MODELING AND SIMULATION STUDY OF PERMANENT MAGNET SYNCHRONOUS GENERATOR BASED WIND TURBINE SYSTEM IN MICRO-GRID APPLICATION

Nagendra K[1], N Krishnamurthy[2], Raghu N[1], Sowjanyareddy[3], Sai Mahesh[3]

[1] *Research Scholar,* [2] *Professor,* [3]*UG Student,*
[1, 2, 3] *Department of Electrical & Electronics Engineering, School of Engineering & Technology, Jain University, Bangalore*

ABSTRACT

This paper presents modeling and simulation study of permanent magnet synchronous generator (PMSG) based wind turbine generator system (WTGS) in micro-grid application. PMSG gives more efficiency, less maintenance and can be used without gear box. It is suitable for variable wind speed application. Wind turbine, PMSG and power electronic circuits are modeled by using MATLAB/Simulink interface for micro-grid application.

Keyword: - *Wind turbine, PMSG, Boost converter, Battery bank, Inverter and micro-grid.*

1. INTRODUCTION

The utilization of wind energy has a very long tradition. Some historians suggest that wind turbines (windmills) were known over 3000 years ago [1]. Earlier days the wind power was utilizing to pump water and to grind grains. The first wind turbines for electricity generation had been developed at the end of the 19th century. Later they are implemented from generation of few kW to few MW ranges [8]. Due to depletion in fossil fuels, the research effort has made towards sustainable energy development. Solar and wind energy renewable resources are major sustainable electrical energy sources available. Wind energy is abundant in nature and it is one of the best technologies today as sustainable energy sources. During initial days the WTGS were more costly. Due to technology advancement in power electronics area and bulk production of WTGS the cost has come down enormously. The wind energy systems can be operated in grid connected mode or isolated mode (micro-grids). For higher generation level, we go for grid connected and for regional applications nowadays we use micro-grids.
Fig -1 shows a model of MG with four feeders, named A, B, C and D. The point of common coupling (PCC) is used to interconnect all feeders of energy sources and circuit breakers are used to isolate the faulty circuits [7].

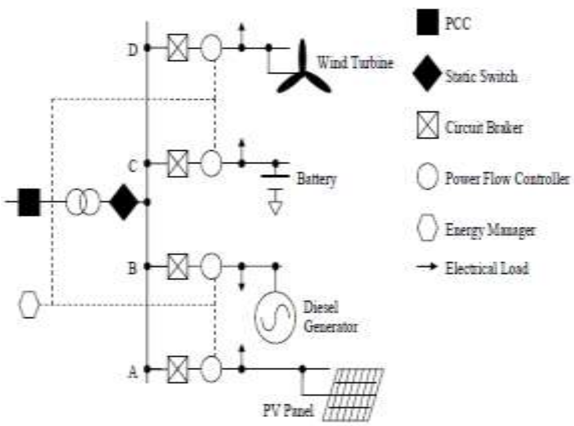


Fig -1: Generalized block diagram of micro-grid (MG)

2. MODELING OF PMSG BASED WTGS

2.1 Block diagram and simulated diagram

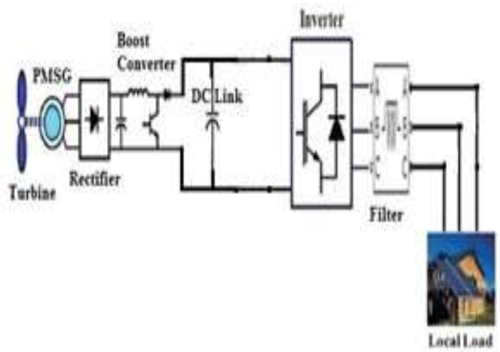


Fig -2: Block diagram of PMSG based WTGS

Fig -2 shows Block diagram of PMSG based stand alone system. Here it consists of DC shunted system with single inverter to feed local load. Inverter is fed from regulated DC input which is generated from renewable or nonrenewable energy sources.

