THINK INDIA JOURNAL

ISSN:0971-1260
Vol-22- Issue-35-December-2019

Dynamic Performance Enhancement of DFIG Based Wind Power System with PI Controller

[1]Girish Maloth, [2]Dr. J Bhavani, [3]Dr.T.Nireekshana
[1] Post Graduate , [2] Associate Professor ,[3] Associate Professor
[1]Girishmaloth@gmail.com, [2] Bhavani_J@vnrvjiet.in,[3] nireeshana_t@vnrvjiet.in

Abstract— ***Simulation of wind energy conversion systems of doubly fed induction generator to improve the efficiency of the steady state error is identified in this paper. On focusing the steady state condition the active power output of the wind energy conversion system is observed. To reduce the error a proportional integral controller is attached to the system output. The PI constants are taken through trial and error method to limit the steady state error of the active power output. Adding up to it, The behavior of DFIG (i.e; torque, rotor speed, and the other characteristics)are observed under the grid voltage . Simulation of model is carried out in MATLAB Software. Necessary outputs are noted.***

Index Terms— ***Doubly Fed Induction generator (DFIG),Wind Energy Conversion System (WECS), Grid, Active power, Proportional Integral Converter***.

I. INTRODUCTION

There is a rapid growth in the power generator from various renewable resources like wind, solar, biomass, geothermal, and hydro power in recent times [1]. The energy that produced by this generating stations has an advantage of clean energy without harming the environment. By using this resources, there are lot of savings in the economy and the efficiency of the power [1]. Energy can be generated in almost all the remote locations.

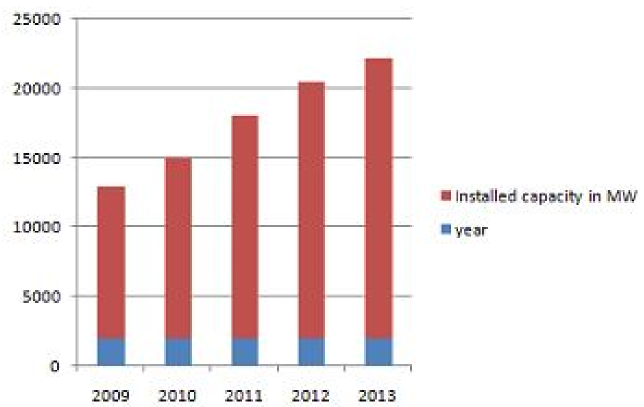


Fig.1. Growth of wind energy system installation in India as per report of GWEC India

In wind energy based system, kinetic energy is used to rotate the rotor of the generator using the gear box [3]. According to the faraday laws of electromagnetic induction an EMF is produced that is connected to the grid through power electronic converter. The available power output [3-4] from a wind turbine is determined by (1).

$P_{tur}=1/2\rho v^3 C_p$ – (1)

Where ρ = density (kg/m^3)

ISSN:0971-1260
Vol-22- Issue-35-December-2019

A = swept area (m^2)
υ = wind speed (m/s)
C_p = power coefficient

The available energy for converting depends on the speed of the wind and the swept area of the wind turbine. Therefore the highest value of the power coefficient is 0.59. It is also called as Betz limit [3]. The coefficient of the power is different to each turbine. The power coefficient lies between 0.35-0.45. The tip speed ratio 'λ' is given by [5-7]

$\lambda = \omega R/\upsilon$ where R is the radius of the rotor and ω is rotor speed. A general functional representation of C_p [3, 7] is given by (2)

$$C_p(\lambda, \theta) = C_1\left(\frac{C_2}{\Lambda} - C_3\theta - C_4\theta^x - C_5\right)e^{-C_6/\Lambda} \quad – (2)$$

Here θ is pitch angle and C_1, C_2, C_3, C_4 , C_5 , C_6 , k are constant and relationship between Λ & θ with tip speed ratio is given by (3)

$$1/\Lambda = 1/(\lambda+0.008\theta)-0.035/(1-\theta^3) \quad – (3)$$

Maximum power extraction curve is plotted with respect to rotor speed [3]. It is also plotted with various wind speeds. The DFIG Generator shows the characteristic for various wind speed level like 5m/s, 12m/s, and 16m/s are shown in this paper. To extract the maximum power from the wind energy conversion system MPPT algorithm is executed [8]. There are numerous types of MPPT algorithm like hill climbing technique, GA (Generic algorithm), Fuzzy based algorithm, Neural network, particle swam optimization (PSO), perturbation optimization (PO), etc [8]. To get the optimum value of rotor speed optimum tip speed ratio is required. Optimum tip speed is obtained from (1) and the corresponding optimum rotor speed gives optimum slip.

