IJCTA, 9(33), 2016, pp. 197-204

MPPT for PMSG Based Standalone Wind Energy Conversion System (WECS)

R. Geetha* K. Suresh kumar G. Angala Parameswari*** and R. Santhiya******

Abstract : This paper describes the control scheme to extract the maximum power from PMSG based wind energy conversion system (WECS) using Maximum Power Point Tracking Algorithm (MPPT) in which boost converter is used to handle wide range of wind speeds. The model of wind conversion system is built and simulated by MATLAB/SIMULINK software. The control scheme for standalone system includes pitch control to ensure wind turbine within rated limits. A Boost converter is incorporated to control the charging and discharging rate of the battery.

Keywords : Boost converter, Permanent Magnet Synchronous Generator(PMSG), Maximum Power Point Tracking algorithm(MPPT),Pitch control, Wind energy conversion system (WECS).

1. INTRODUCTION

Renewable energy sources are more attractive due to high flexibility of the micro grid and easy combination [1],[2]. When compared to renewable energy sources wind energy is clean and readily available and free from fuel cost. The small-sized wind turbine system coupled with battery bank as the energy storage element is common and essential for providing stable and reliable electricity for the rural and to the remote areas[3]–[6]. The power output of WECS depends on wind flow which is erratic in nature. In order to ensure the regulated voltage, WECS are integrated with power converters [7]. Permanent magnet synchronous generators (PMSG) are widely used in small power wind systems. Due to its high power density it is used in low power wind energy applications. The major benefit of using PMSG is the property of self excitation, which permits an operation at a high power factor and high efficiency. Due to the variability of wind speed the generated power is fluctuating and it can store the excess of energy generated from the wind when the generated power is greater than the required load power and then it supplied to the load when there is demand in load power [8-10].In order to ensure the continuous supply of power to load, WECS needs to have an energy storage system[11]. The excitation current is not necessary because of that the diode rectifier used at the generator terminals. The major concept used in this paper is PMSG linked by a diode rectifier and a boost converter to the DC link for small and medium power ranges [12-14].

Various MPPT algorithms are available. Several MPPT algorithms for small wind turbine are carried out in [15] and [16]. As the wind speed exceeds its rated value, the wind turbine power and the speed needs to be regulated to ensure the electrical and mechanical safety [17]. This can be achieved by changing the pitch angle and for this purpose pitch angle control is employed [18]. This paper deals with the extraction of maximum power from the wind by implementing Maximum power point tracking and the control is provided by pitch control technique.

* Department of EEE, Velammal Engineering College, geethabhargav@gmail.com, angala_ gj@yahoo.co.in, sureshbarath@gmail.com, santhiya22@gmail.com.

2. MODELING OF WIND CONVERSION SYSTEM

A. Proposed Conversion System

The proposed system for wind conversion is shown in Fig 1. The circuit topology for proposed standalone wind energy system consists of permanent magnet synchronous generator (PMSG), which is driven by the wind turbine, an ac/dc converter which consists of diode bridge rectifier and boost converter for tracking the maximum power. Finally it is connected to the resistive load through LC filter. The following system is proposed to supply the standalone load where it is difficult to provide the stable and reliable electricity to remote areas. Turbine and the drive train consist of shaft which is coupled to the generator whose purpose is to generate the mechanical torque which is given as input to the wound rotor induction generator. The ac output generated from the PMSG is converted in to constant dc by passing it through the rectifier unit and the boost converter unit. MPPT block consist of the maximum power point tracking algorithm which is used to extract the maximum power from the wind.

