

Modelling and Simulation of Hybrid Wind Solar Energy System using MPPT

K. Pavankumar Reddy* and M. Venu Gopala Rao

Department of EEE, K L University, Vaddaswaram, Guntur - 522502,
Andhra Pradesh, India; pavanreddy4ever@gmail.com, venumannam@gmail.com

Abstract

The main objective of this paper is to enhance the power transfer capability of grid interfaced hybrid generation system. Generally, this hybrid system is a combination of solar and wind energy systems. In order to get maximum and constant output power from these renewable energy systems at any instant of time, this paper proposes the concept of maximum power tracking techniques. The main concept of this maximum power point tracking controller is used for controlling the Direct Current (DC) to DC boost converter. Finally, the performance of this Maximum Power Point Tracking (MPPT) based Hybrid system is observed by simulating using Matlab/Simulink.

Keywords: MPPT Technique, Solar Energy System, Wind Turbine System

1. Introduction

In the present scenario, renewable energy sources are incorporated along with the battery energy storage systems, which are mostly used for maintain the reliability of power. The number of renewable energy sources is increased as distribution sources; generally, to improve the power supply stability, and hence the power quality new strategies of operations are required. The common disadvantage of both wind and solar power plants are as these generate unreliable power¹. In order to overcome this problem a new technique is implemented i.e maximum power point tracking algorithm which is applicable to both wind and solar plants. Dynamic performance of a wind and solar system is analyzed. There are some previous works on hybrid systems comprising of wind energy, photovoltaic and fuel cell have been discussed. All the energy sources are modeled using MATLAB software tool to analyze their behavior. A simple control method tracks the maximum power from the wind/solar energy source to achieve much higher generating capacity factors. The simulation results prove the feasibility and reliability of this proposed system^{2,3}.

2. Proposed Hybrid Energy System

Figure 1 show the configuration structure for hybrid system based solar and wind energy systems. A rotor in the wind turbine captures the wind's kinetic energy, it consists of two or more blades mechanically coupled to an electrical generator⁴. The mechanical power captured from wind by a wind turbine can be formulated as:

$$P_m = 0.5\rho AC_p V^3$$

0.59 is the theoretical maximum value power coefficient value. It is based on two variables the pitch angle Tip Speed Ratio (TSR). With respect to longitudinal axis turbine blades are aligned at an angle that is the pitch angle. The linear speed of the rotor to the wind speed is TSR.

Wind turbine "C Vs. λ " curve is shown in Figure 2. In practical designs, 0.4 to 0.5 is the maximum achievable range for high speed turbines and for slow speed turbines it is in the range of 0.2 to 0.4. At λ_{opt} its maximum value (C_{pmax}) is shown in Figure 2. Which results in optimum efficiency and maximum power is captured from wind by the turbine.

*Author for correspondence

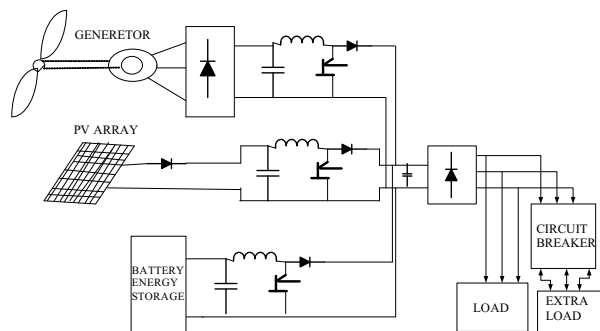


Figure 1. Configuration of Hybrid Energy System.

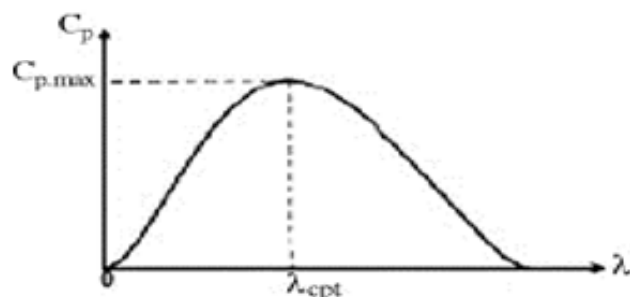


Figure 2. Power coefficient Vs Tip Speed Ratio.

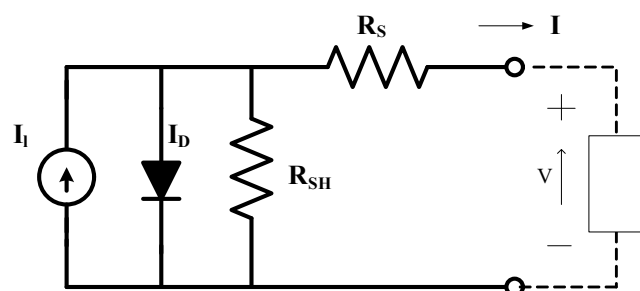


Figure 3. Equivalent circuit of PV Module.

