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Modeling and Simulation of Controller for Solar Photovoltaic System

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Abstract— Solar energy photons incident on the earth surface are variable in nature. So to achieve maximum power from the PV module is necessary, which can only be achieved by MPPT applied to the boost converter. To track the MPP, there are some specific approaches like: P&O, incremental conductance and open circuit voltage. They all have their specific qualities and used as per requirements. But in this research work P&O technique is used for MPPT. The DC output voltage is converted to AC voltage using inverter. The technique used in inverter is as current control technique for voltage source inverter. From this inverter rectangular pulse supply is generated, which further filtered by LC or LCL filters as per requirement. But in this paper a normal LC filter is used. This complete design is installed in MATLAB/SIMULINK for simulate the designed models and the results are verified at many operating points to check the system stability, quality and effectiveness.

Keywords: — MPPT, Boost Converter, Inverter, Filter and Photovoltaic.

I. INTRODUCTION

India is a densely populated and developing country. The factors influencing its status are very common but lack of electricity is also a big issue in the development of this country. This factor can be eliminated by providing estimated electricity to the increasing load demands. In rural areas where power supply is very unstable due to lack of quantity, there renewable power generation takes place for that small need. Solar power generation also generates by two ways: solar photo voltaic and solar thermal. The power generation from solar photo voltaic depends upon external parameters as irradiance and temperature. These two parameters are almost variable in nature at every instant. So it is hard to get stable output voltage from the cell. The efficiency of conversion is also very low and the signal converters make the voltage worst. To get constant voltage at any time the maximum power point tracking techniques are used.

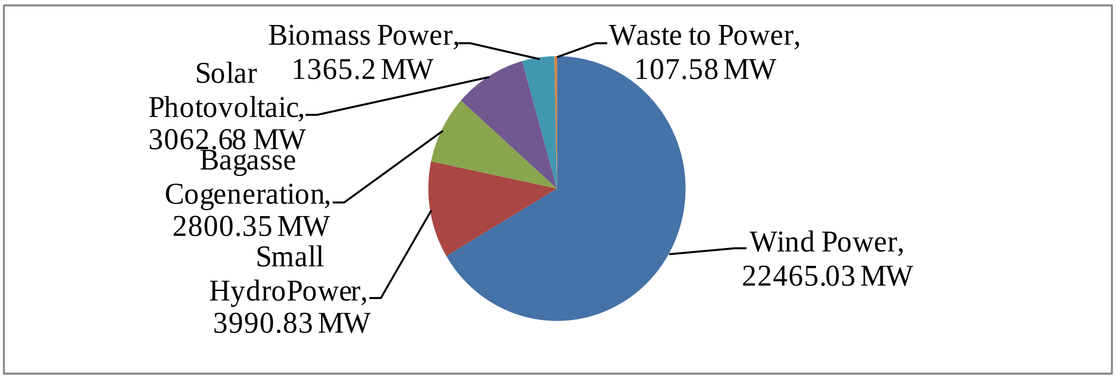

Figure 1. Renewable energy by installed capacity in India

As the latest trend of electricity generation is concentrated on renewable energy source. At present the installed capacity of renewable energy has touched 32,269.6 MW, as on March 31, 2014. The Ministry of New & Renewable Energy (MNRE), Government of India has set a target of achieving

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overall renewable energy installed capacity of 41,400 Mw by 2017. So the growing contribution of those resources as on December 2014 is given in figure 1. In this research work the proper use of inverter current control technique is used. This makes the output voltage more accurate to AC.

II. MODELING AND SIMULATION OF PV ARRAY

A typical PV cell generates around 1 Volt depending on the type of semiconductor material used and its make technology. To increase this voltage, several cells are connected in series or parallel to form PV module and many such arrays forms an array. The working principle of a PV cell is based on the photovoltaic effect. The circuit diagram is presented in figure 2.

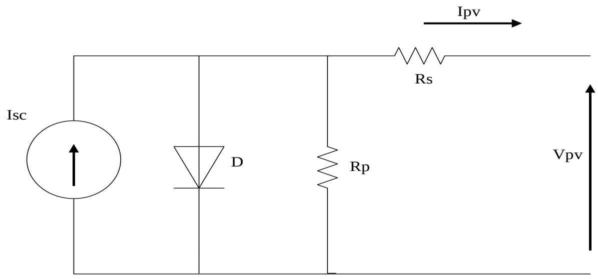

Figure 2. Circuit model for solar cell module

The mathematical equations of SPV system on the basis of which this complete analysis can be done in MATLAB/SIMULINK software. The photocurrent equation is the module photocurrent of the photovoltaic module depends linearly on the solar irradiation and is also influenced by the temperature according to the following equation

$$I_{ph} = [I_{sc} + K_i * (T_k - T_{ref})] * \lambda/1000 \quad (1)$$

Reverse saturation current equation is given as

$$I_{rs} = I_{sc}/[\exp(qV_{oc}/N_s kAT)-1] \quad (2)$$

Module saturation current varies with the variation in cell temperature, which is given as

$$I_o = I_{rs} (T/T_{ref})\text{^}(3) \exp[qE_{g0}/Ak*(1/T_{ref} -1/T)] \quad (3)$$