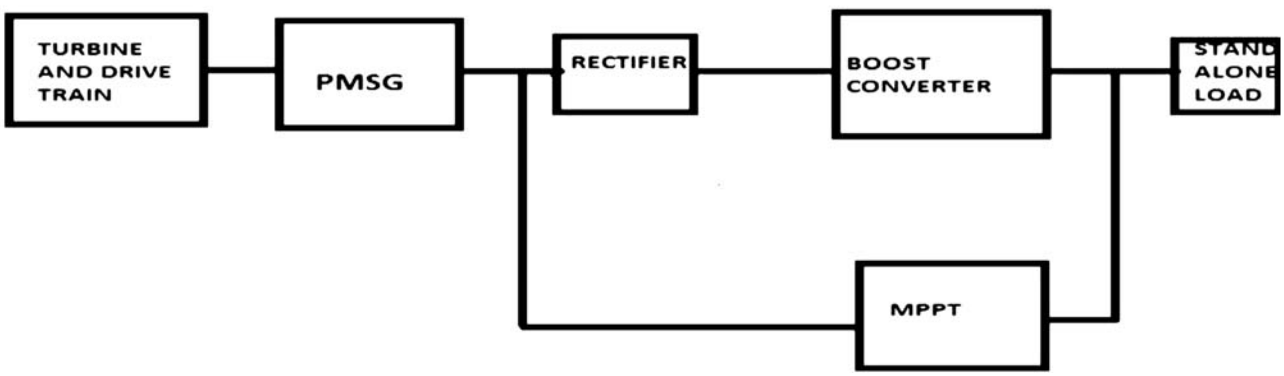

Figure 1: Proposed Wind Energy Conversion System

The turbine power characteristics are shown below in Fig 2. From the Fig max power at the base wind speed is 0.7 pu of nominal mechanical power and the turbine speed is 1 pu of nominal generator speed.

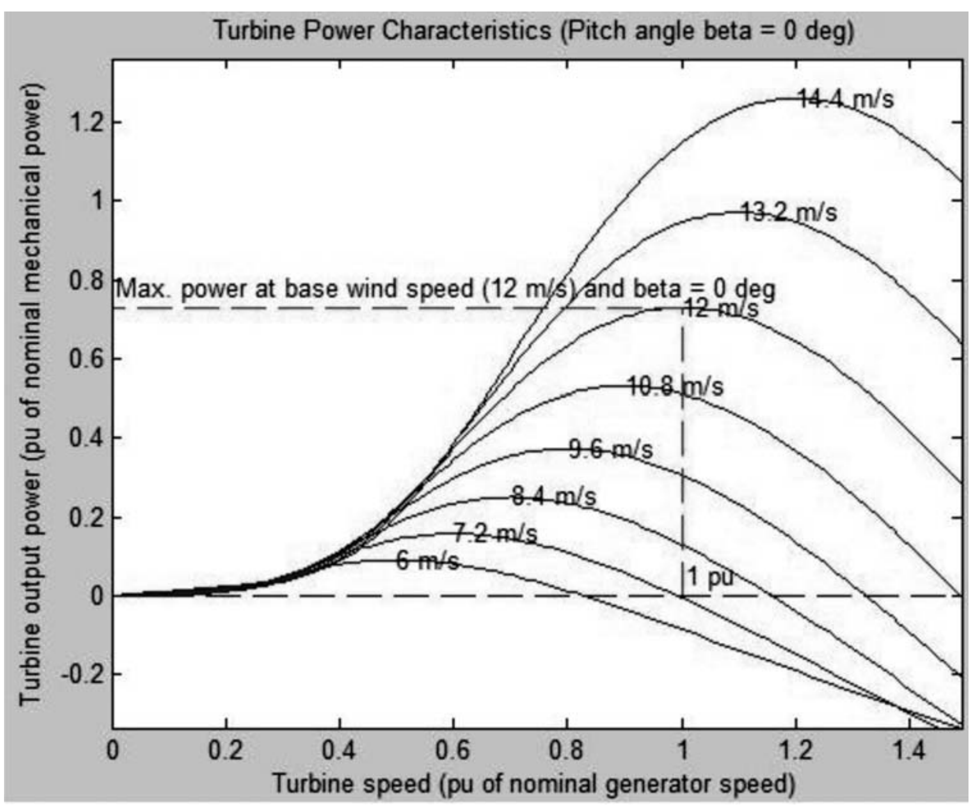

Figure 2: Wind Turbine Power Characteristics

B. Permanent Magnet Synchronous Generator

The wind turbine modeled using permanent magnet synchronous generator (PMSG) consists of a wound rotor induction generator, pitch angle controller, turbine and wind The overall block diagram of PMSG based wind energy conversion system is shown in Fig 3. Pitch angle control is the mechanical method of controlling the blade angle of the wind turbine. If the wind turbine is allowed to operate over the entire range of wind speed without implementation of any control mechanism, the angular speed of the shaft exceeds its rated value and leads to damage the blades. So it is essential to control the speed of the turbine when wind speed exceeds the rated wind speed. The minimum value of limiter is set to 0° and the maximum value for this simulation is 50°. The pitch control generates the command to control the speed which in turn controls the turbine speed.

