MATLAB/Simulink modeling of solar PV and wind turbine based hybrid energy system

[1]Ankit Goyal, [2]R S Rajput, [3]Sunil Kumar Gupta
[1]Reserch Scholar, [2]Profossor, [3]Professor
[1] Department of Mechanical Engineering,
[1] UIT, Rajiv Gandhi Proudyogiki Vishwavidyalaya Bhopal-462033, India

Abstract : This paper presents a method to operate a stand-alone hybrid energy system (HES).The HES composed of a solar photovoltaic (PV) array and a wind turbine is considered. In this paper, the mathematical analysis and MATLAB modeling of the proposed system based on solar PV and wind turbine hybrid energy system developed the academic building. Using well-designed stand-alone HESs, investigate the possibility of supply of electrical power in the Institute area. The site selected for the study is located at 23° 31' N latitude and 77°36'E longitude. From the results of the MATLAB/Simulink analysis, it can be safely concluded the introduced, HES is successful in meeting the load requirements of the educational institutions throughout the year and handle the variation in load profile.

***Index Terms*-Solar PV, Wind Turbine, Battery, Mathematical modeling, MATLAB.**

1. INTRODUCTION

Hybrid Energy System (HES) where a number of renewable energy sources along with electrical energy storage components are hybrid together to operate as a reliable power source and meet the electrical demand of a load [1-3]. They can be either grid-connected or stand-alone installations depending on the application and geography of the site [4]. Electrification of rural villages and other sites which are too far from the general load centers using electricity from the grid would be an extremely costly affair, considering the costs incurred in grid extension and the transmission and distribution losses. This is where autonomous energy systems like stand-alone HES come into prominence and serve as the key to the energy problems faced by such off-grid communities [5,6]. HES employs various components such as solar PV panel, wind turbine, micro hydro-turbine, fuel cell etc. which generate energy, battery banks, capacitors etc. which store energy and act as a backup power source, and power conditioning units consisting of power electronic circuits like choppers, inverters etc. The type of components to be employed in the HES is chosen according to the availability of energy resources and the application.

The hybrid energy system (HES) under consideration consists of two power generating units, i.e., a solar PV and wind turbine. A battery bank used as a power storage system [7,8]. A block diagram of the HES solar PV and wind power is shown in Figure 1. The battery bank to extract the maximum available power from the wind and solar PV energy sources are used to store the surplus energy and to supply the load during times of lean power production by the renewable resources [9-12]. The output of both solar PV panels and the wind turbine are in the DC form. Both the sources along with the battery are connected to a common DC link. The DC to DC converter may be used to step up the DC level available from the bus. The DC to AC inverter is used to interface the DC link voltage and the DC battery voltage to the electrical load requirements. The electrical power produced from each solar PV or/and the wind turbine is transferred to the electrical load through the inverter, while the electrical power surplus is used to charge the batteries [13-15]. The mathematical modeling of solar PV, Wind energy system, battery, DC to DC boost chopper, DC to AC inverter and LC filter has been discussed.