The basic equation which describes the output current of the PV module of single-diode model is given as

$$I_{PV} = I_{ph}N_P - N_P I_o \left[\exp\left\{\frac{q(V_{PV} + I_{PV}Rs)}{N_s AkT}\right\} - 1\right] \quad (4)$$

2.1. PV Array Simulation Analysis

On the basis of all current equations and varying atmospheric parameters, the P-V and I-V characteristics are derived at different solar irradiance and temperature. The results are correlated to each other also. In the below diagram, the solar panel characteristics can be derived clearly. After implementing all equations, the simulation results are derived at different solar irradiance and temperature.

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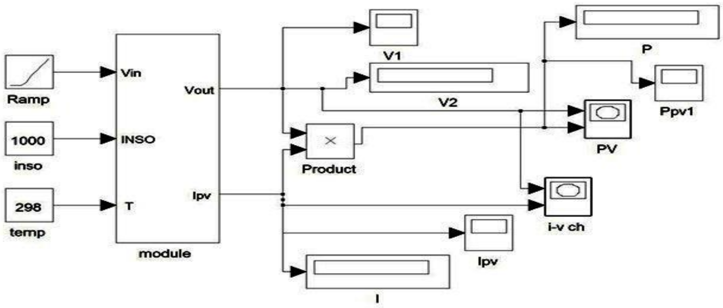

Figure 3. MATLAB/SIMULINK model for P-V and I-V characteristics

2.1.1. Performance Analysis of PV Array at Different Solar Irradiance

The flux of incident light per unit area considered as irradiance. With the increasing solar irradiance both the open circuit voltage and the short circuit current increases and hence the maximum power point varies. The solar irradiance or insolation is varying continuously, so the characteristics changes continuously. At different locations this data also changes with time.

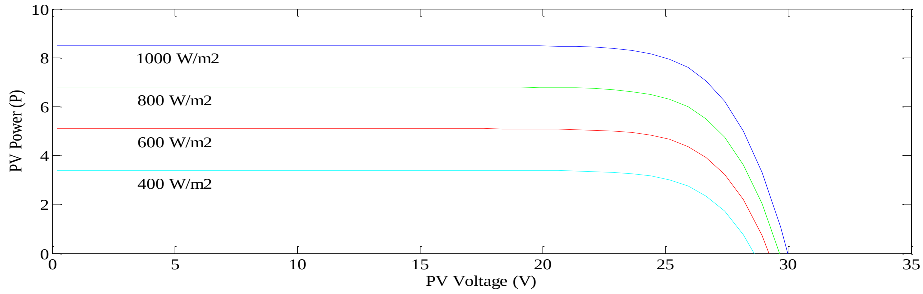

Figure 4. I-V characteristics at various irradiances and constant temperature

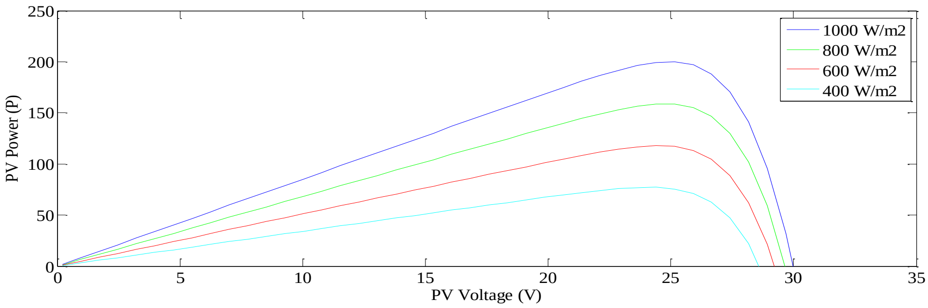

Figure 5. P-V characteristics at various irradiances and constant temperature

2.1.2. Performance analysis of PV array at different temperature

As the temperature increases the rate of photon generation increases thus reverse saturation current increases rapidly and this reduces the band gap. Hence this leads to marginal changes in current but major changes in voltage. The cell voltage reduces by 2.2mV per degree rise of temperature. Temperature acts like a negative factor affecting solar cell performance. Therefore solar cells give their full performance on cold and sunny days rather on hot and sunny weather.