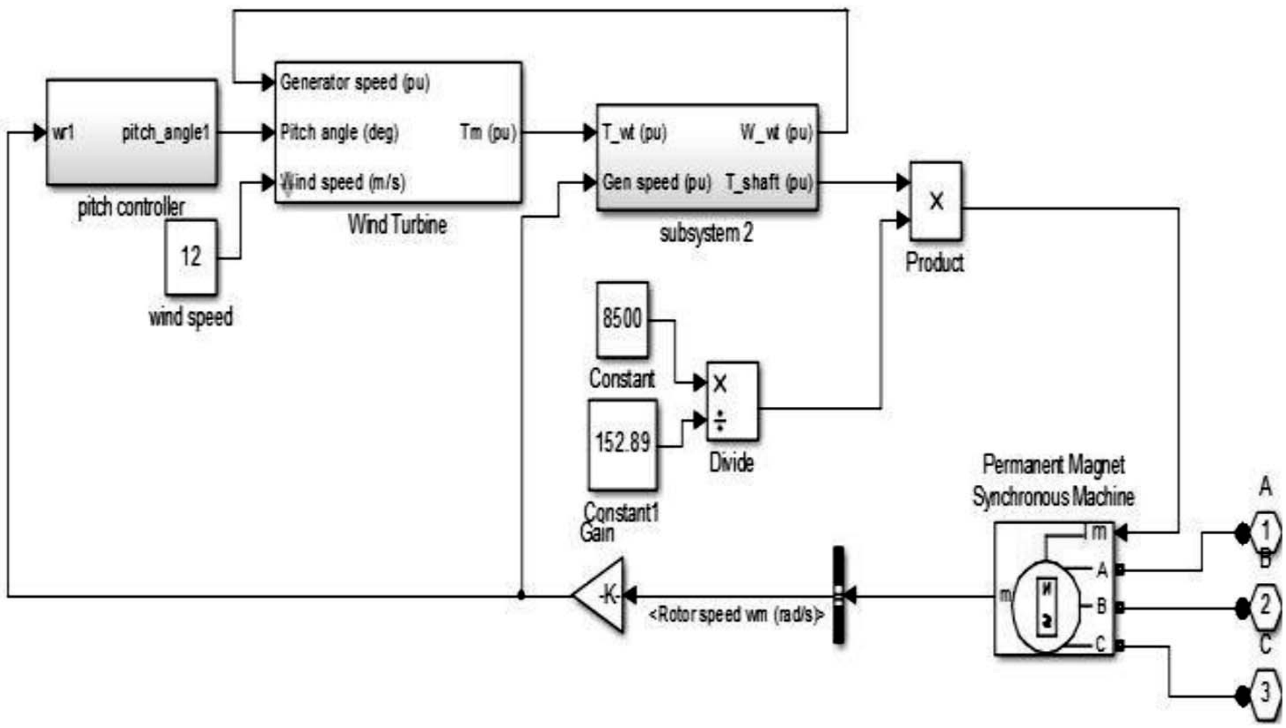

Figure 3: Simulink Model of Permanent Magnet Sunchronous Generator

3. Implementation of Matlab/Simulink

In this chapter various components of wind conversion system like PMSG, boost converter and MPPT and their control is implemented in MATLAB/SIMULINK environment.

Table 1

WT System Specifications

Parameters	*Value*
Rated power	5000W
Cut-in- wind speed	8m/s
Rated wind speed	12m/s
Inertia co-efficient	7kgm^2
Optimum power co-efficient	0.46

Table 2

Permanent Magnet Synchronous Generator Parameters

Parameters	***Value***
Rated Power (P_{rated})	2.5 kW
Rated voltage (V_peak L-1/krpm)	0.575 kV
Armature inductance (H)	0.000835
Flux linkage established by magnets (V.s)	1.3783
Torque Constant (N/m/Krmp)	4
Inertia J(kg./m^2)	0.0062

Table 3

Permanent Magnet Synchronous Generator Parameters

Parameters	***Value***
Capacitance of boost converter	1000µF
Inductance of boos converter	420mH