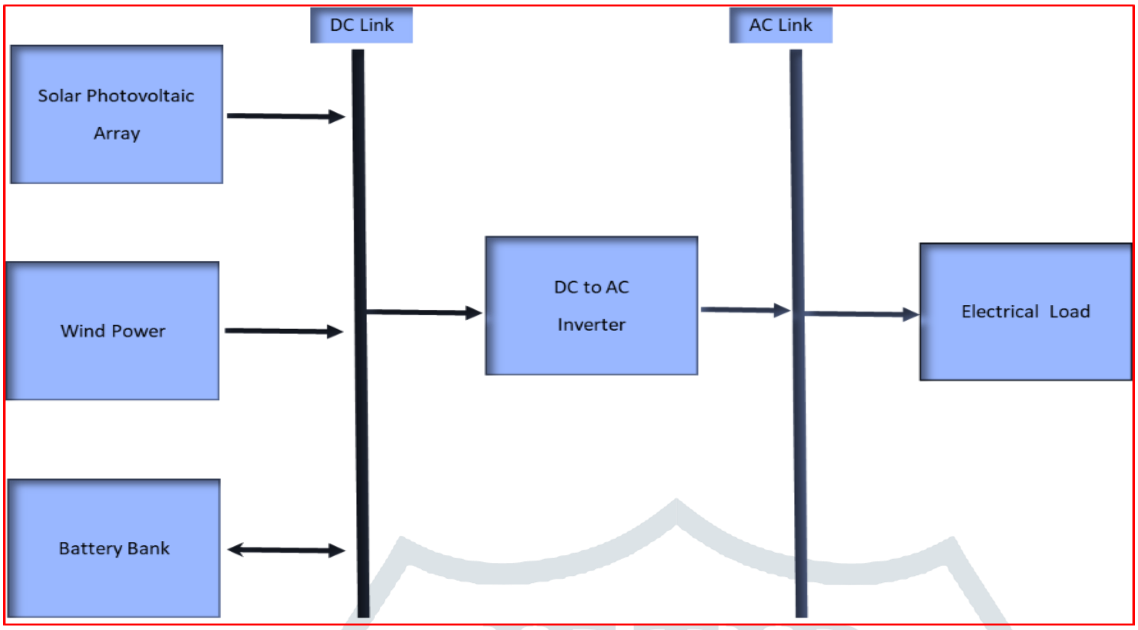

Figure.1: Block diagram of solar PV, wind turbine and battery based hybrid energy systems

2. MATLAB SIMULATION MODEL

For investigating the dynamic performance of the proposed system all the individual components of the hybrid energy system are simulated in MATLAB/Simulink (R2017a) software [16,17]. MATLAB/Simulink model used for the simulation, the proposed model is shown in Figure 2. The power generated by the solar PV would be in low voltage level (48 V) DC form, which is first step up to a higher voltage level using a DC to DC step up (100 V) chopper [18]. Wind turbine generated AC power using AC to DC converter, convert AC to DC which is first step up to a higher voltage level using a DC to DC step up (100 V) chopper. Using DC to AC inverter converted DC to AC and Finally, the AC voltage level is stepped up using a three-phase transformer (230V Line-Line), connected in AC electrical power is supplied to load demand [19,20].