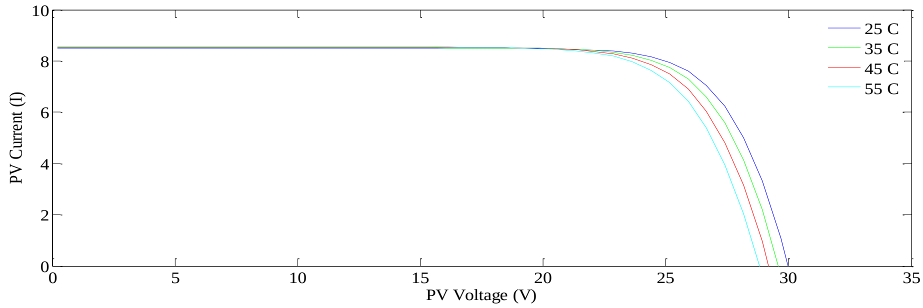

Figure 6. I-V characteristics at various temperatures and constant irradiance

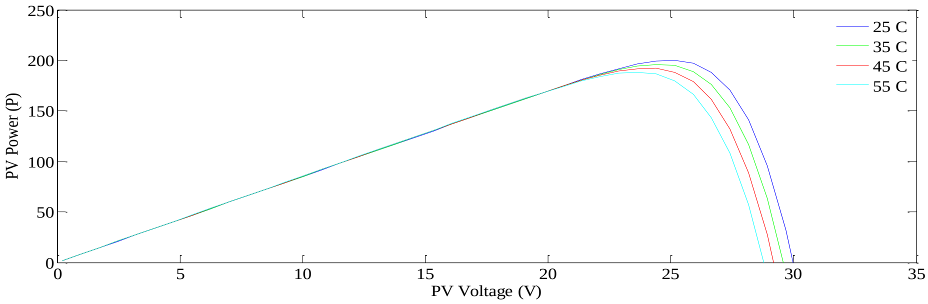

Figure 7. P-V characteristics at various temperatures and constant irradiance

III. CONTROLLERS FOR PV SYSTEM

The proposed system mainly consists of PV array, DC-DC converter with MPPT control and a single phase inverter along with control algorithm. This proposed system is defined as below-

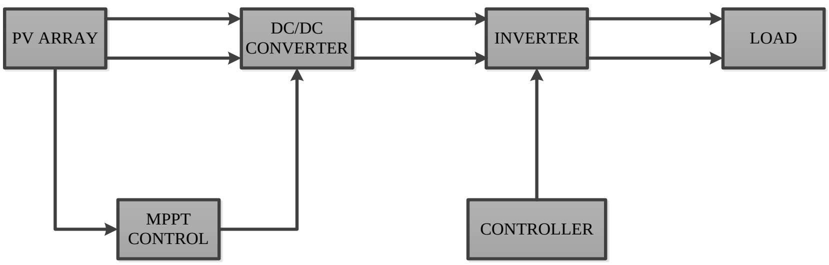

Figure 8. Block diagram of Single phase PV system

The power electronic controllers are modeling and simulating in this paper now. The MATLAB/SIMULINK software is used to perform the model process. The simulation model of boost converter with MPPT control as P&O is shown here.

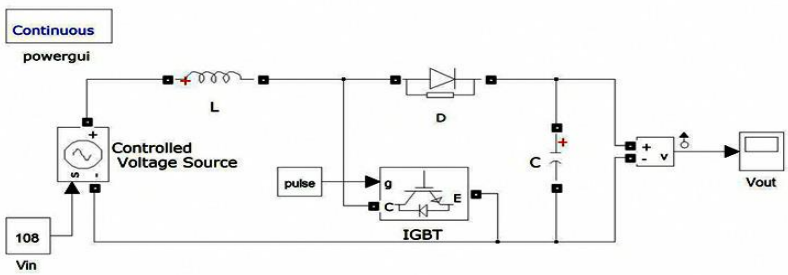

Figure 9. Simulation model of boost converter

The output voltage of boost converter is given in figure 10.

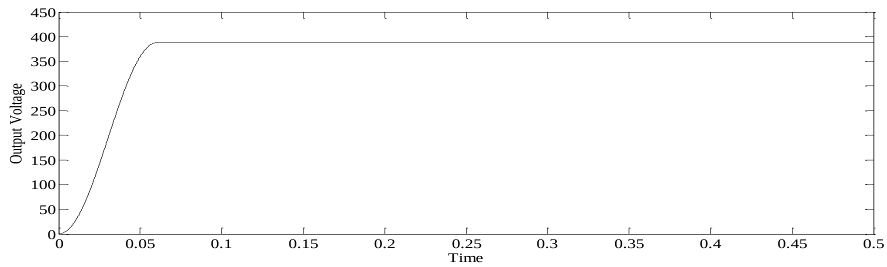

Figure 10. Boost Converter output voltage characteristics

This inverter topology is modeled in simulation software and detailed diagram is shown in figure 11. In this figure LC filter is also attached to filter out the harmonics. This arrangement gives the sinusoidal supply to the load connected.