A. Maximum power point tracking

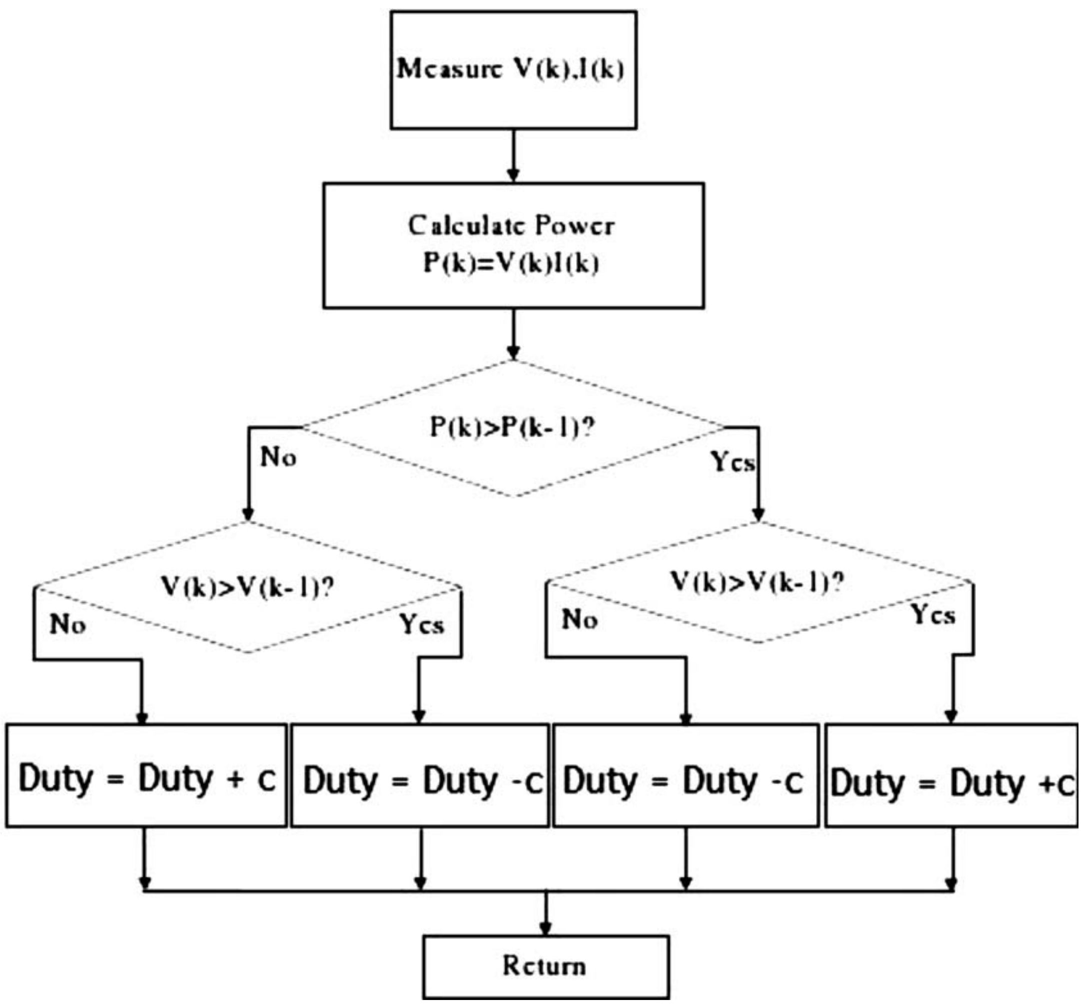

Figure 4: Flow Chart for Perturb and Observe

In the MPPT operation mode, the speed of the turbine is adjusted in such a way that the wind turbine can capture the maximum power based on the given wind speed. At the rated wind speed, the controller attempts to maintain the generator speed and the output power at its rated value by means of machine side converter control. The most commonly used MPPT algorithm is P&O. This algorithm uses a simple feedback arrangement and measures the voltage and current boost converter. These two signals are the inputs to MPPT controller, which generates the duty signal and the speed signal for maximum power extraction. The output of the converter is periodically perturbed and the corresponding output power is compared with the previous output. The change in power correspondingly generates the duty cycle. The major purpose of using MPPT is to generate the required duty cycle and this duty cycle is given as input to the DC-DC boost converter. The flow charts for the proposed perturb and observe algorithm is shown in Fig 4.

