ISSN : 2394-2975 (Online)
ISSN : 2394-6814 (Print)

Modelling and Simulation Hybrid Wind Solar Energy System Using MPPT

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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 DC to DC boost converter. Finally, the performance of this MPPT based Hybrid system is observed by simulating using Matlab/Simulink.

Key Words

MPPT technique, Solar Energy System, Wind Turbine System

Introduction

In the present scenario renewable energy sources are incorporate along with the battery energy storage systems which are mostly used for maintaining the reliability of power. The number of renewable energy sources is increased as distribution sources increases. Generally to improve the power supply stability and power quality new strategies of operations are required. The common disadvantage of this both wind and solar power plants are to generate unreliable power [1]. 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].

Proposed Hybrid Energy System

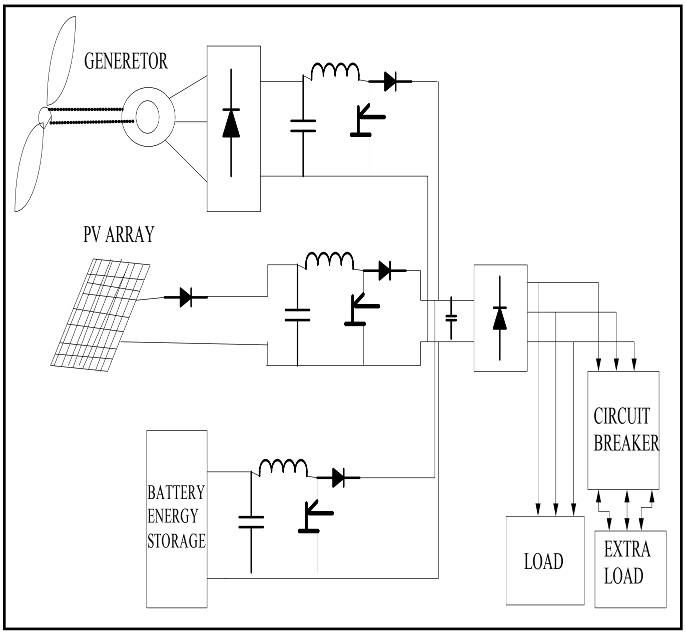

Fig. 1: Configuration of Hybrid Energy System

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 consisting of two or more blades mechanically coupled to an electrical generator [4]. The mechanical power captured from wind by a wind turbine can be formulated as

$P_m = 0.5 \rho A C_p V^3$

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 low speed turbines its range is 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.

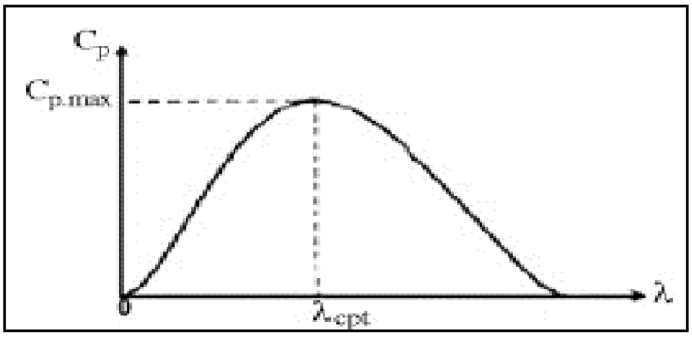

Fig. 2: Power coefficient vs Tip Speed Ratio

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 material [5]. It produces the currents when light absorbed at the junction by photovoltaic effect. Figure 4 shows an insulation output power characteristic curves for the PV array. It can be seen that a maximum power point 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 a forward bias. Load is connected at the output terminals. The current equation of the solar cell is given by [6] [7]

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

$$I = I_{ph} - I_o\left[\exp\left(\frac{q(V+R_sI)}{AkBT}\right) - 1\right] - \frac{V+R_sI}{R_{sh}}$$