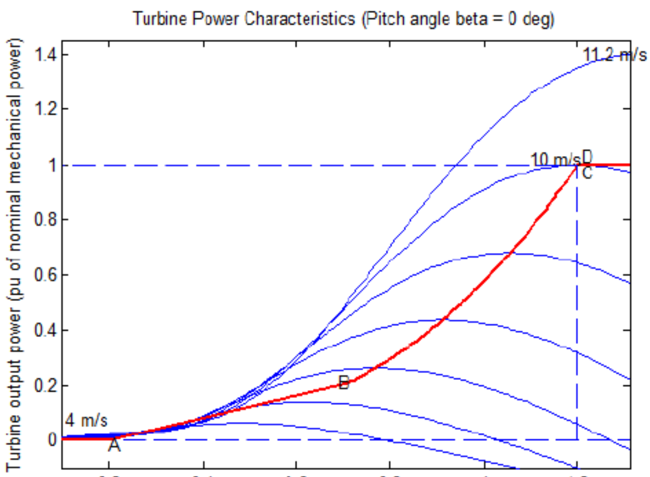
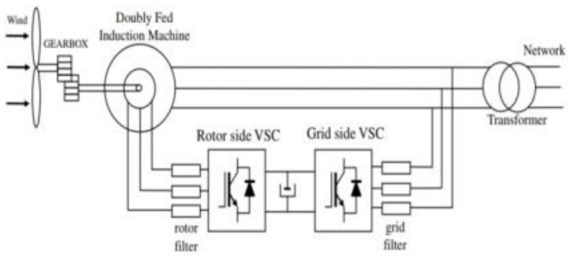


Fig .2 wind turbine power characteristics

II. DFIG SYSTEM MODELLING

Doubly fed Induction Generator is widely used in variable speed drives. The stator directly connected to the grid and the rotor is fed by a bidirectional converter that is also connected to the grid



ISSN:0971-1260
Vol-22- Issue-35-December-2019

Fig .3 Doubly Fed induction generator

Doubly Fed induction machine or wound rotor Induction Generator are common terms that are used to describe a machine. The stator is connected to the grid and the rotor is fed to the power electronic converter which are connected back to back . Coupling capacitor is connected in between back to back power electronic converter. It is used to give constant voltage supply. The converter is controlled by the help of suitable controller with the pulse with modulation technique. With the help of complex vector mathematical model of DFIG can be represented with respect to stator stationary frame [4-10].

Required Equations

$V_s = r_s i_s + d\psi_s/dt$ – (4)

$V_r = r_r i_r + d\psi_r/dt - j\omega_r \psi_r$ –(5)

$\psi_s = L_s i_s + L_m i_r$ – (6)

$\psi_r = L_m i_s + L_r i_r$ – (7)

$T_e = 3/2 * p * Im\{\psi_s i_s\}$ – (8)

$S = P + JQ = 3/2 * i_s V_s$ – (9)

