IJIREEICE
ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526
INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 4, Issue 5, May 2016

MPPT based Control of Stand Alone Wind Battery System

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Abstract: Energy is the considered to be the pivotal input for development. At present owing to the depletion of available conventional resources and concern regarding environmental destruction, the renewable sources are being utilized to meet the ever increasing energy demand. From the available alternative sources of energy, wind energy is considered to be one of the potential sources of clean energy. But the nature of wind flow is stochastic. Thus, the study of WECS with the associated controllers is becoming more and more significant with each passing day. Nowadays, many stand-alone loads are powered by renewable source of energy. In this project, a hybrid wind-battery system is considered to meet the demand of a stand- alone system. The mechanical safety of the WECS is assured by means of MPPT based pitch control technique and a the battery is controlled by a charge controller based on battery state of charge is developed to ensure controlled charging and discharging of battery Both the control schemes are integrated and the efficacy is validated by testing it with various wind profiles in MATLAB/SIMULNIK.

Keywords: Wind energy conversion systems (WECS), Wind turbine(WT), Self excited induction generator (SEIG), Maximum power point tracking (MPPT), Lead acid battery (LAB), state of charge (SOC), Constant voltage (CV), Constant current (CC).

I. INTRODUCTION

Wind energy conversion systems have been attracting wide attention as a renewable energy source due to decreasing fossil fuel reserves and environmental concerns. Wind energy, even though abundant, varies continually as wind speed changes throughout the day. Due to a relatively low cost of electricity production wind energy is considered to be one of the potential sources of clean energy for the future [1]. In the case of wind energy conversion systems (WECSs), the interest is also focused on small-scale units, used to provide electricity supply in remote areas that are beyond the reach of an electric power grid or cannot be feasibly connected to a grid and termed as stand-alone systems. WECSs are the most favored substitute for supplying electricity in stand-alone cases at this moment due to the fact that wind energy is relatively easy to harvest, the sustenance required by the wind turbine generators are reasonable, and there is no fuel cost.

Several electrical generators can be used to implement the electromechanical energy conversion and control, each of which presents different advantages and disadvantages. A Precise comparison between synchronous and asynchronous generators for wind farm application is reviewed in [2]. The major merit of asynchronous machine is that the variable speed operation allows extracting maximum power from WECS and reducing the torque fluctuations [3]. Induction generator with a lower unit cost, inherent robustness, and operational modesty is considered as the most viable option as wind turbine generator (WTG) for off grid applications [4]. The SEIG output power depends on the nature of the wind flow which is erratic. Both amplitude and frequency of the generator voltage vary as with varying wind speed. Such promptly varying voltage when interfaced directly with the load can give rise to unstable fluctuation at the load end. So, the WECS are integrated with the load by power electronic converters to ensure a regulated load voltage [5]. Again due to the highly variable nature of the wind, the usage of an energy storage device such as a battery can necessarily enhance the reliability of a small stand-alone wind system.

Merging an appropriate energy storage device with WECS removes the fluctuations and can maximize the reliability of the power supplied to the loads. In the autonomous system, the wind power converter and suitable storage system is needed to enhance the wind energy converted into electric power. The harvested energy is supplied to the load directly, the inequality between the wind power generation and user consumption are being directed to or supplied by the battery energy storage device connected through the power electronic interface. An analysis of the available storage technologies for wind power application is carried out in [6] and [7]. The advantages of using battery energy storage for an isolated WECS are discussed in [7].

Among the available energy storage systems, lead–acid batteries (LABs) are the predominant energy storage technology, with their merits of low cost, a wide range of operating temperature, high unit voltage and stable performance [8]. Although the LABs has reasonable merits hence constitute an exciting challenge, as major components in the development of the stand-

DOI 10.17148/IJIREEICE.2016.45103

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alone wind energy systems. Using battery energy storage it is possible to capture reliable power [9] from the available wind .several maximum power point tracking (MPPT) algorithms for small wind turbine (WT) are compared in [10] and [11]. The turbine needs to be operated at optimal angular speed to extract maximum power form WECS [13]. To protect against battery overcharging and to observe the charging limitation a charge controller is required. Also the implementation of MPPT is parameter dependent and will be affected by variation i n operating conditions. When the wind speed exceeds its optimum value, the WT power and speed needs to be regulated for ensuring mechanical and electrical safety [15]. This is achieved by changing the pitch angle to the required value. Several pitch control techniques are discussed in [12]–[14]. The small-scale power generating system for areas like remotely located single community, a military post or remote industry where extension of grid is not feasible may be termed as stand-alone generating system. With this renewed interest in wind technology for stand-alone applications, a great deal of research is being carried out for choosing a suitable control scheme for stand-alone WECS.