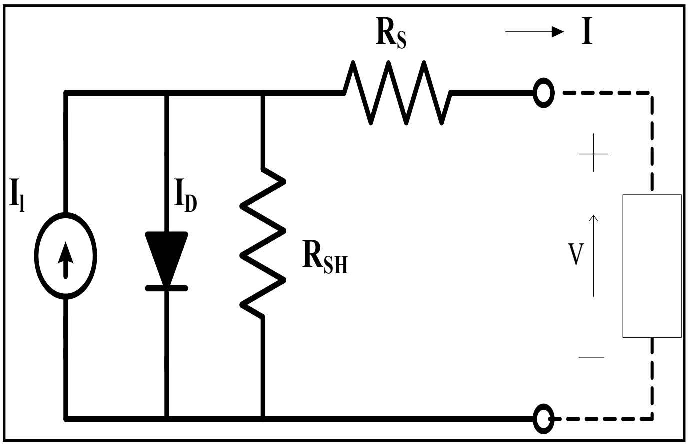

Figure 3: Equivalent circuit of PV Module

Power output of solar cell is P = V * I

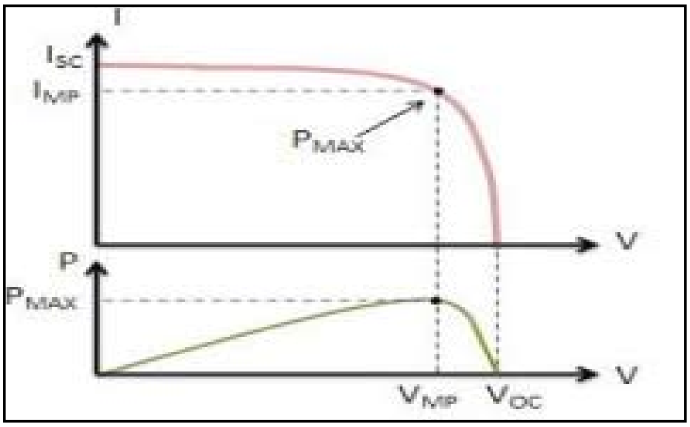

Fig. 4: Output characteristics of PV Array

Battery Energy Storage System (BESS)

The conversion of AC to DC is done by Battery Energy Storage System (BESS). It is having 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 for regulating power flow between batteries and energy systems [8]. Based on type of battery it's having various merits and demerits like cost, weight, size, and power and energy capability. Lithium-Ion, Lead-Acid, Nickel-Cadmium, Nickel Metal Hydride are the important types of energy storage technologies. High discharge rates are achieved by Lead-Acid batteries. These batteries are offering a better solution for applications of energy storage. Long cycle life, high energy density, charge or discharge efficiency is high are the qualities of sodium sulfur batteries. Nickel Cadmium (NiCd) batteries are better in all qualities and low maintenance requirements than the lead-acid batteries [9] [10]. But these batteries cost is 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 are Lithium-Ion batteries. They are currently used in cellular phones, computers, etc. and development of this technology is used in distributed energy storage applications. Because of its sizes availability 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. It estimates the State of Charge (SoC) and capacity of each battery cell and protects all the cells to 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.

Maximum Power Point Tracking

The efficiency of wind turbine and solar panel is improved by MPPT when they are set to operate at point of maximum power. In 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 to be adjusted if the two systems output powers are does not match to their maximum powers [13]. 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].

Simulation Results

The complete system design (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.

Vol. 4, Issue 2 (April - June 2017)
ISSN : 2394-2975 (Online)
ISSN : 2394-6814 (Print)