Where
V_s , V_r are stator voltage and rotor voltage

r_s , r_r are stator resistance and rotor resistance

i_s, i_r are stator current and rotor current

ψ_s, ψ_r are stator and rotor flux respectively

L_s, L_r are stator and rotor self inductance

L_m is mutual inductance

ω_r is rotor electrical speed

T_e is electromagnetic torque

P, Q are active and reactive output power

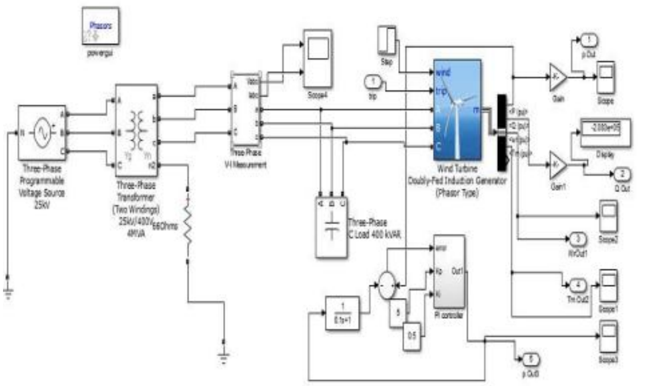
S is defined as complex power

III. MATLAB SIMULINK MODEL & RESULTS

The MATLAB Simulink model of DFIG based wind energy conversion system is shown in figure 4. It shows that Doubly Fed Induction Generator is connected to 25kV grid through a three phase transformer. The capacitor bank provides necessary reactive power to DFIG. The steady state output power is observed and significant steady state error is noticed. The output power is passed through Proportional and Integral controller to find the controller output for various values of k_p and k_i. These are the two constants which are to be randomly taken and through trial and error method, Minimize the steady state error of the active power output.

ISSN:0971-1260
Vol-22- Issue-35-December-2019

Simulink Model



OUTPUT CHARACTERISTICS

The output characteristic of the Simulink Model shows the graphical representation of generated active power output curve. Alongside active output power,a graph of torque versus rotor speed characteristic are also shown. The active power unit is considered as MW .All these plots are taken from Matlab Simulation model before connecting to PI controller.

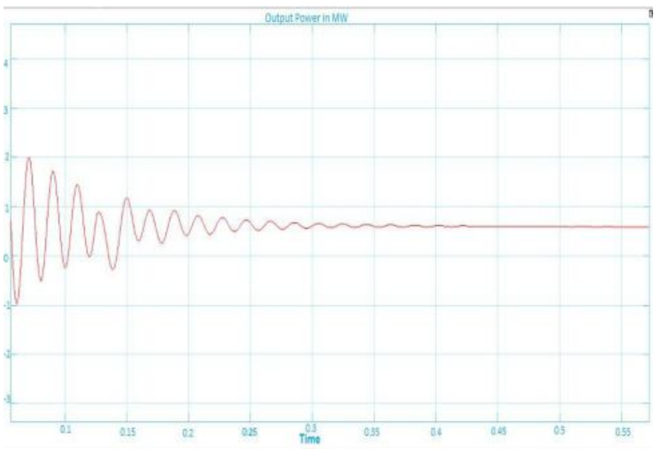


Fig.5 Output power without controller

ISSN:0971-1260
Vol-22- Issue-35-December-2019

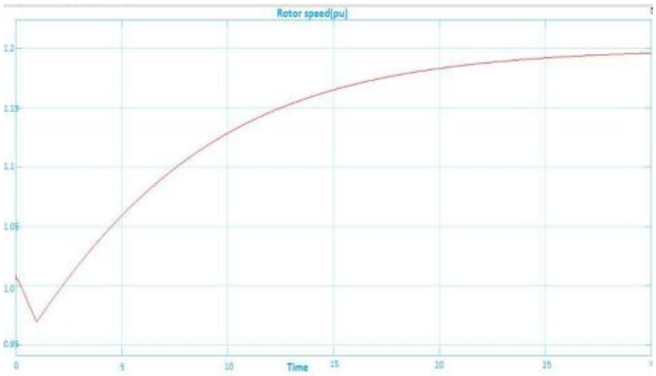


Fig.6 Rotor Speed

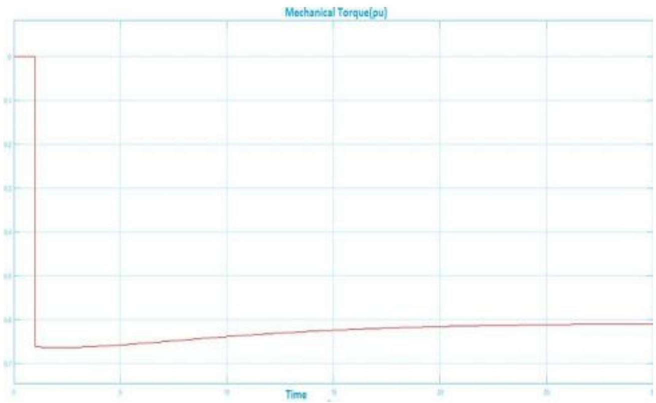


Fig.7 Mechanical Torque

CONTROLLER OUTPUT

The output power which we got is passed through the PI controller. After passing it into PI controller the output is again observed