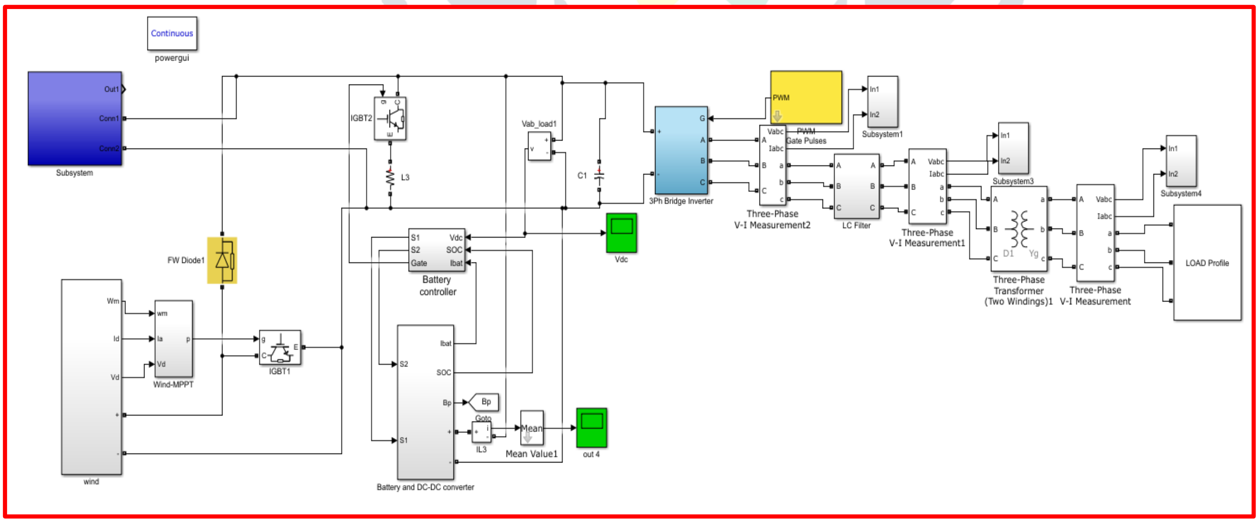

Figure 2: The proposed MATLAB Simulink model of a hybrid energy system.

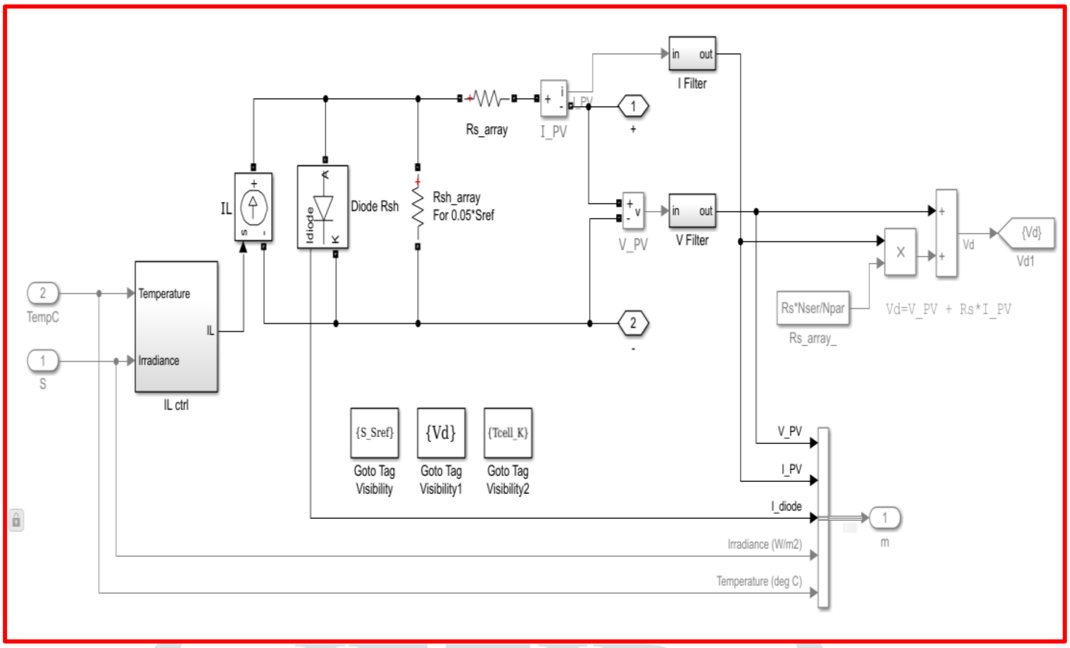

Figure 3: Simulink Model of Solar Photovoltaic (PV)