This paper is organized as follows. In Section II, the stand- alone hybrid wind-battery system configuration is discussed; then, in Section III control methods are presented and it is followed by the simulation results with discussion in Section IV, while conclusions are provided in Section V.

II. STAND -ALONE HYBRID WIND-BATTERY SYSTEM CONFIGURATION

The proposed wind energy conversion system consists of a horizontal axis wind turbine, a self–excited induction generator as the wind turbine generator, battery storage as to supply a stand stand-alone load. The stator terminals of the SEIG are connected to a capacitor bank for self-excitation as it is a stand-alone system. The generated ac output is rectified by three-phase uncontrolled diode rectifier. The uncontrolled dc output of the rectifier is then applied to the charge controller circuit of the battery. The charge controller is a buck converter which determines the charging and discharging rate of the battery. The control method for stand-alone hybrid wind-battery system includes the MPPT based pitch control logic to ensure wind turbine operation within the rated value and charge controller circuit for battery.

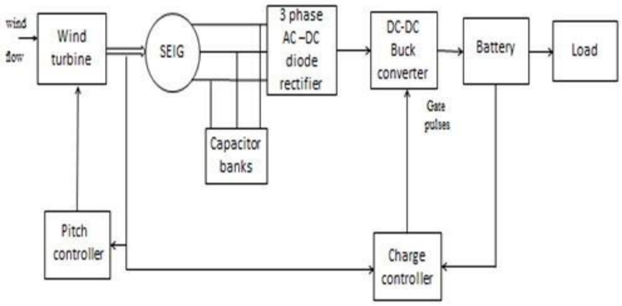


Fig. 1.Block Diagram of WECS

III. CONTROL STRATEGY FOR STAND-ALONE HYBRID WIND-BATTERY SYSTEM

The power output from a wind energy conversion system (WECS) depends upon the efficiency with which the peak power points are tracked by the maximum power point tracking (MPPT) controller of the WECS control system. The maximum power extraction algorithms researched yet can be classified into three main control methods, namely tip speed ratio (TSR) control, power signal feedback (PSF) control and hill-climb search (HCS) control. The proposed method is tip speed ratio (TSR) control method. This TSR control method regulates the angular velocity of the generator with respect to maintain the TSR to an optimum value at which power extracted is maximum. This method requires both the wind speed and the turbine speed to be estimated in addition to requiring the knowledge of optimum TSR of the turbine in to extract maximum possible power.

A. Pitch Control Mechanism

The pitch control system was observed to have a large output power variation and settling time. The pitch function provides full control over the mechanical power and is the most common control technique used in variable speed wind turbines. At wind speeds below the rated power of the generator, the pitch angle is at its maximum; however, it can be lowered to help the wind turbine accelerate faster. At the rated wind speed, the pitch angle is controlled to keep the generator at the rated power by reducing the angle of the blades.

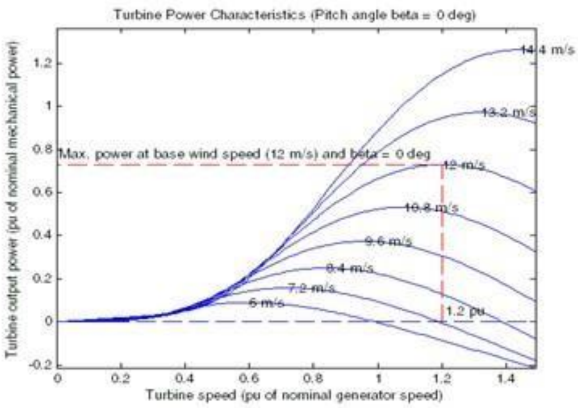


Fig. 2 Turbine speed Versus Turbine power characteristics

Variable speed wind turbines offer improved energy capture over constant speed machines because of the increased range of wind speeds under which maximum power can be generated as in Fig 2. Variable speed wind turbine can be used to generate a fixed value of voltage at the output with the help of a PI controller and it is done by varying the pitch angle of the blades. Here the voltage and speed of the generator are controlled in order to maintain the rated voltage and power according to the wind variation, the PI controller is incorporated controls the power output by reducing the power coefficient at higher wind speeds. Below the rated wind speed the blade pitch is maintained at zero degree to obtain maximum power.