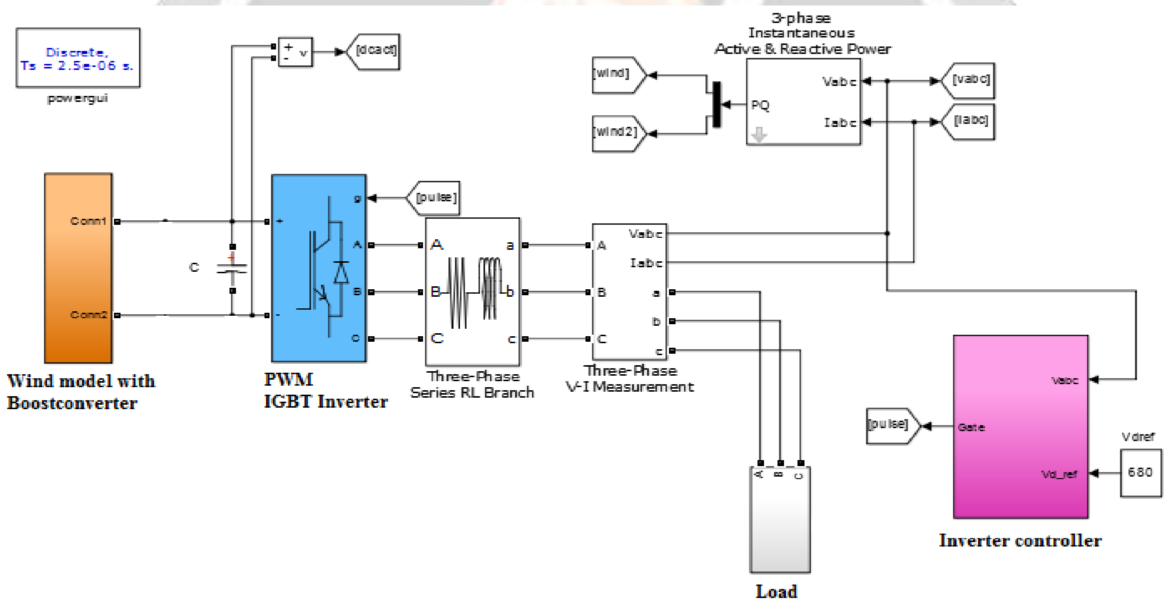


Fig –3: Simulation diagram of PMSG based WTGS

Fig –3 shows the simulation diagram of PMSG based WTGS which is simulated using MATLAB/Simulink.

2.2 Wind turbine (WT)

It converts wind energy to mechanical energy by means of a torque applied to a drive train [3] & [4]. A model of the WT is necessary to evaluate the torque and power production for a given wind speed and the effect of wind speed variations on the produced torque. The torque T and power Pm produced by the WT within the interval [V_{min}, V_{max}], where V_{min} is minimum wind speed and V_{max} is maximum wind speed, are functions of the WT blade radius R, air pressure, wind speed and coefficients C_q and C_p [1].

$$P_m = C_p(\lambda, \beta)\frac{\rho A}{2}{V_{wind}}^3 \qquad (2.1)$$

C_P is known as the power coefficient and characterizes the ability of the WT to extract energy from the wind. C_q is the torque coefficient and is related to C_P according to:

$$C_q = \frac{C_p}{\lambda} \tag{2.2}$$

$$T = \frac{P_m}{\omega} = \frac{1}{2}\rho\prod R^3 C_q(\lambda,\beta){V_{wind}}^2 \tag{2.3}$$

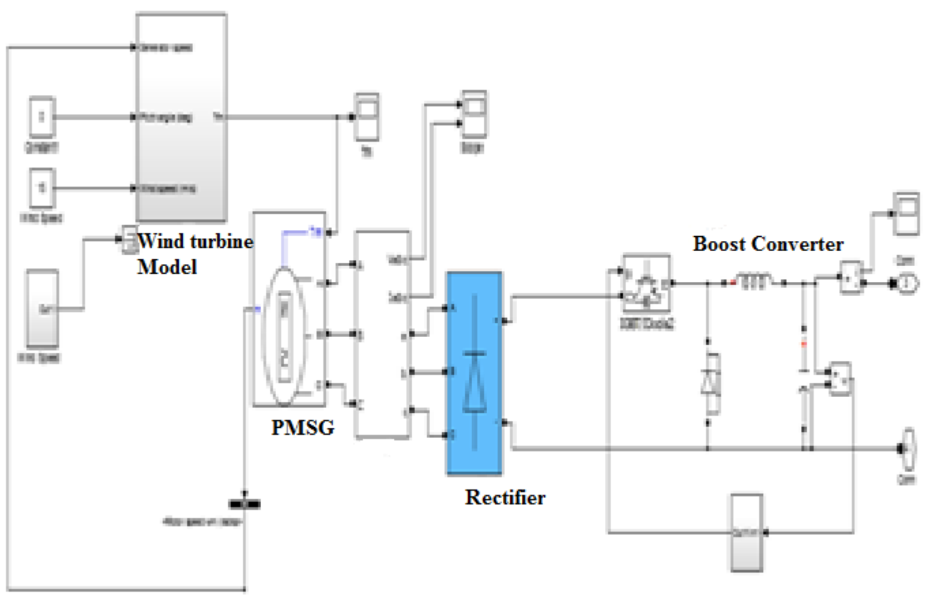
$$\lambda = \frac{R * \omega}{V_{wind}} \tag{2.4}$$