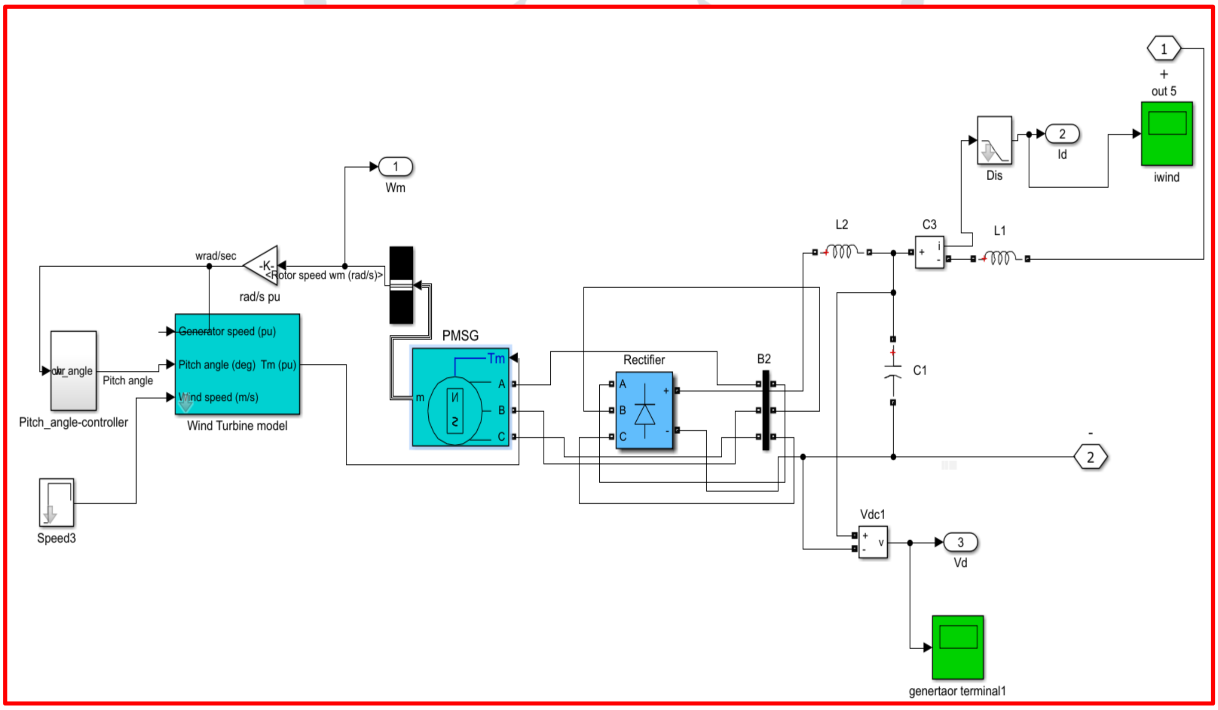

Figure 4: Simulink Model of Wind energy system

3. RESULTS AND DISCUSSION

In this section results analysis of a model in the proposed system is developed using MATLAB Simulink platform. Using MATLAB software find the V-I characteristics and the power curve of a single photovoltaic module using 36 solar cells have been shown in Figure.5 and array of solar photovoltaic of with different solar irradiation have been shown in Figure.6. Figure.7 showing the array of solar photovoltaic of with different temperature.