The pitch control scheme shown in Fig.3 reads the value of each input. It is compared with desired WT parameters to calculate the error. The errors are tuned by PI controller. Then the MAX block chooses the maximum output from each PI controller which is then passed on to a limiter to generate the pitch command for the WT. The actual pitch command is compared with the limited value. The lower limit of the pitch command is set at zero. There arises an error when the actual pitch command goes above or below the specified limit. This is multiplied with the error obtained from each of the comparator. The product is compared with zero to determine the switching logic for integrator. This technique is carried out to avoid saturation of integrator.

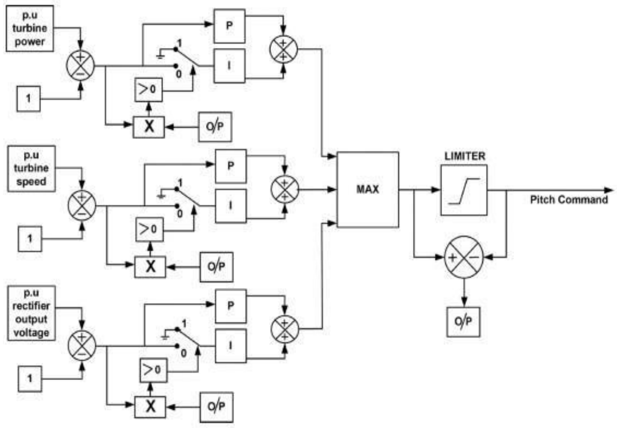


Fig.3 Pitch control scheme

The pitch controller changes the pitch command owing to variation in turbine rotation speed, power, and output voltage of rectifier, which ensures safe operation of the WECS.

B. Battery charge control technique

The charge controller is a buck converter which determines the charging and discharging rate of the battery. The essential gate pulses are provided by the pulse generator which is controlled by the PI controller. The charge controller charges the battery based on battery state of charge. The battery connected to the system can either act as a source or load depending on whether it is charging or discharging.

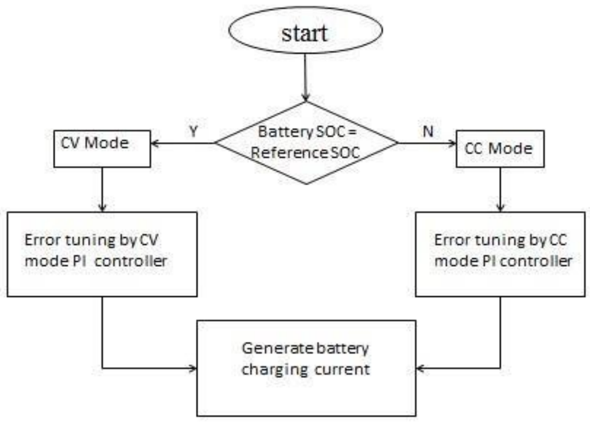


Fig.4 Flowchart of battery charge control

The charge controller has two modes of battery charging. They are CC mode and CV mode and the charge control scheme as shown in Fig.4. In the CC mode, the voltage and SOC of the battery rises fast with time. However, the charge controller should not overcharge the batteries to avoid gasification of electrolyte. As a result, once the battery SOC becomes equal to the reference SOC the controller must switch over from CC mode to CV mode.

