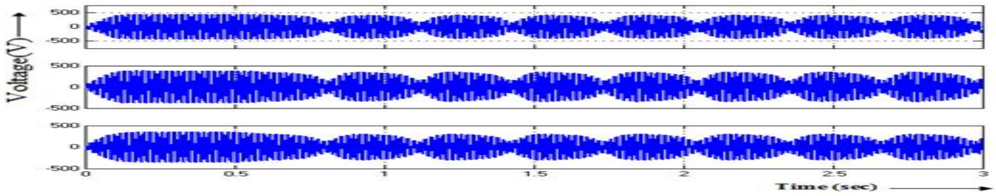

Fig. 8 Output voltage of grid

The Fig.8 describes about the output voltage of wind generator and its value is 400V and the output voltage consists of ripples and they cause losses.

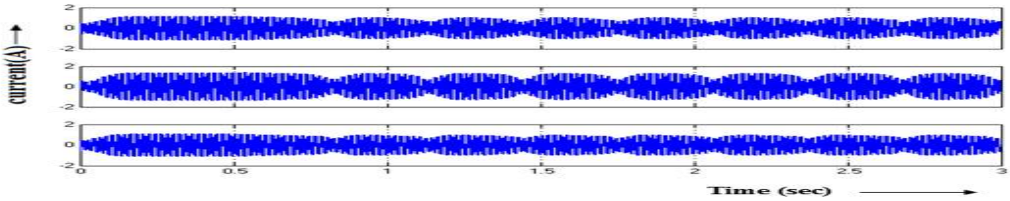

Fig. 9 Output current of grid

The Fig.9 describes about the output current of wind and its value is 1.5A and the wind output current consists of ripples and they cause losses.

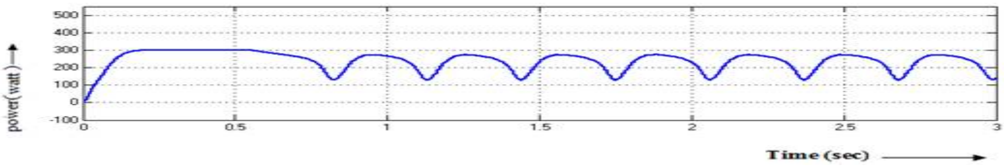

Fig. 10 Real power of grid

The Fig.10 describes about the real power of grid and its value is 300W and the wind output power consists of ripples.

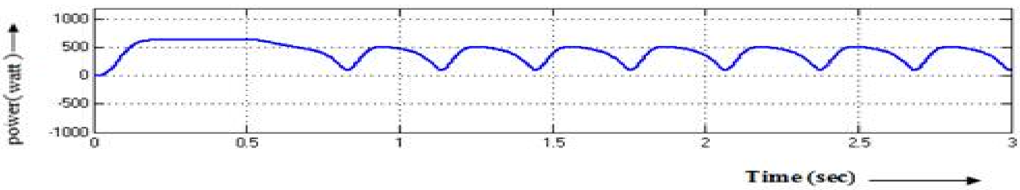

Fig. 11 Reactive power of grid

The Fig.11 describes about the reactive power of grid and its value is 500VAR and the wind output power consists of harmonic losses.

E. SVM WITH CLOSED LOOP PI CONTROLLER WITH LOAD INCREASE

The Fig.12 describes about the simulink model of the closed loop wind system and they have the controller options used to regulate the voltage.