The performance coefficient $C_p(\lambda, \beta)$, which depends on tip speed ratio λ and blade pitch angle β, determines how much of the wind kinetic energy can be captured by the wind turbine system. A nonlinear model describes $C_p(\lambda, \beta)$ as:

$$C_p(\lambda,\beta) = C_1\left(\frac{C_2}{\lambda_i} - C_3\beta + C_4\right)e^{\frac{-C_5}{\lambda_i}} + C_6 \tag{2.5}$$

Where, C_1=0.5176, C_2=116, C_3=0.4, C_4=5, C_5=21and C_6=0.0068

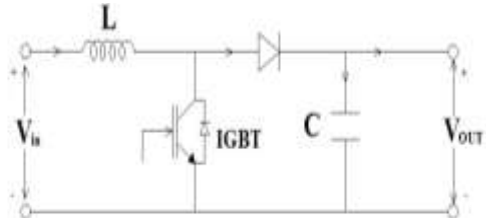
$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \tag{2.6}$$



1) Fig –4: ***Wind turbine model with PMSG, rectifier and boost converter***

2) *2.3 DC/DC boost converter*

3) ***DC/DC converters are widely used in regulated switch mode DC power supplies. The input of these converters is an unregulated DC voltage, which is obtained by wind and PV arrays. In this case the average DC output voltage must be controlled by DC/DC boost converter. DC/DC boost converter needs four external components: Inductor, Electronic switch, Diode and output capacitor. The block diagram of boost converter is shown in Fig -5.***



4) *Fig -5:* ***Block diagram of DC/DC boost converter***

A boost converter is connected in between RES and DC link as shown in Fig -5 The gate pulse of IGBT switch is controlled by Proportional integral (PI) controller [5].

2.4 Design LC Filter

The waveform quality of the sensitive load is improved by putting an LC filter at the output of the pulse width modulation (PWM) inverter.

According to thumb rule of control theory the frequencies of LC filter configuration have at least multiples of 10 between fundamental, resonance and switching frequencies to decouple the effects. According to this rule, for 50 Hz fundamental frequency, resonance frequency has to be at least 500 Hz, switching frequency of the inverter has to be at least 5000 Hz [6]. The resonance frequency is given by,

$$\omega_r = \frac{1}{\sqrt{L_f * C_f}} \qquad (2.11)$$

Where,

ω_r = Resonance frequency.

L_f = Filter inductance.

C_f= Filter capacitance.