IV. RESULTS AND DISCUSSIONS

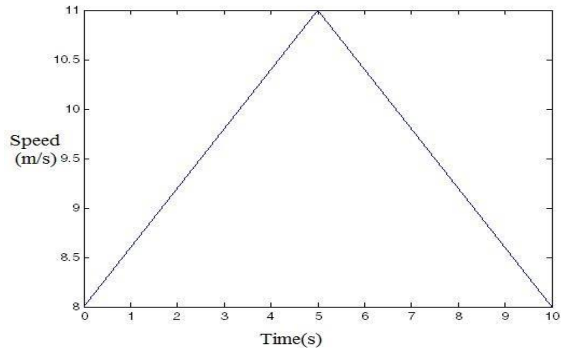
A WECS needs to be potent to ensure continuous power flow to the load. The effectiveness can be achieved by integrating the wind-battery system with suitable control logic. This includes the pitch control logic and the charge control logic. The charge controller regulates the charging and discharging rate of the battery while the pitch controller controls the WT parameter during high wind speed conditions. Both the control schemes are integrated with the hybrid system and simulated with various wind profiles to validate the efficiency of the system.

In order to analyze the system's operation, the WT and battery parameters are observed for the following wind profiles:

1) Gradual rise and fall in wind speed.
2) Step variation in wind speed.
3) Arbitrary variation in wind speed.
4) Constant wind speed.

Case 1: Gradual rise and fall in wind speed

A gradual rise and fall in wind speed as shown in Fig. 5 is applied to the WT. The wind speed gradually rises from 8 to11 m/s in 5 s and then falls to 8 m/s in the next 5 s.



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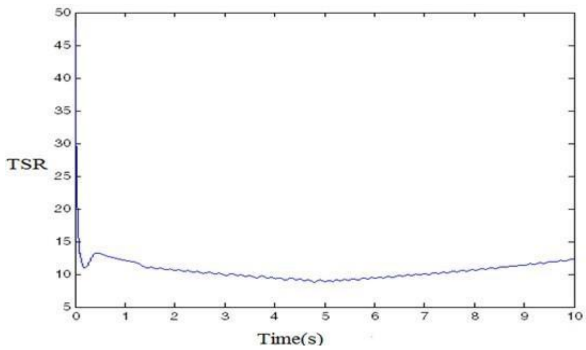

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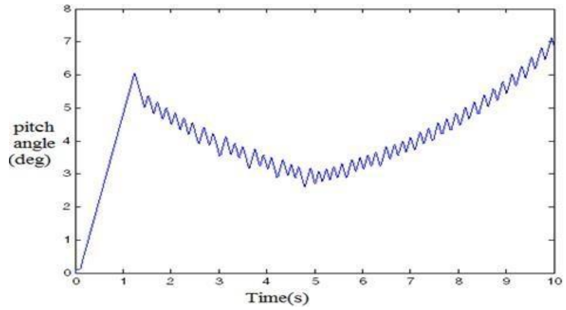

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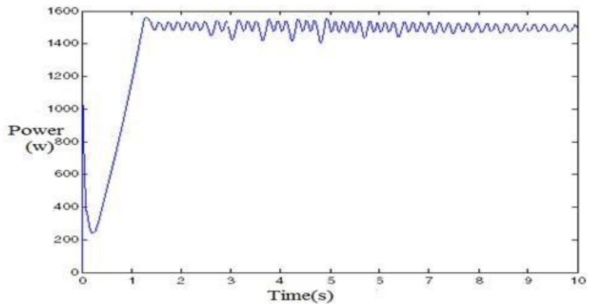
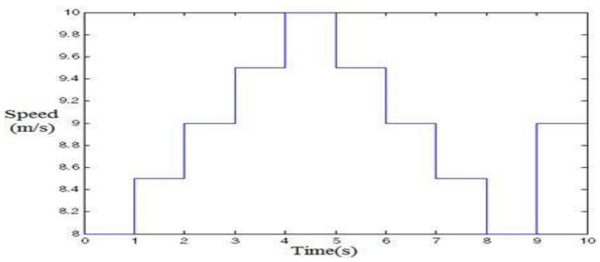


(d)

Fig.5 Under gradual variation in wind speed a) Wind profile b) Tip speed ratio (TSR) c) Pitch variation d) Turbine Power

Case 2: Step variation in wind speed
The variation of the wind profile in step from 8 to 10 m/s is highlighted in Fig.6.