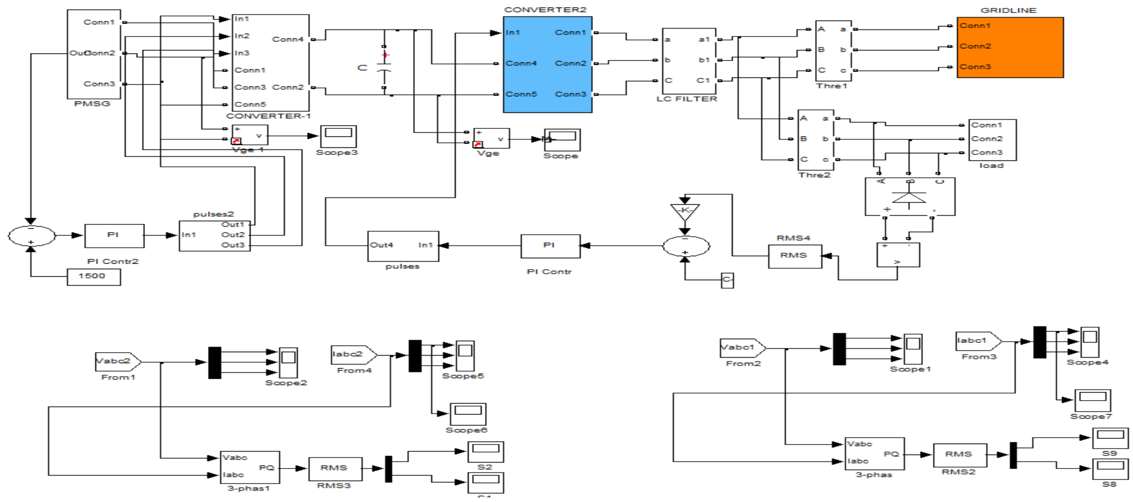

Fig. 12 Simulink diagram closed loop PI controlled wind generator

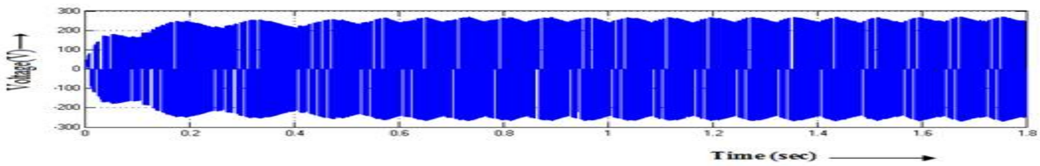

Fig. 13 Output voltage of wind generator

The Fig.13 describes about the output voltage of wind generator and its value is 230Vand the wind output voltage consists of fluctuations and they are reduced by PI controller.

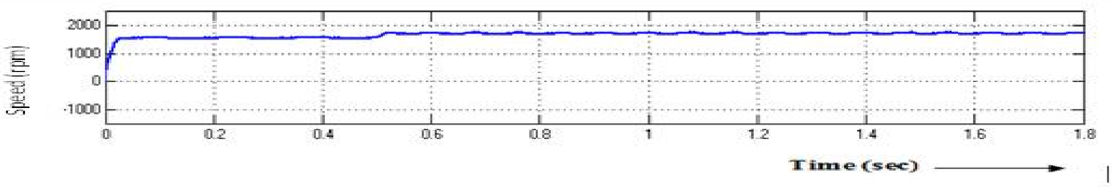

Fig. 14 Rotor speed of wind generator

The Fig.14 describes about the rotor speed of wind generator and its value is 1800rpm and the rotor speed is controlled with the help of PI controller.

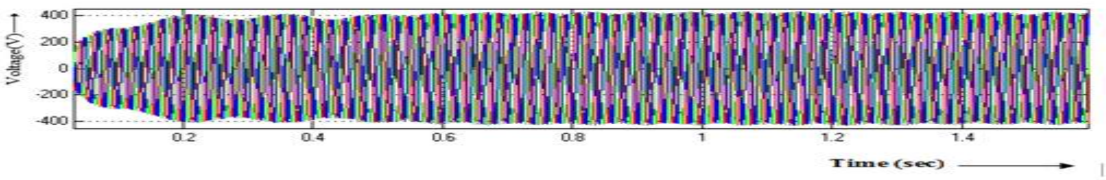

Fig. 15 Output voltage of grid

The Fig.15 describes about the output voltage of wind and its value is 400V and the wind output voltage consists of ripples and they reduces with the help of PI controller. The Fig.16 describes about the output current of wind and its value is 1.8A and the wind output current consists of ripples and they reduces with the help of PI controller.

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. 6, Special Issue 2, March 2017