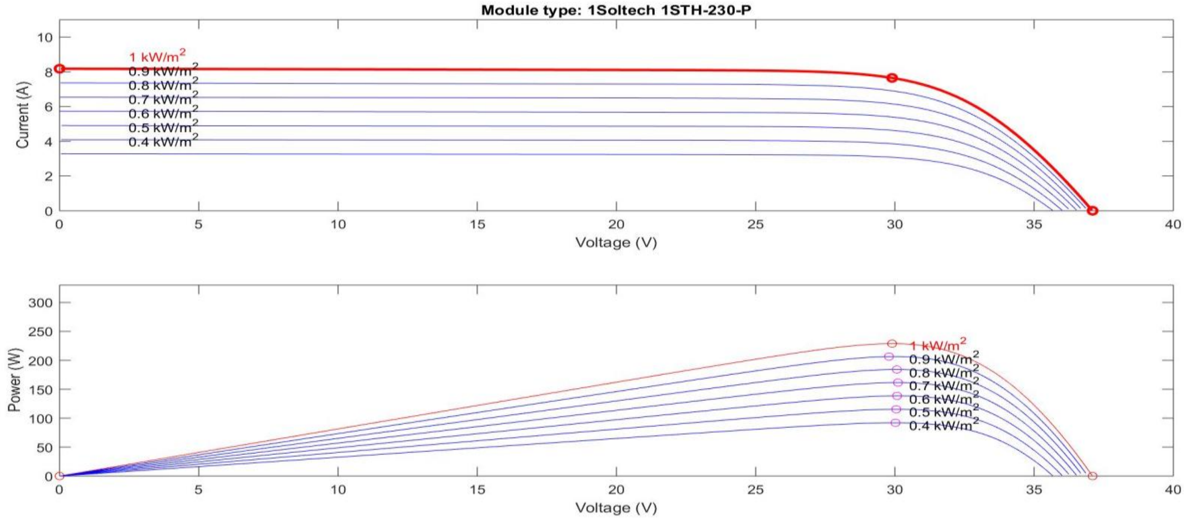

Figure.5 Module power, voltage and current waveform with different radiation.

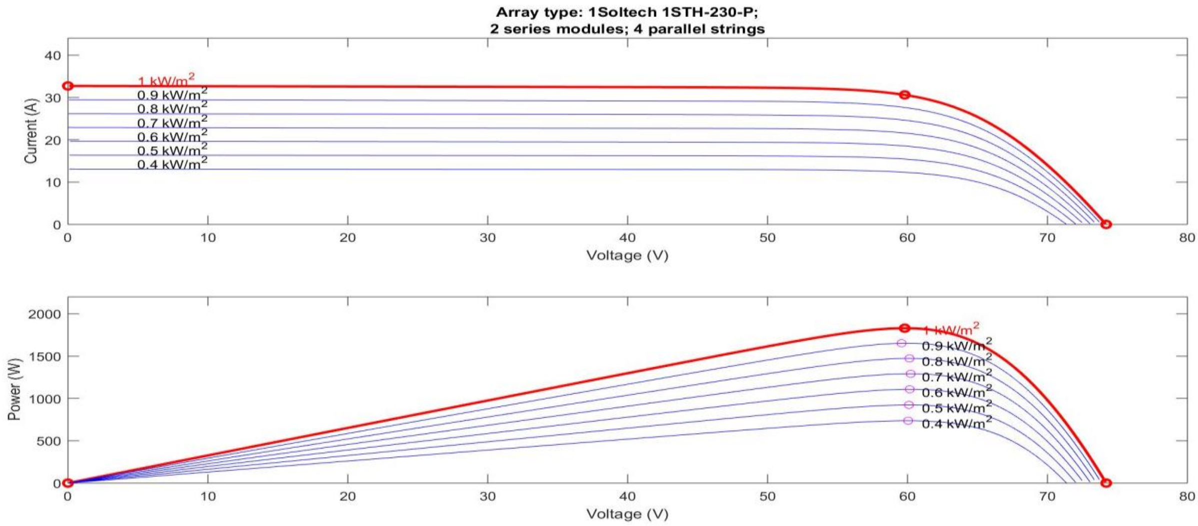

Figure.6 Array power, voltage and current waveform with different radiation.