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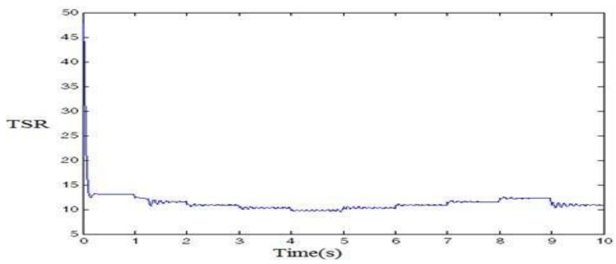

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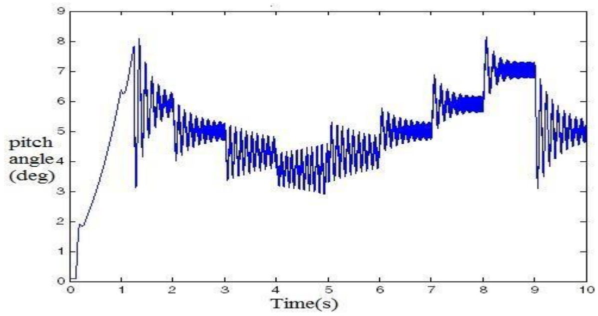

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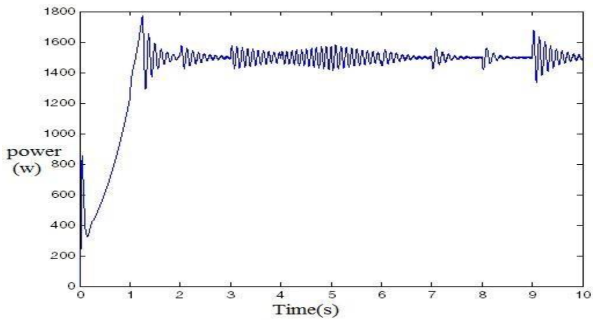
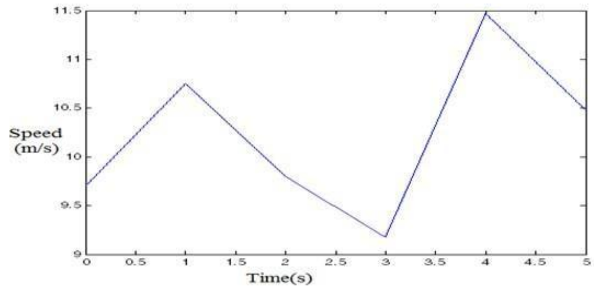


(d)

Fig.6 Under step variation in wind speed a) Wind profile b) Tip speed ratio (TSR) c) Pitch variation d) Turbine Power

Case 3: Arbitrary variation in wind speed
The variation of the wind profile under the arbitrary variation with wind speed from 9 to 11 m/s shown in Fig.7



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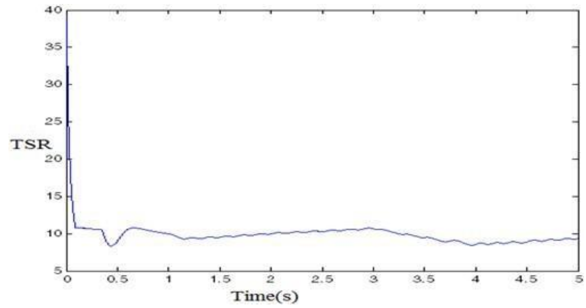

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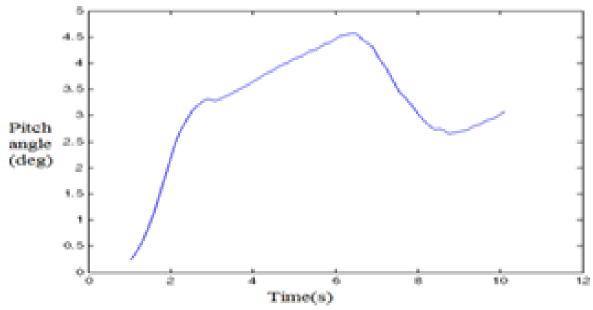