4. RESULTS AND DISCUSSION

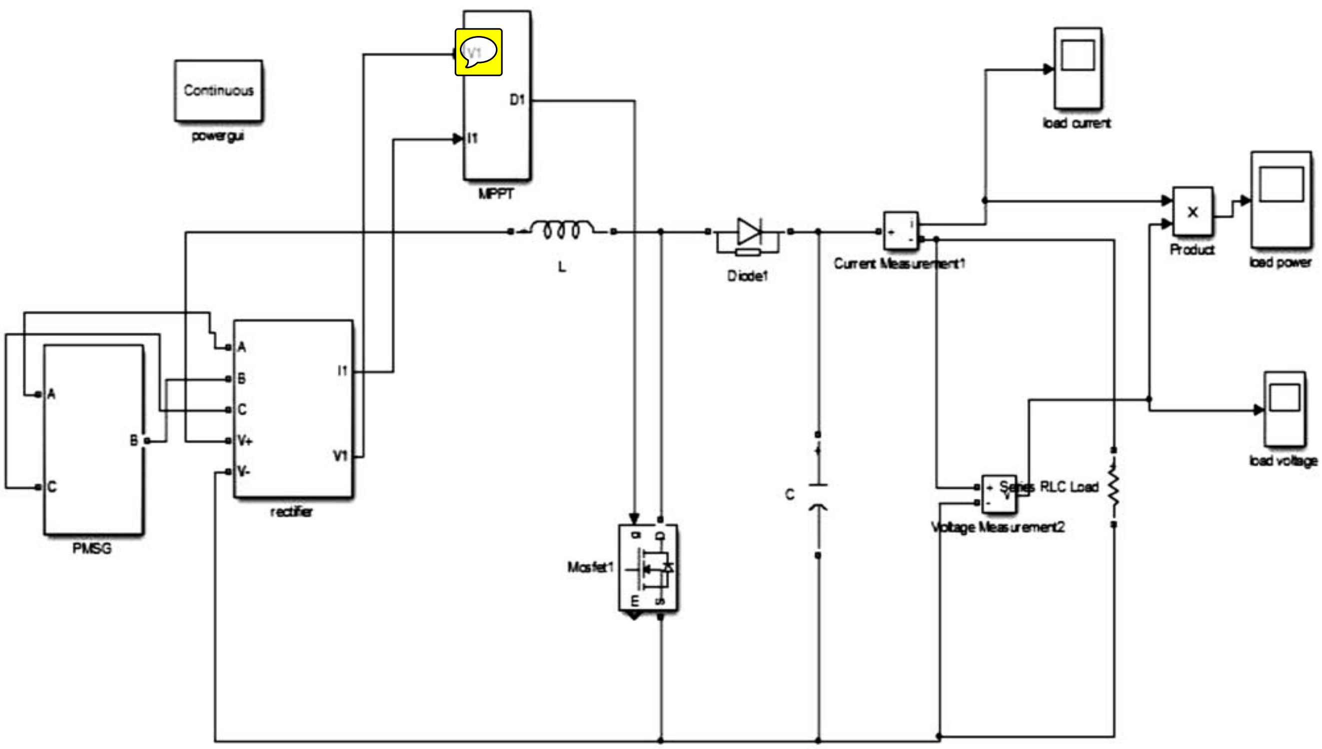

Figure 5: Modeling of Wind Conversion Module

In order to study the effects of entire WECS, the proposed System is modeled in MATLAB/SIMULINK environment by using different toolboxes. It includes wind turbine, drive train, rotor side converter and grid side converter. The simulation of wind conversion system using PMSG is shown in Fig 5. The numerical illustrations considered for the wind conversion system with the parameter values are given in the following tables. For modeling the wind conversion system a 4 hp machine is used. The active power is maintained at 0MVar. Furthermore, the turbine speed is 1 pu of generator's synchronous speed. The switch in the converter circuit is operated with the help of MPPT technique. It observes the output voltage and current value from the converter and it generates the duty cycle for the converter switch. The entire module consists of wind turbine, permanent magnet synchronous generator (PMSG), which is driven by the wind turbine, three phase rectifier based on PWM and DC-DC boost converter. It is connected to the load through LC filter. The wind turbine operates at the speed of 12 m/s. The output of the wind is AC which is converted into uncontrolled DC. This uncontrolled output is given as input to the boost converter and the controlled output is given directly to the load and the surplus energy is stored in the battery. The values of boost converter used here are calculated by using the necessary equations. The duty cycle for the power MOSFET is generated by the Maximum power point tracking which tracks the voltage and current from the boost converter and it generates the duty cycle accordingly. The generated voltage obtained from the wind conversion system is shown in Fig 6.

A. Simulation Result of Boost converter

The input for boost converter is obtained from the bridge rectifier and the parameters of boost converters are shown in Table III. The purpose of the boost converter is to convert the uncontrolled DC into the controlled one. The simulated output voltage of the boost converter is shown in Fig 7. This waveform is plotted between the output voltage of the boost converter and time.