3. RESULTS AND DISCUSSION

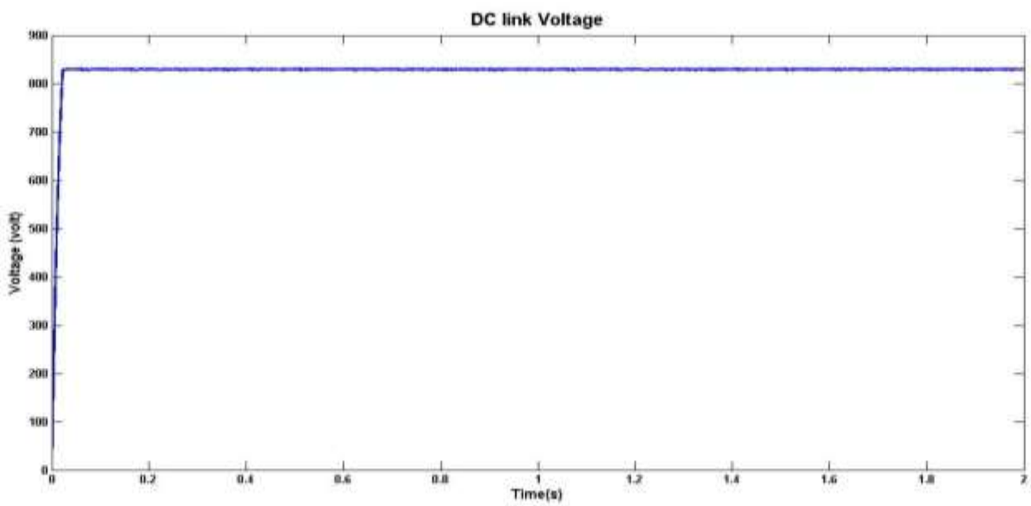


Fig -6: DC Link Voltage

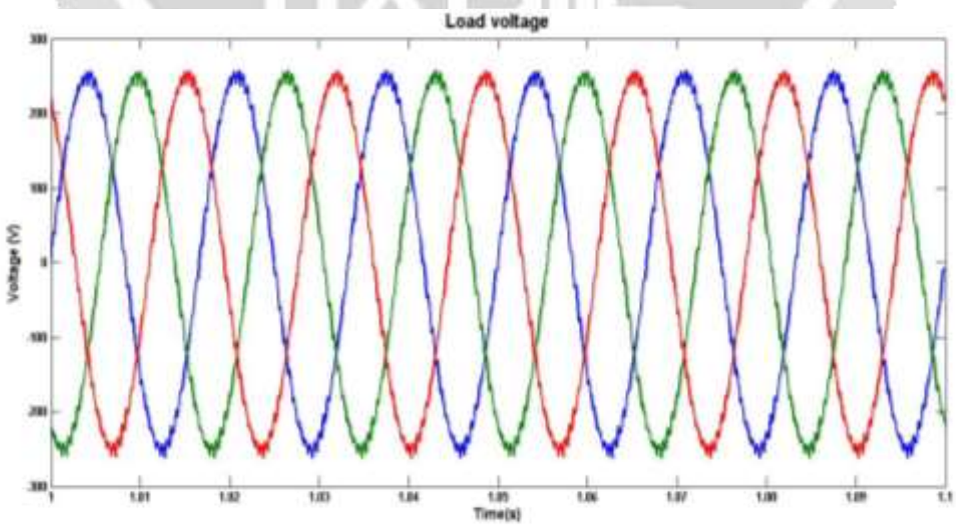


Fig -7: AC Load side Voltage

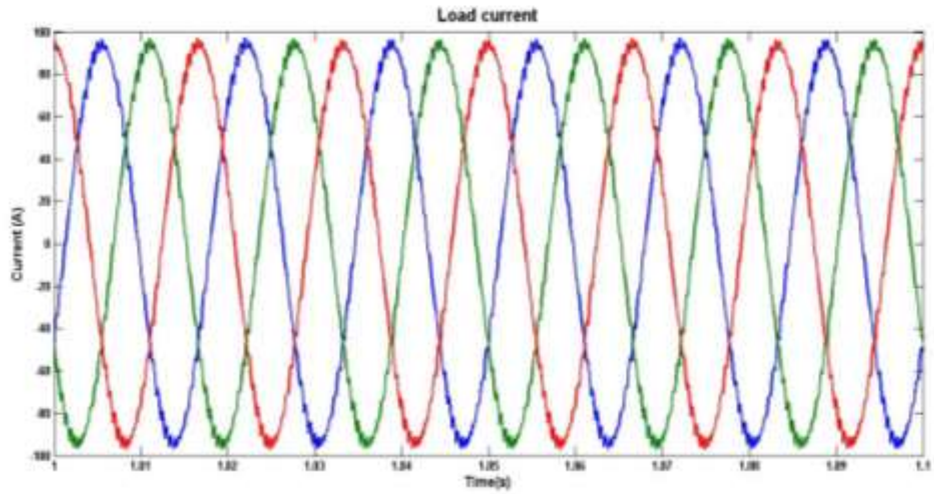


Fig -8: AC Load side current

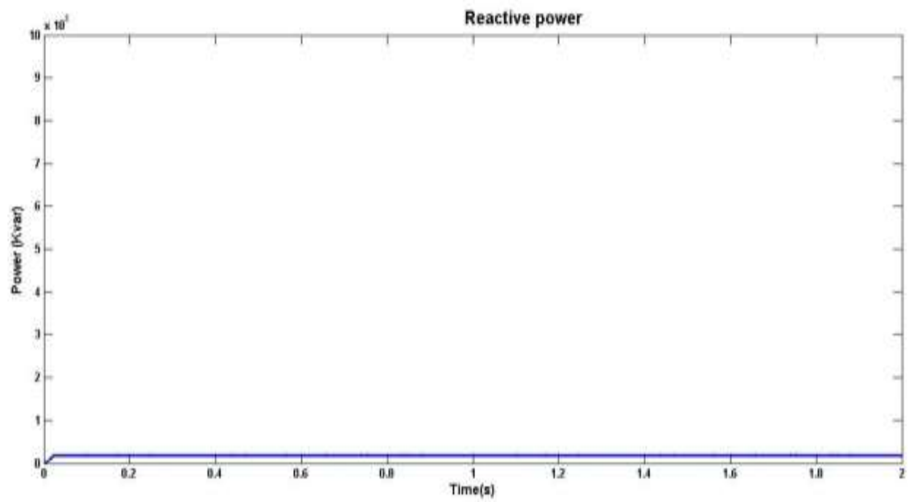


Fig -9: Reactive power

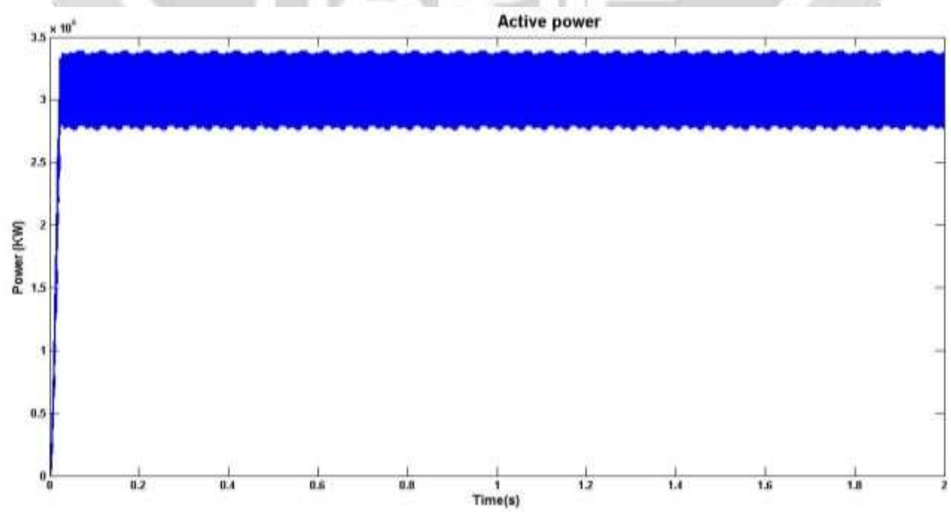


Fig -10: Active power

Fig -6 shows the DC Link Voltage, DC voltage is constant and the ripple is within the limit at DC link output, Fig -7 shows load voltage, Fig -8 shows load current, Fig -9 shows generated reactive power and Fig -10 shows average 3kW generated active power. The generated power from wind turbine can be utilized either directly connecting to loads or storing to battery then feed to the load. The power management control is used to manage the generated power from WTGS to local loads.

4. CONCLUSION

The PMSG based WTGS for MG application has been modeled in order to analyze its behavior of the system. The model is based on wind turbine, PMSG, uncontrolled rectifier and VSI used for micro-grid operation. The VSI plays an important role because it acts as interface and fixes the AC voltage amplitude and frequency of the signal into the MG. PV control strategy is used to control VSI. In this particular case, simulations results show that using a VSI and classical control strategies (PV control) [7], it is possible to have a good control in MG operation. The present work is a first step to study MG behavior.