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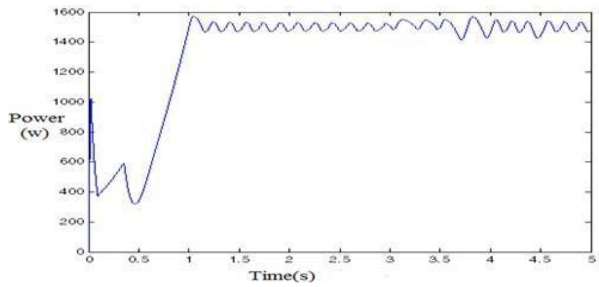

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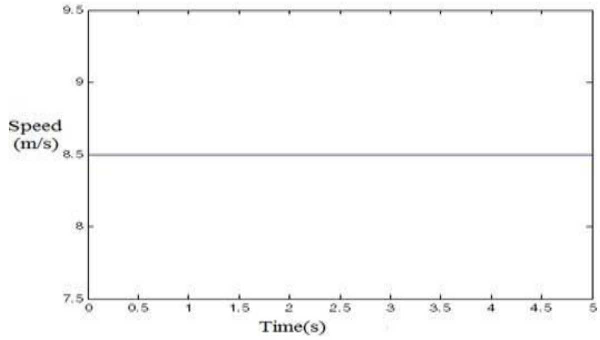
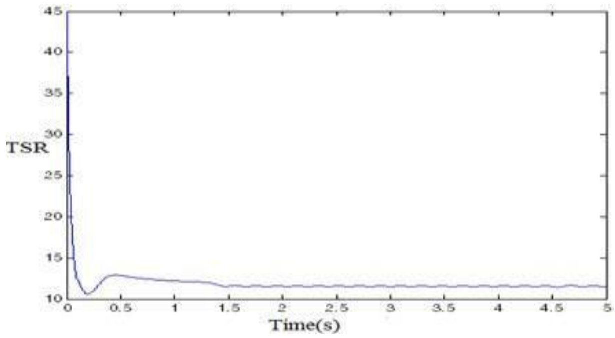
Fig.7 Under arbitrary variation in wind speed a) Wind profile b) Tip speed ratio (TSR) c) Pitch variation d) Turbine Power

Case 4: Constant wind speed

The variation of the wind profile in constant wind speed from 8.5 m/s is highlighted in Fig.8.



(a)



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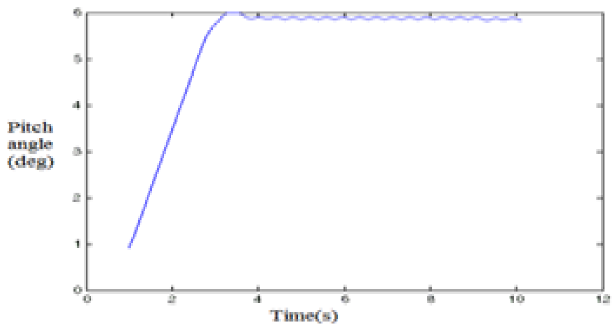

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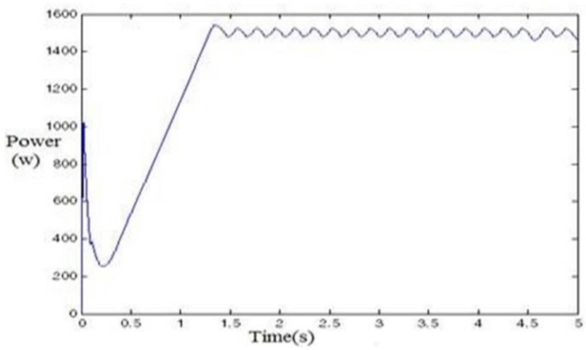
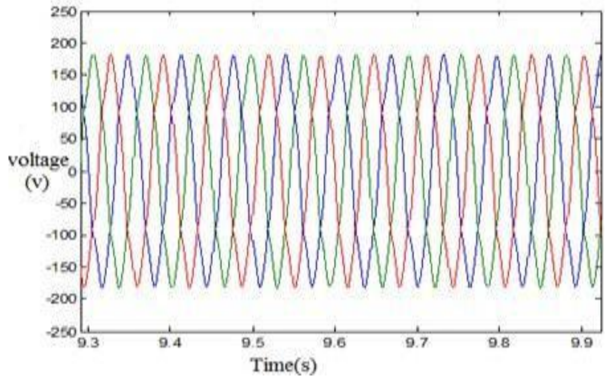