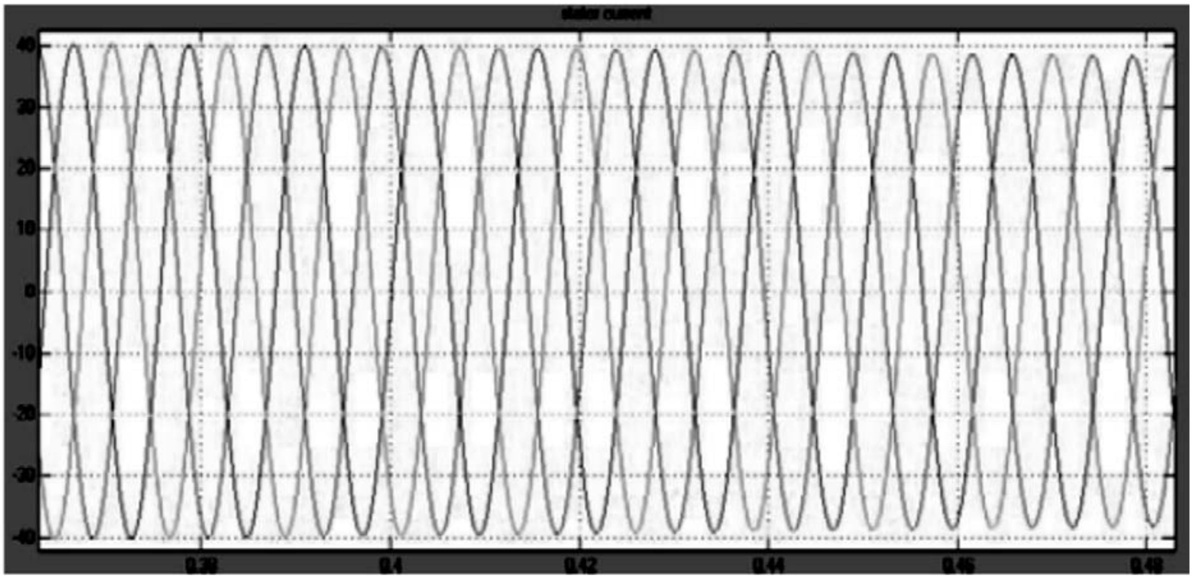

Figure 6: Generator Voltage

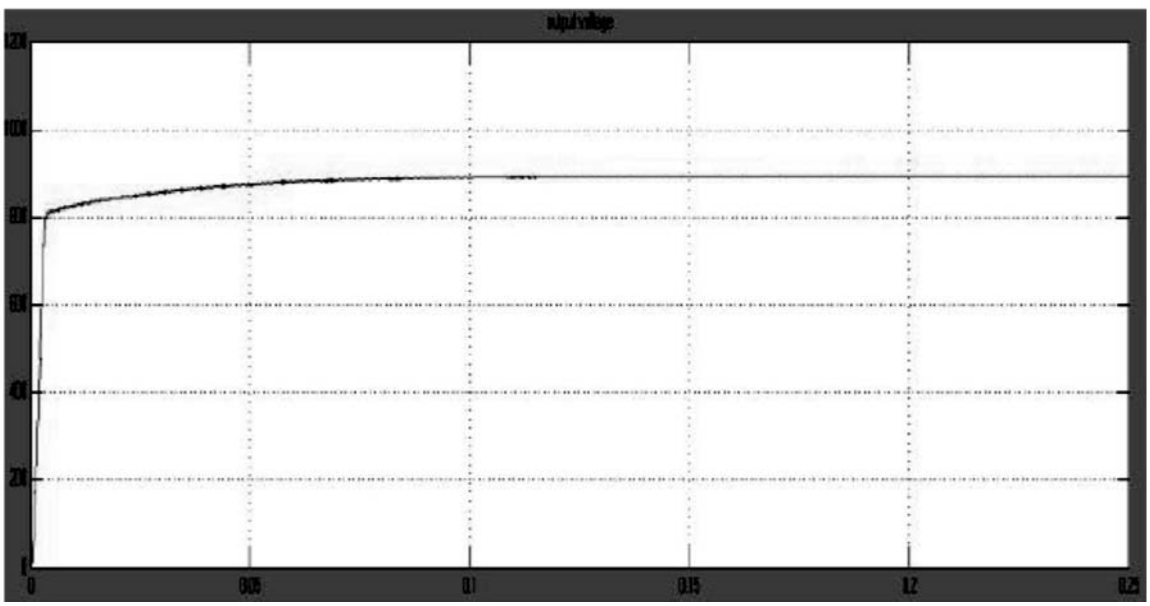

Figure 7: Boost Converter Output

The output power, voltage and current obtained across the load for various cases shown below. In the first case the operation is performed without the MPPT algorithm and in the second case the same system is operated with the implementation of MPPT algorithm. Fig 8 shows the output voltage waveforms that are obtained when the MPPT algorithm is not implemented. From the waveform it is seen that the magnitude of voltage is 1.2 kV.