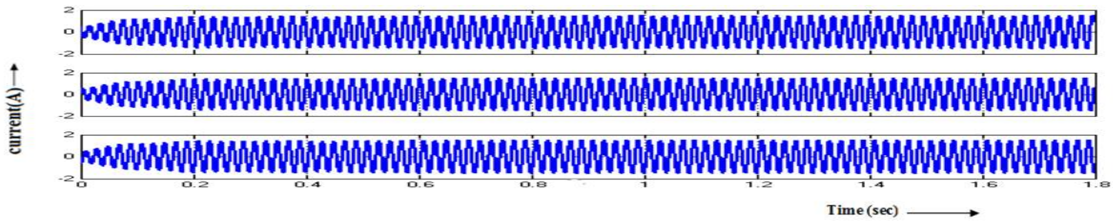

Fig. 16 Output current of grid

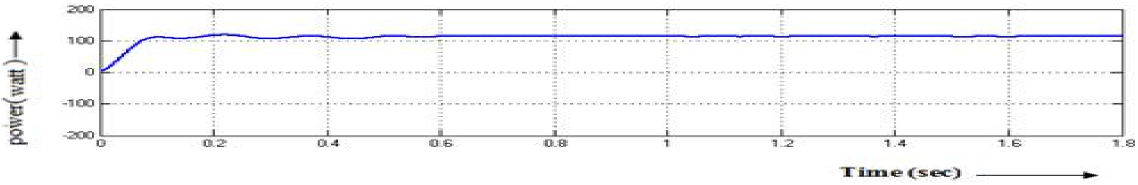

Fig. 17 Real power of grid

The Fig.17 describes about the output voltage of wind and its value is 400V and the wind output voltage consists of ripples and they reduces with the help of PI controller. The Fig.17 describes about the real power of grid and its value is 120W. The Fig.18 describes about the reactive power of grid and its value is 500VAR

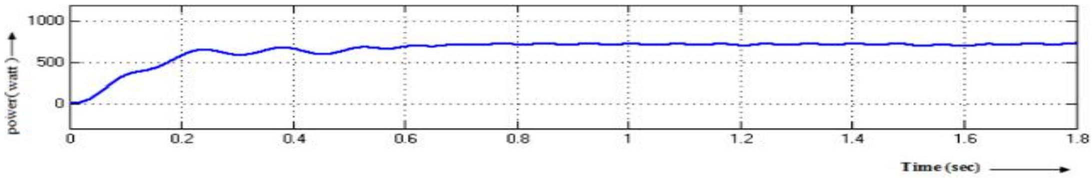

Fig. 18 Reactive power of grid

I. SVM WITH CLOSED LOOP FUZZY CONTROLLER WITH LOAD INCREASE

II.

The Fig.19 describes about the Simulink model of the closed loop wind generator and controller is used in voltage regulation is improved and oscillation are reduced.

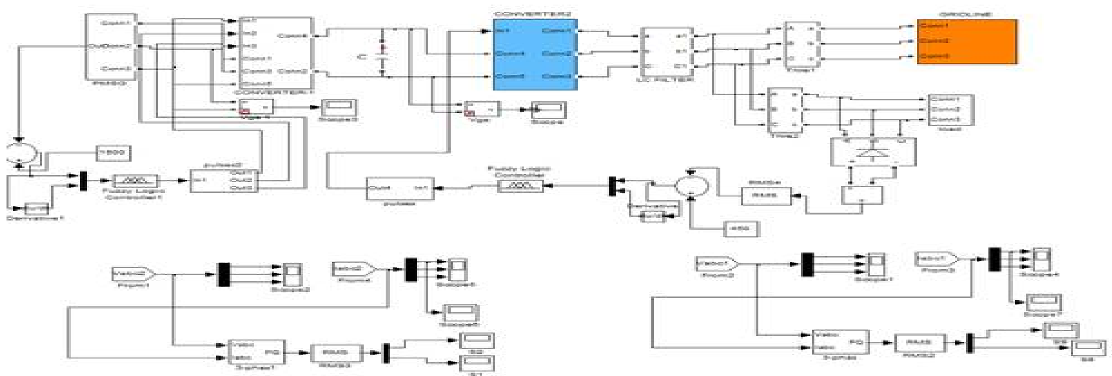

Fig. 19 Simulink diagram closed loop PI controlled wind generator with load increase.

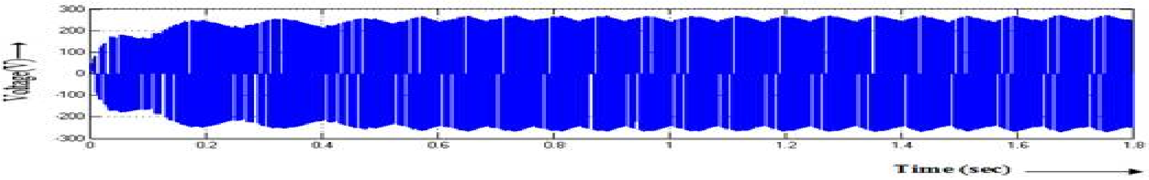

Fig. 20 Output voltage of wind generator

The Fig.20 describes about the output voltage of wind generator is 230V and the wind output voltage consists of fluctuations and they are reduced by Fuzzy controller. The Fig.21 describes about the rotor speed of is 1800rpm and the rotor speed is controlled with the help of Fuzzy controller.