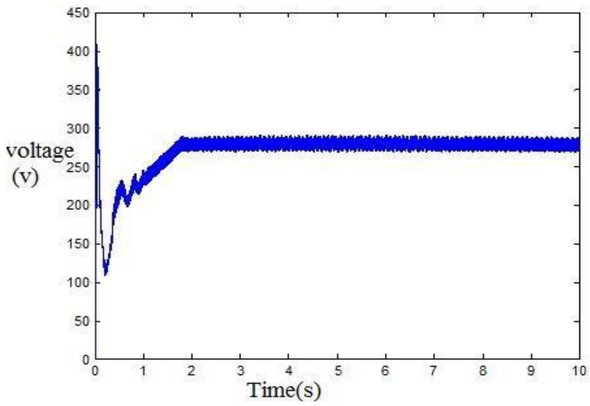
(d)

Fig. 8 under constant wind speed A) Wind profile b) Tip speed ratio (TSR) c) Pitch variation d) Turbine Power

It is observed from the above variation in wind profiles even when the wind speed varies continuously from the rated value the control scheme regulates the TSR of WT at its optimum value there by pitch angle is adjusted which ensures mechanical safety of the turbine and to extract the constant output power and voltage which ensures maximum power extraction and mechanical safety. The simulation outputs are as follows:



(a)



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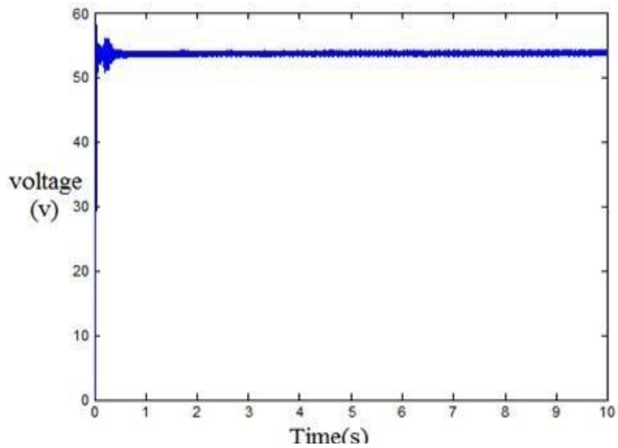
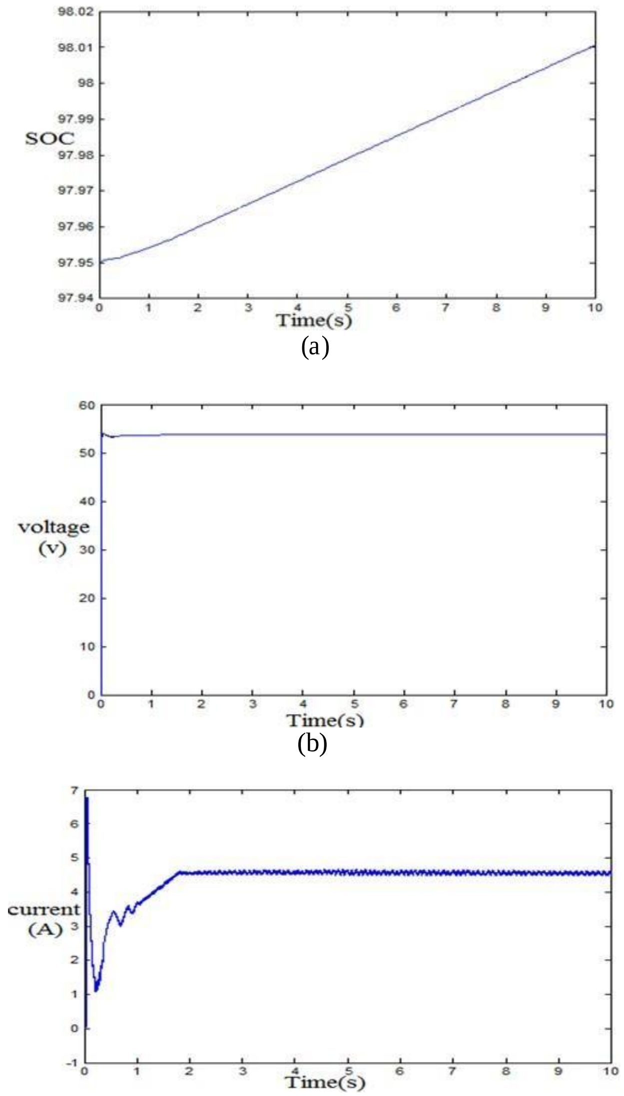