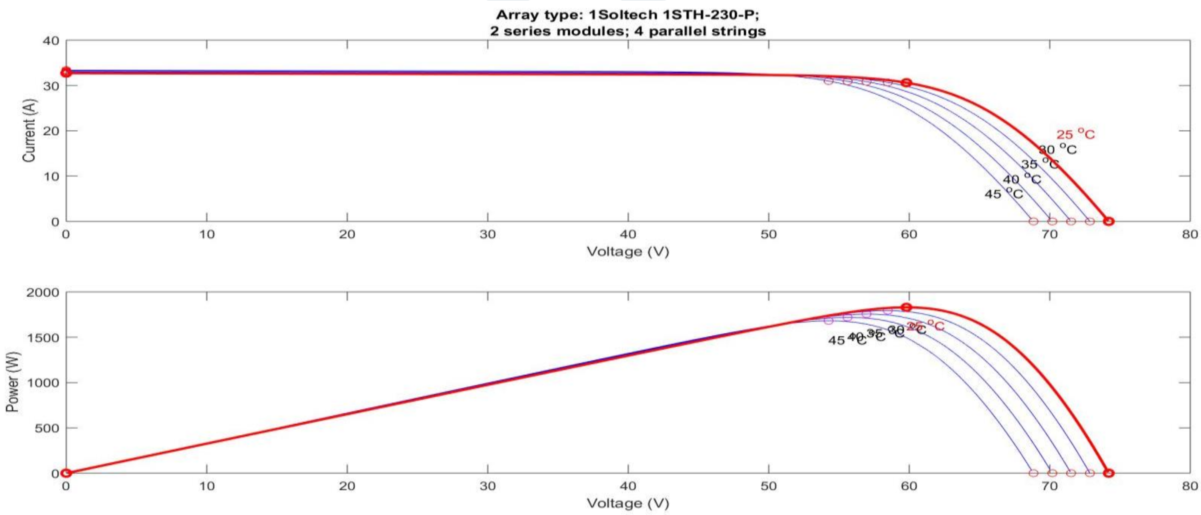

Figure.7 Array power, voltage and current waveform with different temperature.

Figure 8 shows the voltage at the output of the DC to DC boost converter. The inverter converts the Voltage from 100V DC to three phase 100V AC is shown in Figure 9. The output voltage of the inverter is a stepped wave and not sinusoidal wave. To crate sinusoidal wave using a low pass LC filter is employed at the output terminal of the inverter. The LC filter with transformer converts 100V AC stepped waveform to 230V AC sinusoidal is shown in Figure 10. Figure 11 shows the load current waveform and figure 16 shown the output load power.

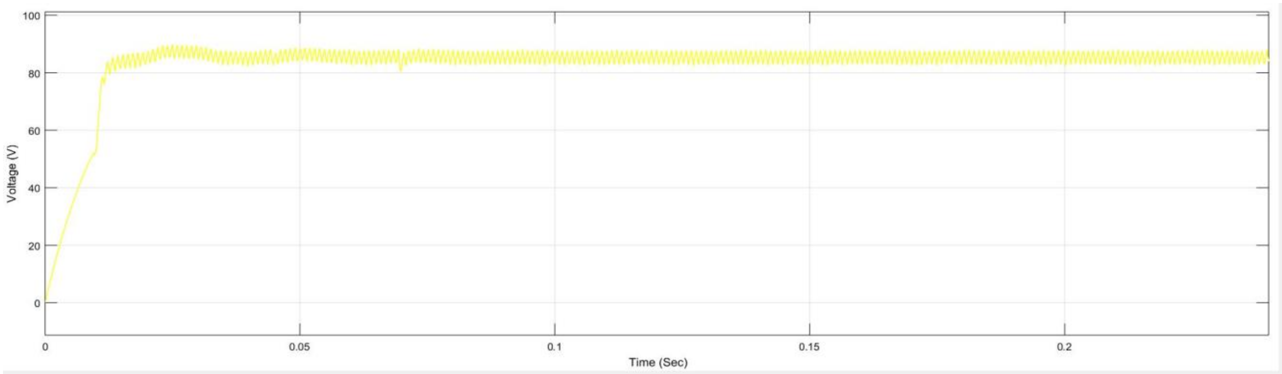

Figure 8 Voltage at the output of the DC to DC boost converter.