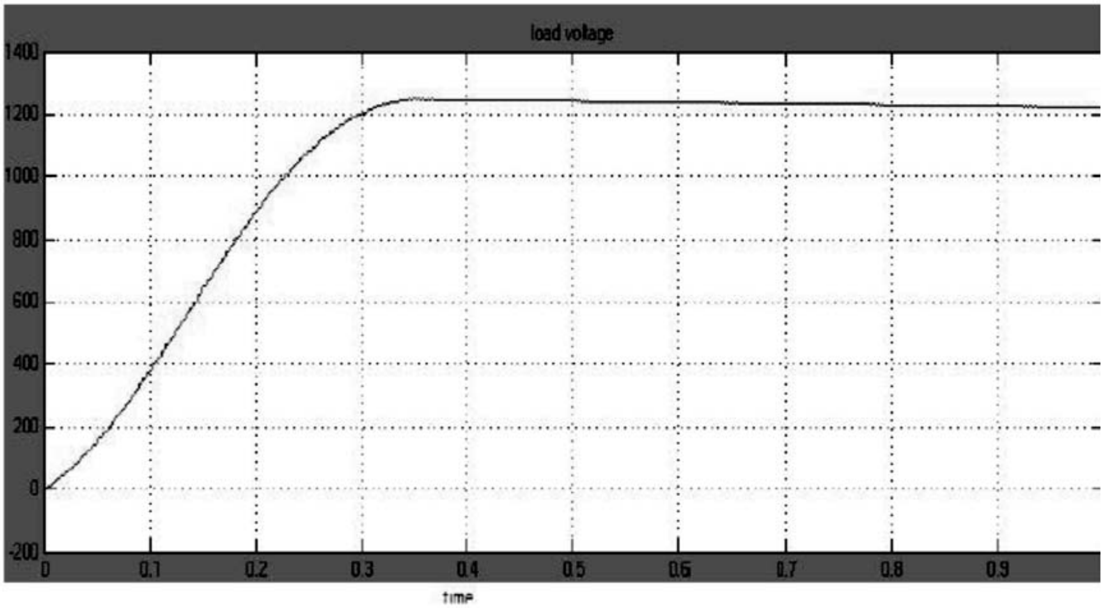

Figure 8: Voltage Waveform Obtained Across The Load Before Using MPPT

The waveform for output voltage is shown in Fig 9. This waveforms are obtained after implementing the MPPT technique. It can be seen that the output voltage is improved 2.4 kV.

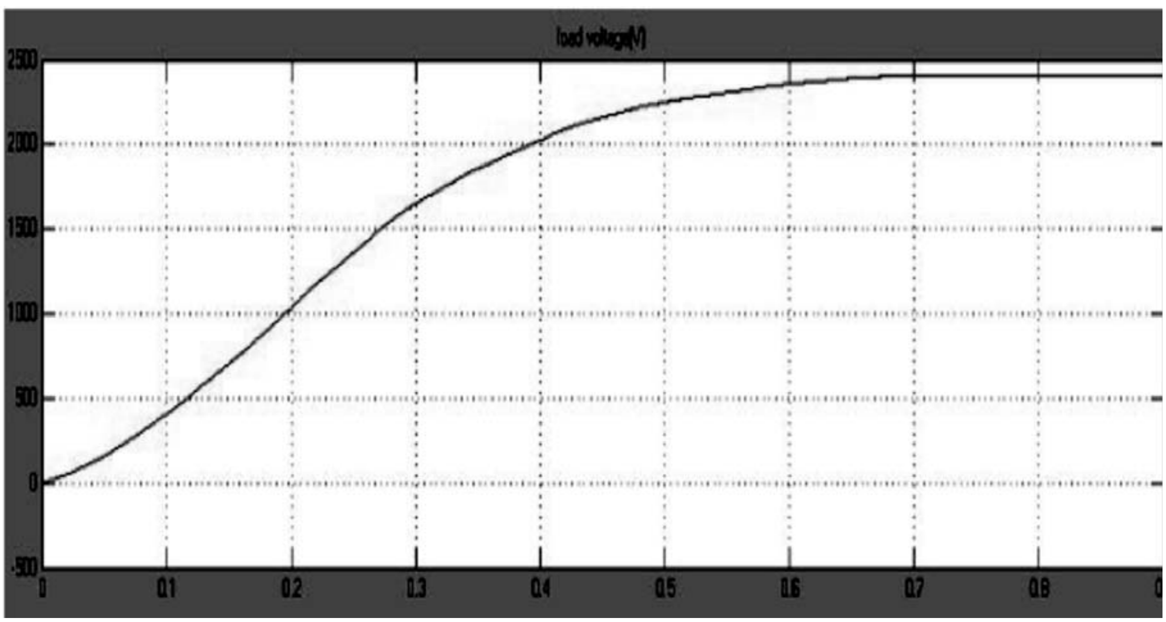

Figure 9: Voltage Waveform Obtained Across The Load After Using MPPT

From the Fig 8 and 9 it is observed that the magnitude of output voltage is improved by using the Maximum power point tracking. We can see that the power is initially started from zero and reaches the steady-state after a certain period of time.