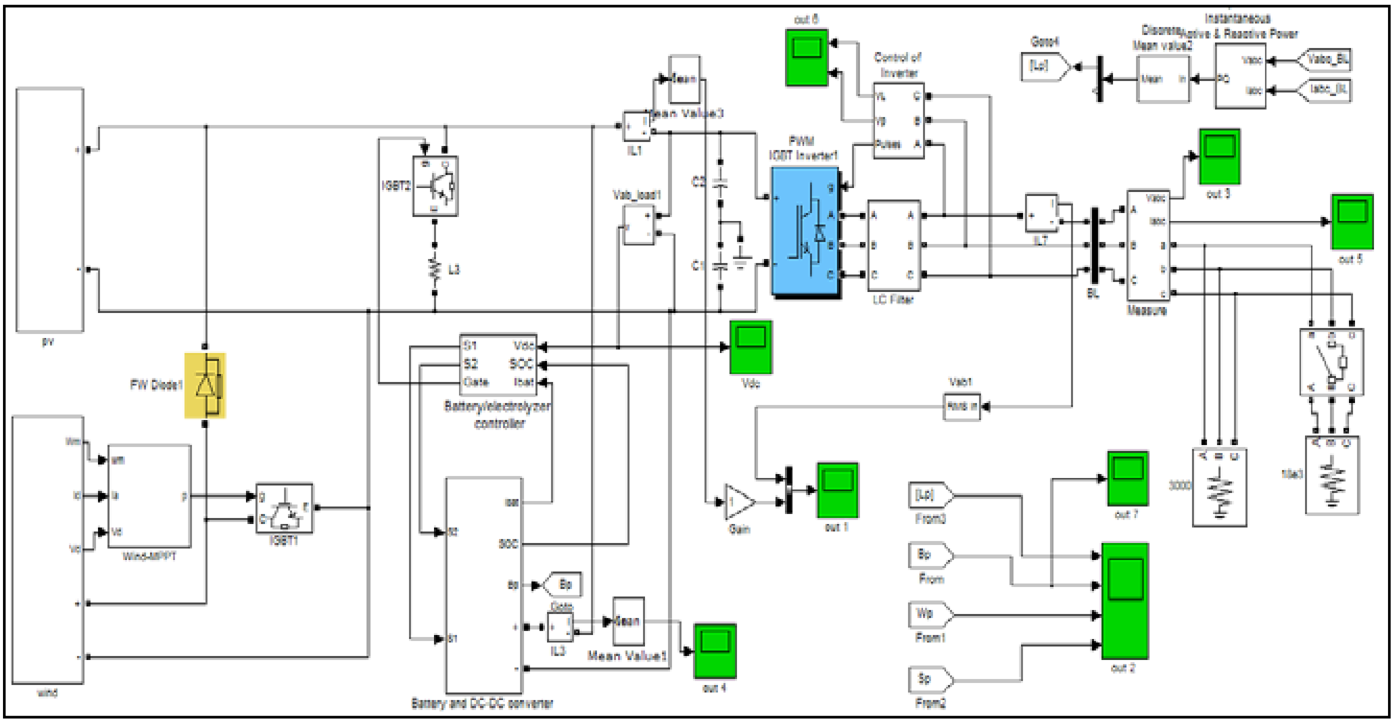

Fig. 5: Simulation diagram for Hybrid Wind-PV System

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 the changes occur in either wind or solar plants.
- 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 thesis we suddenly applied the load during the time of 1 to 2 sec and then in this period the current rises.
- Figure 8 shows the wave form for powers which are obtained from the solar plant and wind energy system and with this the line power is depended. Figure 9 shows the simulation result for wind turbine output voltage.
- Figure 10 show the simulation result of output power from the battery system.