In Photovoltaic (PV) system, solar cell is the basic component. PV array is nothing but solar cells are connected in series or parallel for gaining required current, voltage and high power. Each Solar cell is similar to a diode with a p-n junction formed by semiconductor material⁵. It produces the currents when light absorbed at the junction, by the photovoltaic effect. Figure 4 shows an insulation output power characteristic curves for the PV array. It can be seen that a maximum powerpoint exists on each output power characteristic curve. The Figure 4 shows the (I-V) and (P-V) characteristics of the PV array at different solar intensities. The equivalent circuit of a solar cell is the current source in parallel with a diode of

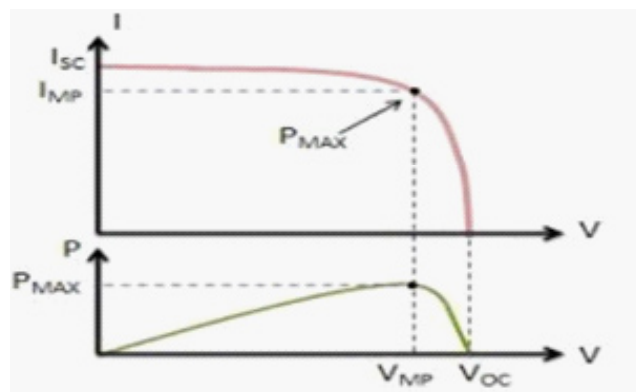


Figure 4. Output characteristics of PV Array.

a forward bias. Load is connected at the output terminals. The current equation of the solar cell is given by^{6,7}:

$$I = I_{ph} - I_D - I_{sh}$$

$$I = I_{ph} - I_o [\exp (q V_D / nKT)] - (V_D / R_s)$$

$$\text{Power output of solar cell is } P = V * I$$

3. Battery Energy Storage

The conversion of Alternating Current (AC) to Direct Current (DC) is done by Battery Energy Storage System (BESS), it has power electronic devices control system and batteries. Here, the working of battery is conversion of electrical energy into chemical energy for storing purpose. By using DC power Batteries are charged and discharged. Bi-directional power electronic devices are regulating power flow between batteries and energy systems⁸. Based on the type of battery, it has various merits and demerits like cost, weight, size, power and energy capability. Lithium-Ion, Lead-Acid, Nickel Cadmium, Nickel Metal Hydride are important types of energy storage technologies. High discharge rates are achieved by Lead-Acid batteries; these batteries offer a better solution for applications of energy storage. Long cycle life, high energy density, charge or discharge efficiency is high is qualities of sodium sulfur batteries. Nickel Cadmium (NiCd) batteries are better in all qualities and have low maintenance requirements than the Lead-Acid batteries^{9,10}. However, the cost of these batteries are high when compared to Lead-Acid battery. It is an expensive alternate option. Nickel Metal Hydride (NiMH) batteries are used in hybrid electric vehicles and tele-communication applications because these are compact batteries and light in weight.

The highest energy density among all types of batteries is Lithium-Ion batteries. They are currently used in cellular phones, computers, etc. and development of this technology is used in distributed energy storage applications. But high cost and limited applications of technology. Because of its availability in different size: small, medium and large scale renewable energy systems and high rate of progress in development it is commanding the electronics market. During coupled operation, changes in the outputs of wind and solar PV generation^{11,12} will change in the output of BESS and BESS must neutralize by quick changes in output power. Rate variation control or ramp rate control is applied for an associated coupled system to smooth their real power fluctuations. The information is processed by the Battery Energy System controller and estimates the State of Charge (SOC) of each battery cell and capacity of each battery cell and protects all the cells operate in the designed SOC range.

On a smaller scale the economic and technical merits of energy storage systems are as follows:

- Electrical supply quality and reliability are improved.
- For critical loads it supplies backup power.

4. Maximum Power Point Tracking

The efficiency of wind turbine, solar panel is improved by Maximum Power Point Tracking (MPPT) when they set to operate at point of maximum power. There are different techniques of MPPT. The most popular techniques are: Incremental Conductance method, Perturb and Observe, Fuzzy logic, neural networks. Initial photovoltaic array reference voltage and the initial rotor speed reference for the wind turbine are adjusted if the two systems output powers does not match to their maximum powers¹³. We need to adjust the initial reference values in direction of increasing manner of output power and vice-versa. Until the wind turbine and photovoltaic array reach the maximum power points same process repeats. The characteristic power curve for a PV array is shown in Figure 4. If MPPT techniques considered it as a problem, then it finds the voltage V_{MP} or current I and automatically under a given temperature and irradiance the PV array should get the maximum output power P_{MP} ¹⁴.