5. CONCLUSION

In this paper PMSG based wind energy conversion system for standalone load with MPPT is implemented and the results were implemented using MATLAB/SIMULINK. From the simulated results, it can be seen that the maximum power extracted from the wind is improved by using the maximum power point tracking algorithm and the speed of the turbine is controlled by pitch angle control. Considering the simulated results, it has been proved that the implementation of this proposed control strategy has improved the overall performance and efficiency of the existing Wind Energy Conversion System (WECS).

6. REFERENCES

1. V. C. Gungor, D. Sahin, T. Kocak, S. Ergut, C. Buccella, C. Cecati, and G. P. Hancke, “Smart grid technologies: Communication technologies and standards,” IEEE Trans. Ind. Informat., vol. 7, no. 4, pp. 529-539, Nov. 2011.
2. S. Wencong, H. Eichi, Z. Wente, and M. Y. Chow, “A survey on the electrification of transportation in a smart grid environment,” IEEE Trans. Ind. Informat., vol. 8, no. 1, pp. 1-10, Feb. 2012
3. B. S. Borowy and Z. M. Salameh, “Dynamic response of a stand-alone wind energy conversion system with battery energy storage to a wind gust,” IEEE Trans. Energy Convers., vol. 12, no. 1, pp. 73–78, Mar. 1997.
4. R. Billinton, Bagen, and Y. Cui, “Reliability evaluation of small standalonewind energy conversion systems using a time series simulation model,” IEE Proc.-Generat., Transmiss. Distrib., vol. 150, no. 1, pp. 96– 100, Jan. 2003.
5. Bagen and R. Billinton, “Evaluation of different operating strategies in small stand-alone power systems,” IEEE Trans. Energy Convers., vol. 20, no. 3, pp. 654–660, Sep. 2005.
6. B. Singh and G. K. Kasal, “Solid state voltage and frequency controller for a stand alone wind power generating system,” IEEE Trans. Power Electron., vol. 23, no. 3, pp. 1170–1177, May 2008.
7. A. Chakraborty, “Advancements in power electronics and drives in interface with growing renewable energy resources,” Renewable Sustainable Energy Rev., vol. 15, no. 4, pp. 1816–1827, May 2011.
8. Bhende,C.N,Mishra,s.malla,S.G. “Permanenet magnet synchronous generator-based standalone wind energy supply system”.IEEEtrans.sust.energy 2011,2,361-373.
9. Mittal, R.sandhu,K.S,Jain. “Battery energy storage system for variable speed driven pmSG for wind conversion. int.J.Innov.Manag.tech.2010,I,300-304.
10. M. H. Nehrir, C. Wang, K. Strunz, H. Aki, R. Ramakumar, J. Bing, Z. Miao, and Z. Salameh, “A review of hybrid renewable/alternative energy systems for electric power generation: Configurations, control, and applications,” IEEE Trans. Sustain. Energy., vol. 2, no. 4, pp. 392-402, Oct. 2011.
11. B. Singh, S. Singh, A. Chandra, and K. Al-Haddad, “Comprehensive study of single-phase AC-DC power factor corrected converters with high frequency isolation,” IEEE Trans. Ind. Informat., vol. 7, no. 4, pp. 540-556, Nov. 2011.
12. L. Barote and C. Marinescu, “Storage analysis for stand-alone wind energy applications,” in Proc. IEEE OPTIM, 2010, pp. 1180-1185.
13. Zeng,R;Nian,H;quan,Y;Liu,J. “Improved adaptive control strategy for PMSG based stand alone wind energy generation.In Proceeding of the international conference on electrical machines and system,Tokyo,November 2009,pp 1-6.
14. F. D. Gonz´alez, A. Sumper, O. G. Bellmunt, and R. V. Robles, “A reviewof energy storage technologies for wind power applications,” RenewableSustainable Energy Rev., vol. 16, no. 4, pp. 2154–2171, May 2012.
15. R. Kot, M. Rolak, and M. Malinowski, “Comparison of maximum peak power tracking algorithms for a small wind turbine,” Math. Comput. Simul., vol. 91, pp. 29–40, 2013.
16. M. Narayana, G. A. Putrus, M. Jovanovic, P. S. Leung, and S. McDonald,“Generic maximum power point tracking controller for small-scale windturbines,” Renewable Energy, vol. 44, pp. 72–79, Aug. 2012.
17. K. Y. Lo, Y. M. Chen, and Y. R. Chang, “MPPT battery charger for standalone wind power system,” IEEE Trans. Power Electron., vol. 26, no. 6,pp. 1631–1638, Jun. 2011.
18. H. Camblong, “Digital robust control of a variable speed pitch regulatedwind turbine for above rated wind speeds,” Control Eng. Practice, vol. 16,no. 8, pp. 946–958, Aug. 2008.