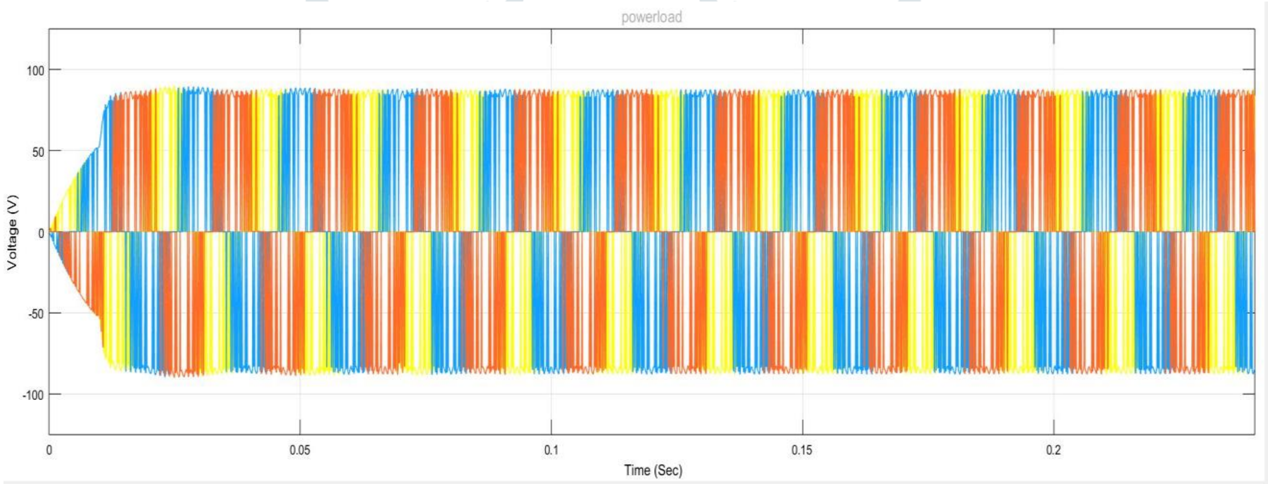

Figure 9 Voltage at the output of the DC to AC converter.

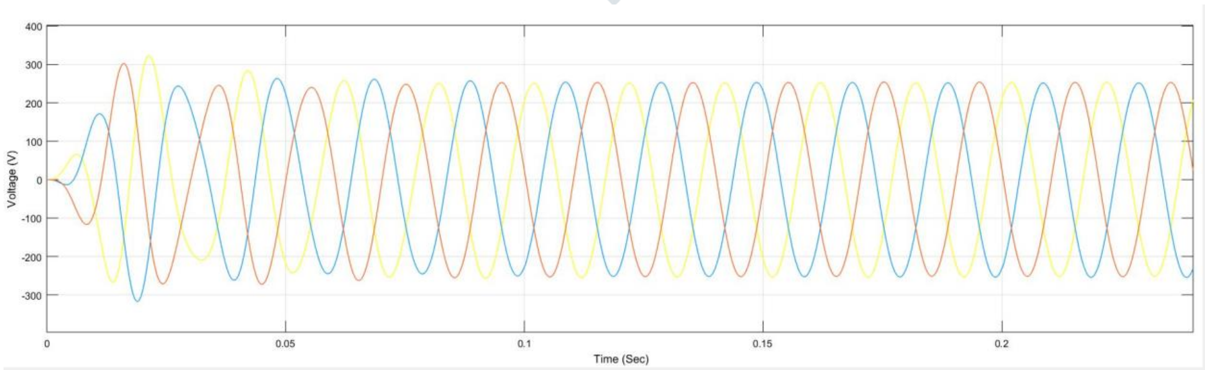

Figure 10. The LC filter with transformer converts 100V AC stepped waveform to 230V AC sinusoidal