5. Simulation Results

The complete system design i.e hybrid energy system is simulated using SIMULINK. A 10-kW wind/PV/BESS

hybrid system was considered. The simulation study of system parameters are presented below and to predict their actual characteristics three energy sources are modeled accurately in SIMULINK. Figure 5 show the simulation diagram for hybrid system with solar and wind systems.

5.1 Simulated Graphs

- The load demand to fulfill is 10 KW throughout the time scale except at 4 to 5 sec when it increases to 14 KW.
- Solar energy drops its irradiance to 15 % from 2 sec.
- Wind turbine initially rotating at 5m/s excels to base speed 12m/s after 0.5 sec. Its rotating speed is decreased to 25 % of its base speed.
- All these conditions are clearly observed in the below graph.
- The Maximum Voltage of PV Array is observed at around 640 V. The curve below explains that the varying irradiance is the deciding factor of the maximum voltage derivations

Figure 6 shows the simulation result for output voltage across load terminals. From this result we observed that the voltage changes with respect to change in either the wind or solar plants.

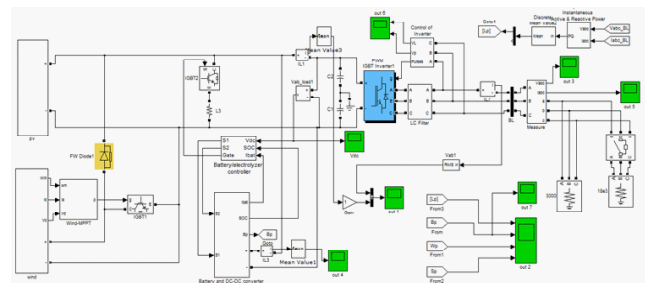


Figure 5. Simulation Diagram for Hybrid Wind-PV System.

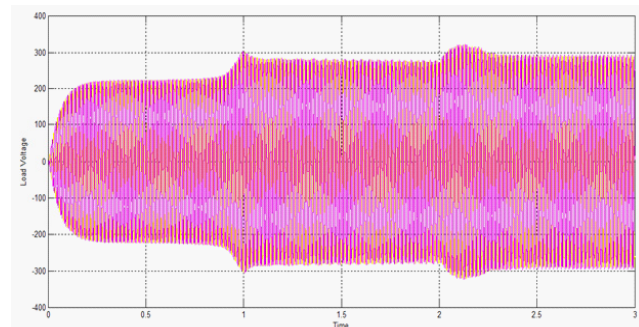


Figure 6. Output Load Voltage.

Figure 7 show the simulation result of output current through the load. If the load is changed or suddenly extra load applied to the system then changes occur in the load current. In this paper we suddenly applied the load during the time 1 sec to 2 sec, then in this period the current rises.

Figure 8 shows the wave form for powers which are obtained from the solar plant, wind energy system. And with this the line power is depends. And Figure 9 shows the simulation result for wind turbine output voltage.

Figure 10 show the simulation result of output power from the battery system.

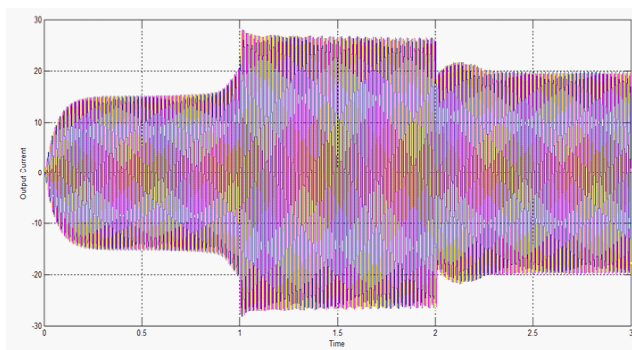


Figure 7. Output Load Current.

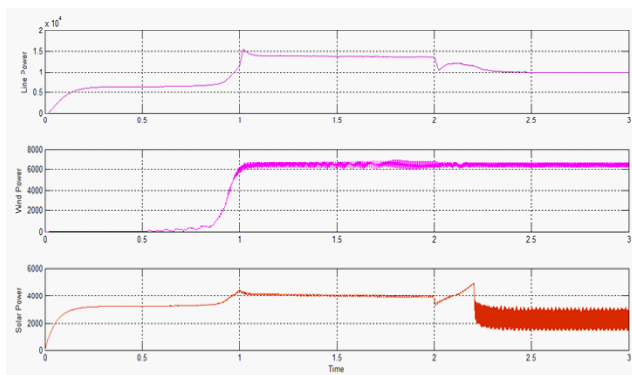


Figure 8. Powers: Line, Wind, Solar.