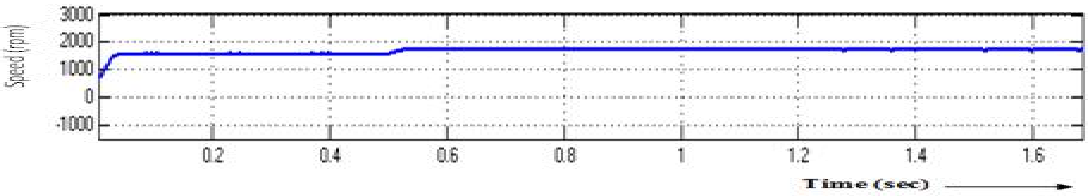

Fig. 21 Rotor speed of wind generator

The Fig.22 describes about the output voltage of converter and its value is 230V and the converter output voltage consists of ripple direct current reduces with the help of Fuzzy controller.

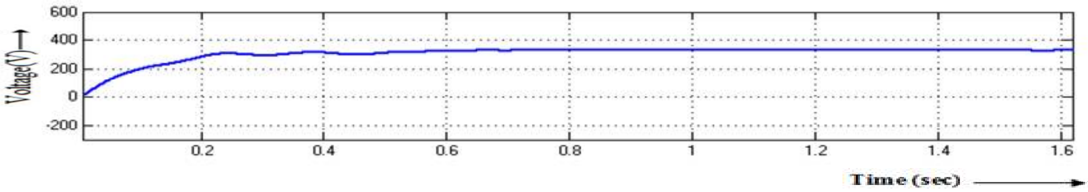

Fig. 22 output voltage of converter

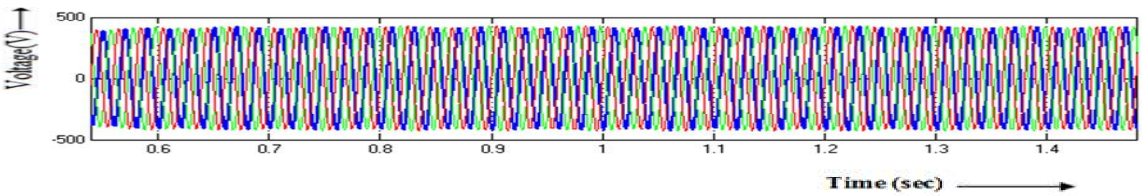

Fig. 23 Output voltage of grid

The Fig.23 describes about the output voltage of wind generator and its value is 400V and the wind output voltage is regulated with the help of Fuzzy controller. The Fig.24 describes about the output current of wind generator and its value is 1.5A and the oscillation are reduced with the help of Fuzzy controller.

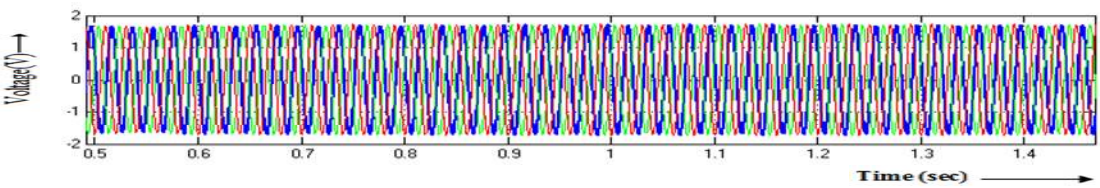

Fig. 24 Output current of grid

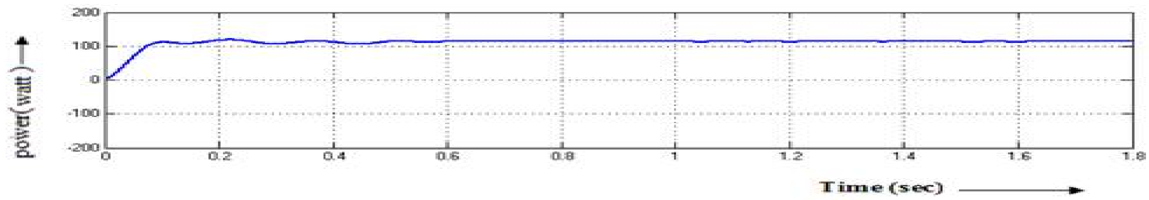

Fig. 25 Real power of grid

The Fig.25 describes about the real power of grid and its value is 120W and the wind output power consists of ripples reduced with the help of Fuzzy controller. The Fig.26 describes about the reactive power of grid and its value is 500VAR.