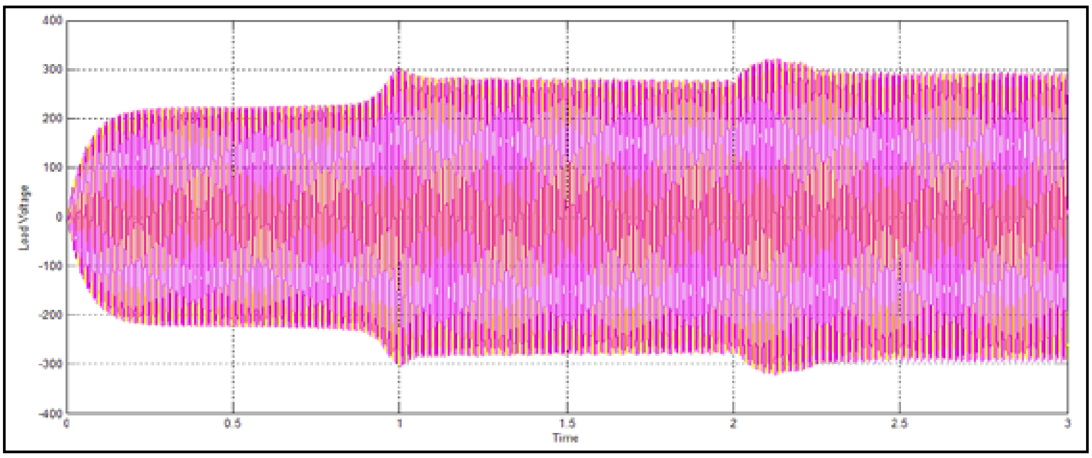

Fig. 6: Output load voltage

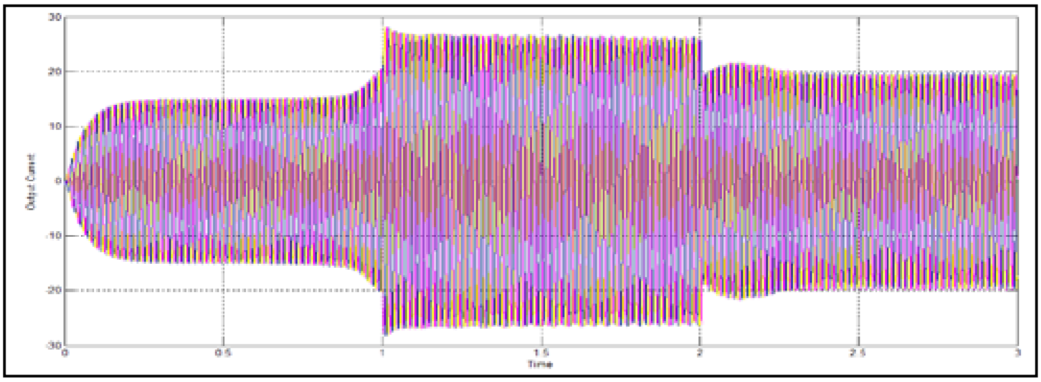

Fig. 7: Output load current

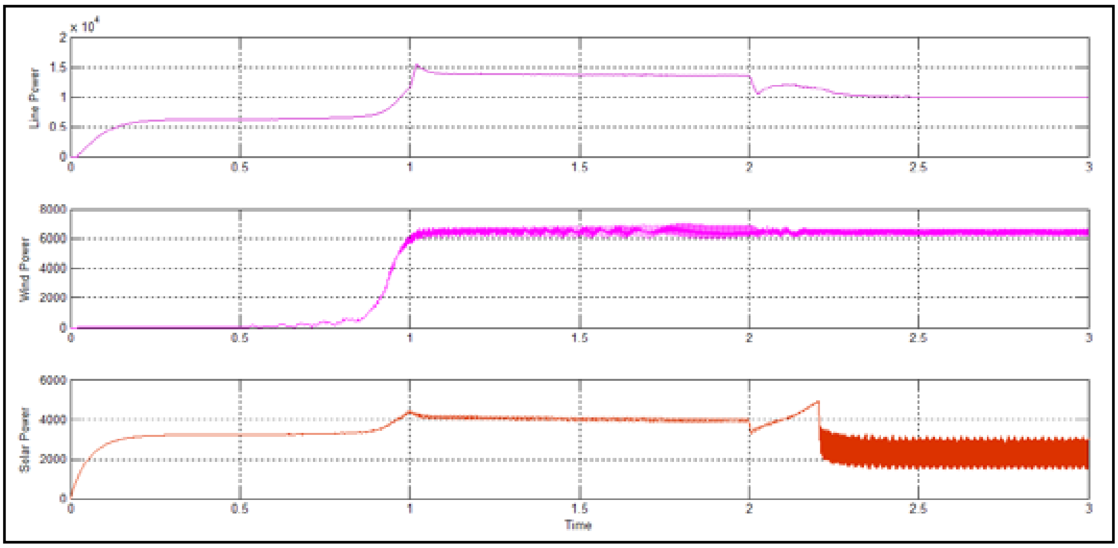

Fig. 8: Powers: Line, Wind, Solar

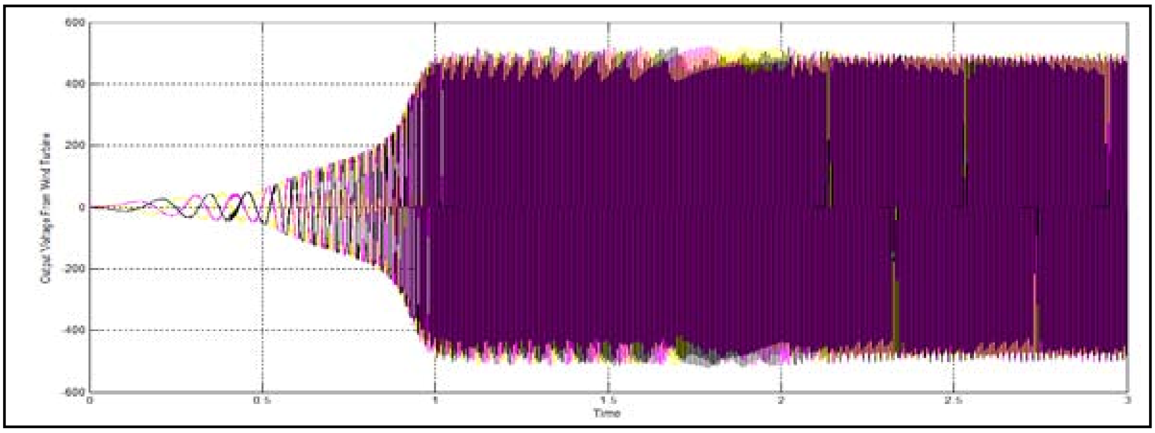

Fig. 9: Output voltage from wind dystem