(c)

Fig.9 WECS parameter a) Generator voltage b) Rectified voltage C) DC buck voltage

The dc buck converter acts as charge controller which regulates the charging and discharging rate of the battery which depends on battery SOC and battery parameters are as follows:



(a) (b) (c)

Fig.10 Battery parameter a) State of charge (SOC) b) Charging voltage c) Charging current

V. CONCLUSION

The wind power generation is very unreliable in nature. So, a WECS cannot ensure uninterrupted power supply to the load. In addition to meet the load requirement at all instances, suitable storage device is needed. Therefore, in this project a hybrid wind battery system is chosen to supply the desired load power. A control structure for stand-alone wind energy conversion system is also analyzed. This includes MPPT based pitch angle controller and an associated charge controller for battery storage system, with the role to stabilize the output voltage in autonomous applications. The outcome of the simulation ensures the improved performance of the system.

REFERENCES

[1] A. D. Sahin, ―Progress and recent trends in wind energy,‖ Progress in Energy Combustion Sci., vol. 30, no. 5, pp. 501–543, 2004.
[2] M. T. Ameli, S. Moslehpur, and A. Mirzale, ―Feasibility study for replacing asynchronous generators with synchronous generators in wind farm power stations,‖ in Proc. IAJC – IJME, Int. Conf. Eng. Technol., Music City Sheraton, Nashville, TN, US, ENT paper 129Nov. 17–19, 2008.
[3] G. K. Singh, ―Self excited generator research—A survey,‖ Electric Power Syst. Res., vol. 69, no. 2/3, pp. 107 114, 2004.
[4] R. C. Bansal, ―Three-phase self-excited induction generators: An overview,‖ IEEE Trans. Energy Convers., vol. 20, no. 2, pp. 292–299, Jun. 2005.
[5] 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.
[6] F. D. Gonz´alez, A. Sumper, O. G. Bellmunt, and R. V. Robles, ―A review of energy storage technologies for wind power applications,‖ Renewable Sustainable Energy Rev., vol.16, no. 4, pp. 2154–2171, May 2012.
[7] N. S. Hasan, M. Y. Hassan, M. S. Majid, and H. A. Rahman, ―Review of storage schemes forwind energy systems,‖ Renewable Sustainable Energy Rev., vol. 21, pp. 237–247, May 2013.
[8] R. C. Harwood, V. S. Manoranjan, and D. B. Edwards, ―Lead–acid battery model under discharge with a fast splitting method,‖ IEEE Trans. Energy Convers., vol. 26, no. 4, pp.1109–1117, Dec. 2011.
[9] 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.
[10] M. Narayana, G. A. Putrus, M. Jovanovic, P. S. Leung, and S. McDonald, ―Generic maximum power point tracking controller for small-scale wind turbines,‖ Renewable Energy, vol. 44, pp. 72–79, Aug. 2012.
[11] 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.
[12] H. Camblong, ―Digital robust control of a variable speed pitch regulated wind turbine for above rated wind speeds,‖ Control Eng. Practice, vol. 16, no. 8, pp. 946–958, Aug. 2008.
[13] E. Muljadi and C. P. Butterfield, ―Pitch-controlled variable-speed wind turbine generation,‖ IEEE Trans. Ind. Appl., vol. 37, no. 1, pp. 240–246, Jan./Feb. 2001.
[14] B. M. Nagai, K. Ameku, and J. N. Roy, ―Performance of a 3 kW wind turbine generator with variable pitch control system,‖ Appl. Energy,vol. 86, no. 9, pp. 1774–1782, Sep.2009.