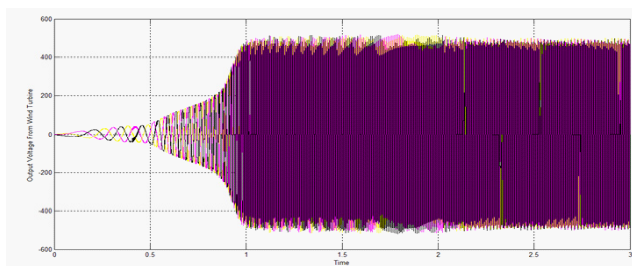


Figure 9. Output Voltage from Wind System.

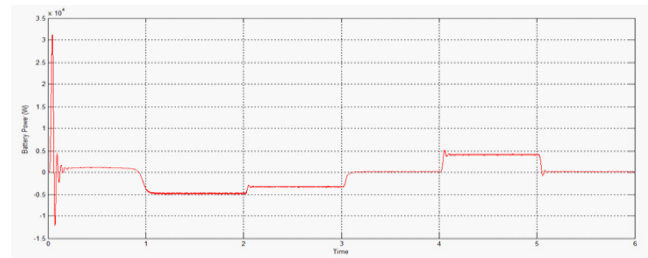


Figure 10. Output Voltage from Wind System.

6. Conclusion

Output from solar and a wind system is converted into AC power output by using inverter. In the given time additional load of 5 KW is connected by using Circuit Breaker. Under all operating conditions to meet the load the hybrid system is controlled to give maximum output power. Battery is supporting to wind or solar system to meet the load and Also, simultaneous operation for the same load.

7. References

1. Huil J, Bakhshai A, Jain PK. A hybrid wind-solar energy system: A new rectifier stage topology. 2010 25th Annual IEEE Proceedings of Applied Power Electronics Conference and Exposition (APEC); 2010 Feb 21–25. p. 156–61.
2. Kim SK, Jeon JH, Cho CH, Ahn JB, Kwon SH. Dynamic modeling and control of a grid-connected hybrid generation system with versatile power transfer. IEEE Transactions on Industrial Electronics. 2008 Apr; 55(4):1677–88.
3. Ezhilarasan S, Palanivel P, Sambath S. Design and development of energy management system for DG source allocation in a micro grid with energy storage system. Indian Journal of Science and Technology. 2015 Jun; 8(13):58252.
4. Patel MR. Wind and solar power systems design analysis and operation. 2nd ed. Taylor and Francis Group Publishing Co. 2006; 30(3):265–6.
5. Chen YM, Liu YC, Hung SC, Cheng CS. Multi-input inverter for grid-connected hybrid PV/wind power system. IEEE Transactions on Power Electronics. 2007 May; 22(3):1070–7.
6. Jain S, Agarwal V. An integrated hybrid power supply for distributed generation applications fed by nonconventional energy sources. IEEE Transactions on Energy Conversion. 2008 Jun; 23(2):622–31.
7. Das D, Esmaili R, Xu L, Nichols D. An optimal design of a grid connected hybrid wind/photovoltaic/fuel cell system

- for distributed energy production. Proceedings of IEEE Industrial Electronics Conference; 2005 Nov. p. 2499–504.
8. Soundarapandian R, Jayashree R. An improved artificial fish swarm optimization for proficient solving of advanced unit commitment problem with wind energy and pumped hydro storage. Indian Journal of Science and Technology. 2014 Oct; 7(S6):95–104.
 9. Jalili S, Effatnejad R. Simultaneous coordinated design of power system stabilizer 3 band (PSS3B) and SVC by using hybrid big bang big crunch algorithm in multi-machine power system. Indian Journal of Science and Technology. 2015 Feb; 8(S3):62–71.
 10. Ambika R, Rajeswari R, Nivedita A. Comparative analysis of nature inspired algorithms applied to reactive power planning studies. Indian Journal of Science and Technology. 2015 Mar; 8(5):445–53.
 11. Garimella N, Nair NKC. Assessment of battery energy storage systems for small-scale renewable energy integration. IEEE Conference. 2009 Jan. p. 1–6.
 12. Sera D, Kerekes T, Teodorescu R, Blaabjerg F. Improved MPPT algorithms for rapidly changing environmental conditions. IEEE Conference. 2006 Sep. p. 1614–9.
 13. Gheydi M, Effatnejad R, Ramezanpour P. Evaluation of uncertainty in hybrid plants, including wind turbine, photovoltaic, fuel cell, and battery system using fuzzy logic. Indian Journal of Science and Technology. 2014 Feb; 7(2):113–22.
 14. Izadbakhsh M, Rezvani A, Gandomkar M, Mirsaeidi S. Dynamic analysis of PMSG wind turbine under variable wind speeds and load conditions in the grid connected mode. Indian Journal of Science and Technology. 2015 Jul; 8(14):51864.