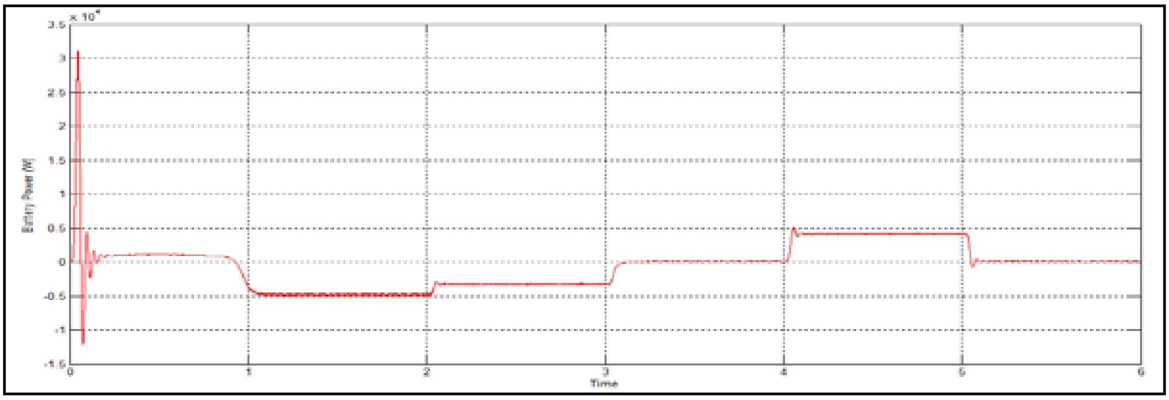

Fig.10: Output Voltage from battery power

ISSN : 2394-2975 (Online)
ISSN : 2394-6814 (Print)

Conclusion

Output from solar and wind system is converted into AC power 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.

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