MATLAB model of PI Controller

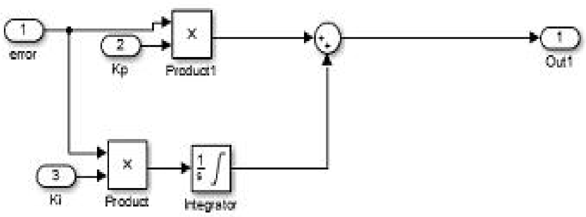


Fig.8 PI controller Simulation model

ISSN:0971-1260
Vol-22- Issue-35-December-2019

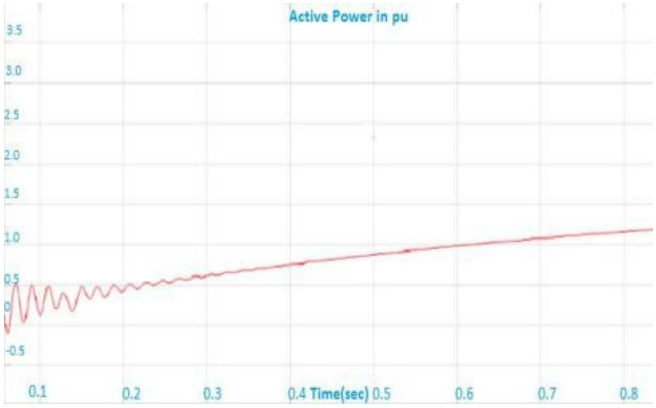


Fig. 9 Controller output for K_P =0.06 and K_I =1

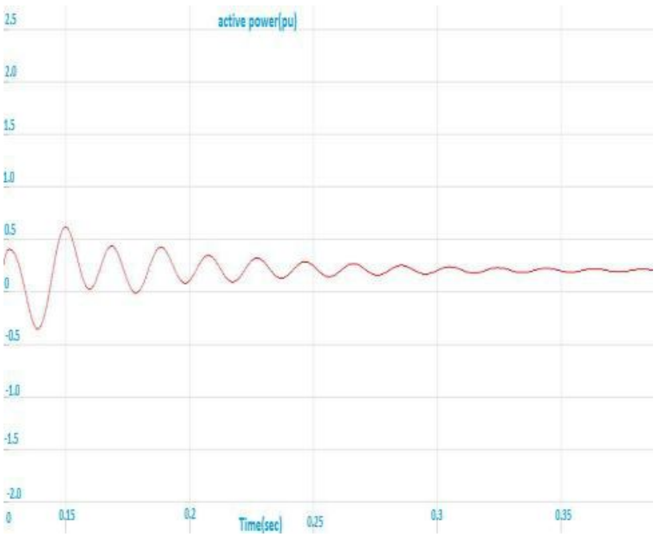


Fig.10 Controller output for K_P = 1, and K_I = 0.06

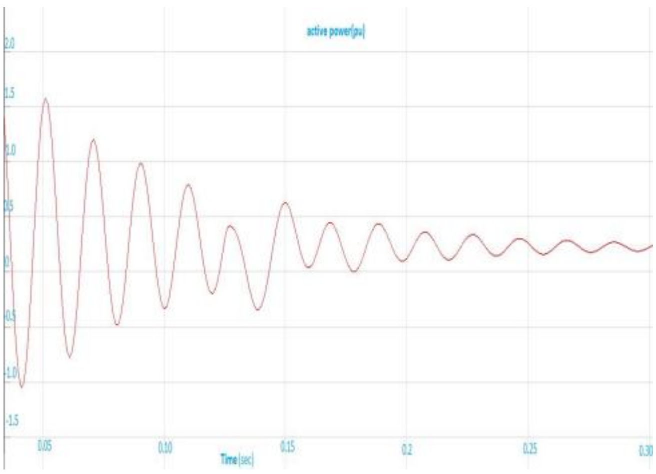


Fig.11 Controller output for K_P = 1 and K_I = 0.6

ISSN:0971-1260
Vol-22- Issue-35-December-2019

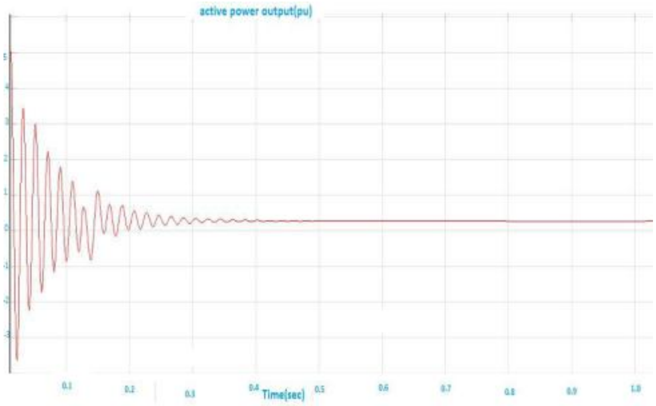


Fig.12 controller output for k_p = 2 and k_i = 0.05

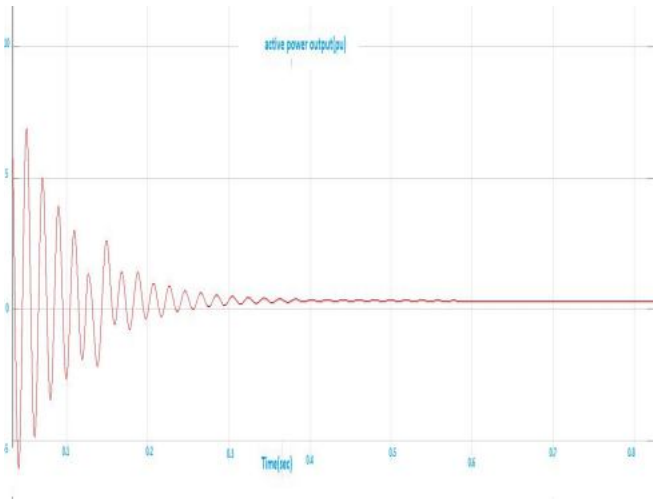


Fig. 13 Controller output for k_p = and k_i = 0.05

IV.RESULTS AND DISCUSSIONS

DFIG based wind energy conversion system has been simulated using the MATLAB Software. The behavior of DFIG under grid voltage is observed . In fig.6 and fig.7 Shows the behavior of mechanical torque and rotor speed. Steady state power output power is observed and in addition to this rotor speed and mechanical torque are shown in graph. Then PI controller is connected to the output power of the generator and controller output is observed for various values of k_p and k_i. The controller will add the system to type by 1 and decreases the steady state error. In the simulation it shows that steady state error is minimum for k_p=5 and k_i= 0.05 which is shown in fig .13. Fig 5 shows power output without PI controller having significant error value from its desired input value. For $k_p = 0.05$ and k_i= 1 it shows high error. For $k_p = 1$ and k_i= 0.06 fig. 10 the error is minimized with respect to fig 9. Fig 11 shows no significant changes with respect to fig 10 for $k_p = 1$ and k_i= 0.6 but to fig 12 fro k_p = 2 and k_i= 0.05 shows more change in respect of error reduction improvement. But for $k_p = 5$ and $k_i = 0.05$ we got almost 0% steady state error shown in fig 13. The tabular form shows the comparison of various constant values. The values of k_p and k_i are taken through trial and error method and corresponding waveform of controller output is observed. Different ranges of k_p and k_i are shown in order to get minimum range of values which give steady state error. On increasing the value of proportional constant

ISSN:0971-1260
Vol-22- Issue-35-December-2019

power output value also increases. From fig 13 we observe that the steady state error after connecting to PI controller is close to zero but power increases significantly. Therefore PI controller improves the performance of steady state error.