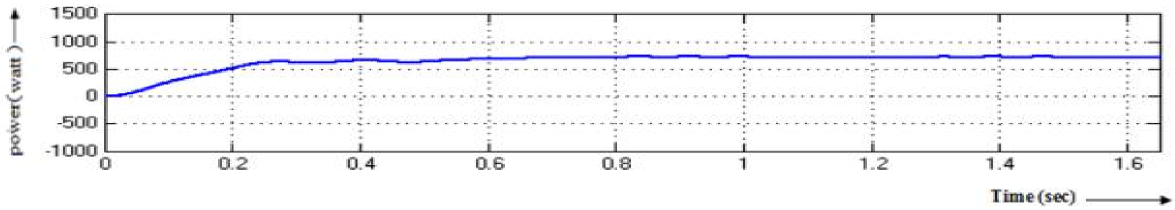

Fig.26 Reactive power of grid

V. CONCLUSION

This project investigates voltage regulation of PMSG-based wind turbines during transient events for enhancing the voltage regulation. PI and Fuzzy for PMSG-based wind turbine is used in voltage regulation The main conclusions drawn from the proposed control method are as follows. Thus, wind turbines equipped with controllers and they reduce the oscillation damping functions and ensuring system stability. Thus, the proposed control control scheme for wind turbines has both voltage regulation with improved system stability.

REFERENCES

[1] N. Miller and P. E. Marken, "Facts on grid friendly wind plants," in *Proc.IEEE Power Energy Soc. Gen. Meeting*, 2010, pp. 1–7.

[2] M. Cardinal and N. Miller, "Grid friendly wind plant controls: Windcontrol-field test results,"in *Proc. Amer. Wind Energy Conf.*, 2006,pp. 1–8.

[3] J. G. Slootweg and W. L. Kling, "The impactof large scale wind power generation on power system oscillations," Electr. Power Syst. Res.,vol. 67, no. 1, pp. 9–20, Feb.2011.

[4] G. Tsourakis, B. M. Nomikos, and C. D. Vournas, "Contribution of doubly fed wind generators to oscillation damping," IEEE Trans. Energy Convers., vol. 24, no. 3, pp. 783–791, Sep. 2009.

[5] R.D.Fernandez R. J. Mantz, and P.E.Battaiotto, "Contribution of wind farms to the network stability," in Proc. IEEE Power Eng. Soc. Gen.Meeting, Jun. 2006.

[6] P. Ledesma and C. Gallardo, "Contribution of Variable-speed wind farms to damping of Power system oscillations," in Proc. IEEE Power Tech.,Lausanne, Switzerland, Jul. 2007, pp. 190–194.

[7] Y. Lei, A. Mullane, G. Lightbody, and R.Yacamini, "Modeling of the wind turbine With a doubly fed induction generator for grid Integration studies," IEEE Trans. Energy Convers. vol. 21, no. 1, pp. 257–264, Mar.2006.

[8] I.Erlich, J. Kretschmann, J. Fortmann, S.Mueller-Engelhardt, and H.Wrede, "Modeling of wind turbines based on doubly-fed induction generators for power system Stability studies," IEEE Trans. Power Syst.,vol. 22, no. 3, pp. 909– 919, Aug. 2007.

[9] P. Kundur, Power Systems Stability and Control. New York, NY, USA:McGraw-Hill, 1994.

[10] A.Mendonc,and J.A.P.Lopes,, "Simultaneous tuning of power system stabilizers installed in DFIG – based wind generation," in *Proc IEEE Power Tech*., Lausanne, Switzerland, July 2007.

[11] F. M. Hughes, O. Anaya-Lara, N. Jenkins, and G. Strbac, "A power system stabilizer for dfig- based wind generation," Power Systems, IEEE Transactions on, vol. 21, no. 2, pp. 763–772, 2006.

[12] M. Q. Duong, F. Grimaccia, S. Leva, M.Mussetta, and K. H. Le, "Improving transient stability in a grid-connected squirrel-cage induction generator wind turbine system using a fuzzy logic controller," Energies, vol. 8, no. 7, pp. 6328–6349, 2015.

[13] S. Abe, "Fuzzy function approximators with ellipsoidal regions," Systems, Man, and Cybernetics, Part B: Cybernetics, IEEE Transactionson, vol. 29, no. 5, pp. 654–661, 1999.

[14] Mohamed Moudjahed and et.al., "Optimal Power flow by IPFC using fuzzy logic Controller", Inter.Journal of Power and Energy System, Vol.34, No.2, pp.63-70, 2014.