5. REFERENCES

[1]. Alejandro Rolan, Alvaro Luna, Gerardo Vazquez and Gustavo Azevedo, “Modeling of a Variable Speed Wind Turbine with a Permanent Magnet Synchronous Generator”, IEEE International Symposium on Industrial Electronics, 2009.

[2]. B. M Hasaneen and Adel A. Elbaset Mohammed, “Design and Simulation of DC/DC Boost Converter”, IEEE, 2008.

[3]. Chen Wang, Liming Wang, Libao Shi and Yixin Ni, “A Survey on Wind Power Technologies in Power Systems”, IEEE, 2007.

[4]. Jitendra Kasera, Ankit Chaplot and Jai Kumar Maherchandani, “Modeling and Simulation of Wind-PV Hybrid Power System using Matlab/Simulink”, IEEE Students’ Conference on Electrical, Electronics and Computer Science, 2012.

[5]. Kiam Heong Ang, Gregory Chong and Yun Li, “PID Control System Analysis, Design, and Technology”, IEEE Transactions on Control Systems Technology, vol. 13, no. 4, 2005.

[6]. Mehmet Tumay K.Çagatay Bayindir Mehmet Ugraş Cuma and Ahmet Teke, “Experimental Setup for a DSP Based Single-Phase PWM Inverter” IEEE, 2004.

[7]. Vechiu, A. Llaria, O. Curea and H. Camblong, “Control of Power Converters for Microgrids”, MONACO, 2009.

[8]. Z. Lubosny, “Wind Turbine Operation in Electric Power Systems”, Springer, 2003.