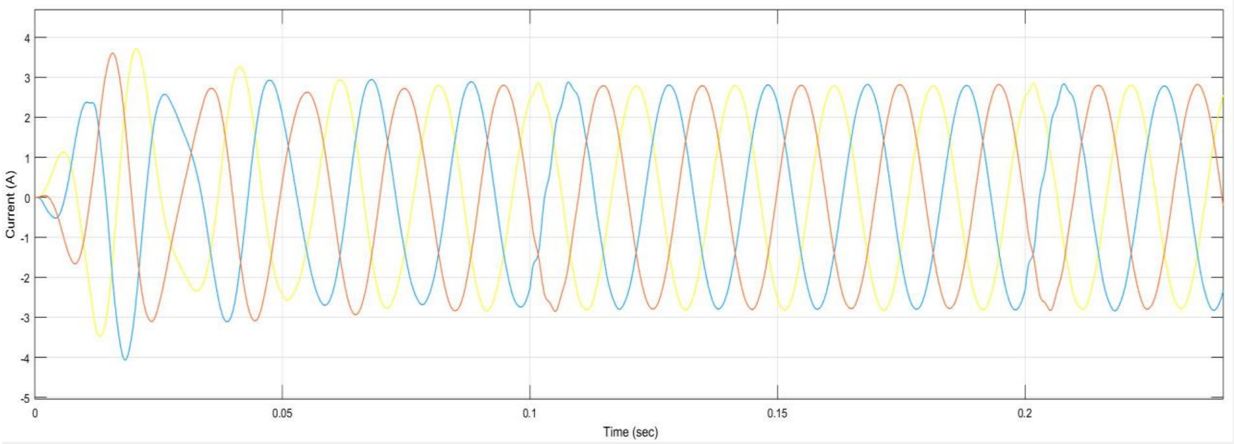

Figure 11 load current waveform

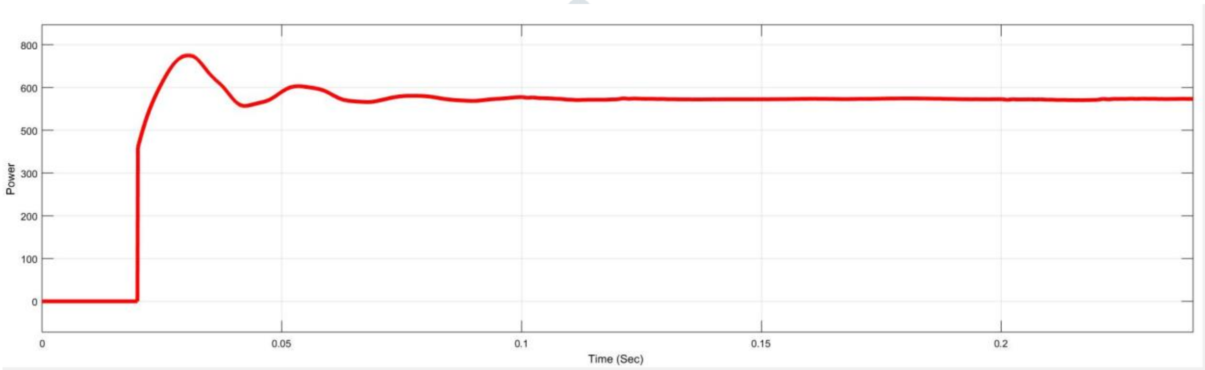

Figure 12 load power waveform

4. CONCLUSION

Hybrid Energy Systems (HES) are emerging as the most popular and effective solution for energy supply problems encountered in many parts of the world. They can be employed either as grid-connected systems or stand-alone systems depending upon the site and application. Stand-alone Hybrid Energy Systems which uses renewable energy sources, serve as reliable and clean sources of energy and have huge scope especially in areas that are isolated and not connected to the utility grid. This paper has investigated the prospect of supplying electrical energy to the educational institute, University Institute of Technology RGPV Bhopal, Madhya Pradesh. The proposed HES consists of two sources i.e. solar PV system and wind turbine system with a battery which acts as the backup source. The power generated by the sources would be in low voltage DC form, which is first boosted to a higher voltage level using a DC/DC boost chopper, then converted to sinusoidal three-phase AC form using a three-phase inverter and LC filter. Finally, the AC voltage level is stepped up using a three-phase transformer and then the power is supplied to load. As the initial step, the mathematical model of each component of the HES has been developed for a clear understanding of their characteristics. To examine the behavior of the system under varying load demand, dynamic model of the HES and its components were developed on MATLAB Simulink platform.

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