TABLE .1

Fig no	*PI Controller*	*Steady state Error(pu)*
5	Without Controller	0.8
9	kp=0.06 & ki=1	>1
10	*kp=1 & ki=0.06*	<0.5
11	*kp=1 & ki=0.6*	<0.4
12	*kp=2 & ki=0.05*	<0.35
13	*kp=5 & ki=0.05*	<0.2

CONCLUSION

The steady state analysis of power system has become more important now a days due various factors like machine parameters, inertia, inherent nonlinear characteristic of machine etc causes changes in output of the system when response approaches the final value and this error is known as steady state error . It depends on type of input as well as the system type. The controller which was used here enables us to decrease the steady state error. Fine adjustment of constant values gives better results in coming work.

APPENDIX

Generator Parameter

The three phase programmable 25kV voltage source has been considered as grid. HV side of 25kV/400V transformer is yg connected, whereas LV side yn connected.400KVar capacitive load is connected to the stator of generator to meet the sufficient reactive power demand. Generator stator resistance is taken as 0.0044 P.U and stator Self Inductance is 0.119 P.U and 0.1699 P.U respectively. Magnetizing inductance is taken as 7 P.U and 6 Poles are taken. Expected wind turbine mechanical output is taken as 1.5 MW. Wind speed is taken as 12m/s. Pitch angle is 45 deg. Converter max power is 0.5 P.U. Nominal dc bus voltage is 1200 V and dc bus capacitor is 10000µF.

TABLE.2

Name	Particulars	Value
Transfer Function (Negative feedback)	Numerator coefficient	[1]
Transfer Function (Negative feedback)	Denominator coefficient	[0.1 1]
Constant block	Positive input to summation block	1
Integrator	Upper saturation Limit	+10
Integrator	Lower saturation limit	+10

ISSN:0971-1260
Vol-22- Issue-35-December-2019

REFERENCES

[1] P. V. Babu, S. Singh and S. P. Singh, "Distributed generators allocation in distribution system," 2017 IEEE Power *&* Energy Society General Meeti ng, Chicago, IL, pp. 1-5, 2017

[2] Sangroya, Deepak, and Jogendra Kumar Nayak. "Development of Wind Energy in India." International Journal of Renewable Energy Research *(* IJRER*)* 5.1 (2015): pp.1-13, 2015

[3] S. G. Bharathi Dasan, Sharon Ravichandran Kamesh and R. P. Kumudini Devi, "Steady-state analysis of Grid connected WECS using FACTS cont roller," 2011 International Conference on Emerging Trends in Electrical and Computer Technology, Nagercoil, pp. 127-132, 2011

[4] S. Dileep Kumar Varma and N. V. Annapurna Bhavani, "Power quality improvement in standalone battery integrated wind energy system," 2016 International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES*)*, Paralakhemundi, pp. 642-647, 2016

[5] D. R. Chandra et al., "Impact of SCIG, DFIG wind power plant on IEEE 14 bus system with small signal stability assessment," 2014 Eighteenth Nat ional Power Systems Conference *(*NPSC*)*, Guwahati, pp. 1-6, 2014

[6] S. P. Uma and S. Manikandan, "Control technique for variable speed wind turbine using PI controller," 2013 IEEE International Conference ON E merging Trends in Computing, Communication and Nanotechnology *(*ICECCN*)*, Tirunelveli, pp. 640-643, 2013

[7] Behera, Sasmita & Subudhi, B & Pati, B.B. "Design of PI controller in pitch control of wind turbine: A comparison of PSO and PS algorithm," Inte rnational Journal of Renewable Energy Research *(*IJRER*)* 6.(2016) pp.271-281, 2016

[8] S. Mishra, S. Shukla, N. Verma and Ritu, "Comprehensive review on Maximum Power Point Tracking techniques: Wind Energy," 2015 Communic ation, Control and Intelligent Systems *(*CCIS*)*, Mathura, pp.464-469, 2015

[9] M. B. Mohamed, M. Jemli, M. Gossa and K. Jemli, "Doubly fed induction generator (DFIG) in wind turbine modeling and power flow control," Ind ustrial Technology, 2004. IEEE ICIT '04. 2004 IEEE International Conference, Vol.2,pp.580-584, 2004

[10]Y. K. Wu, W. H. Shu, H. Y. Cheng, G. T. Ye and D. C. Jiang, "Mathem atical modelling and simulation of the DFIG-based wind turbine," 2014 CACS International Automatic Control Conference *(*CACS2014*)*,Kaohsiung, pp.5 7-62, 2014