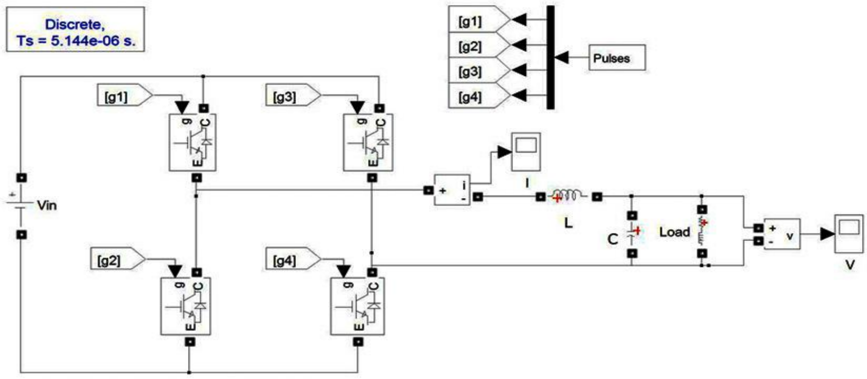

Figure 11. Simulink model of inverter

Inverter output voltage is shown in figure 12. This is the voltage signal without applying filter. The output of this inverter with filters is given in figure 13; this shows a perfect sinusoidal output voltage.

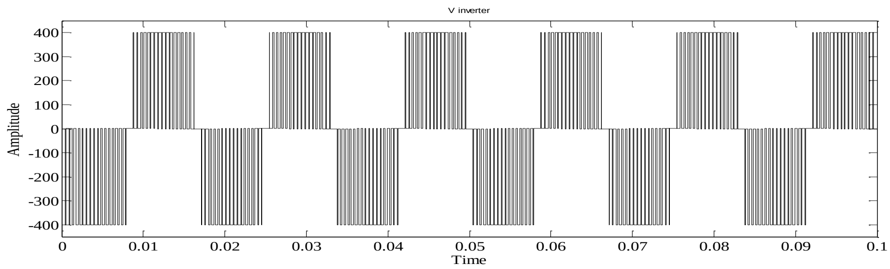

Figure 12. Inverter output voltage (without filter)

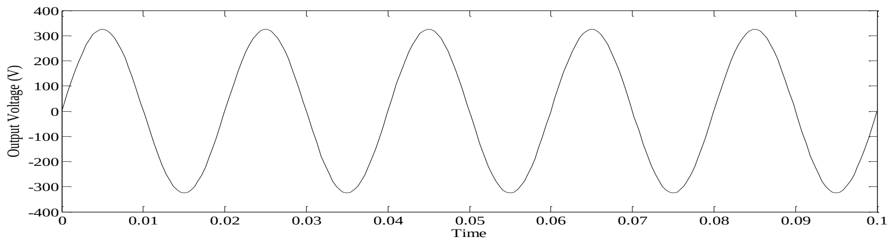

Figure 13. Inverter output voltage (after filtering)

3.1. Standalone System

In this section a combined model of single phase standalone SPV system is presented. In which all the above defined parameters are inbuilt. On the basis of which this model works and the complete analysis gives the simulation results.

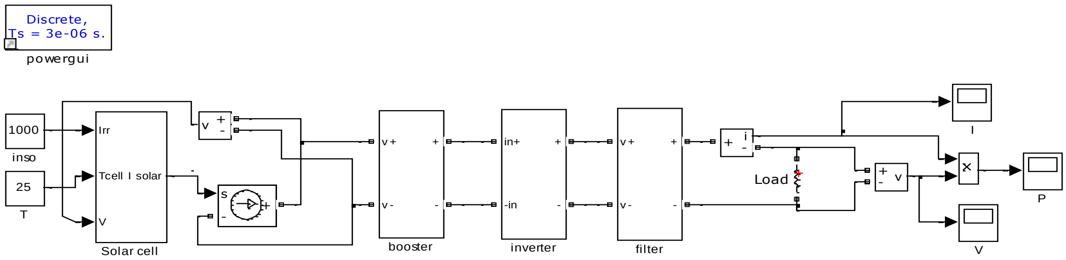

Figure 14. Simulation model for single phase standalone system

IV. RESULTS

The complete modeling of solar photovoltaic system cosists different voltage profiles. The PV panel output voltage is the main factor to make the further components to design in that manner, in which the exact correlation meets the desired output from the complete system. The PV voltage is given in Figure 15.

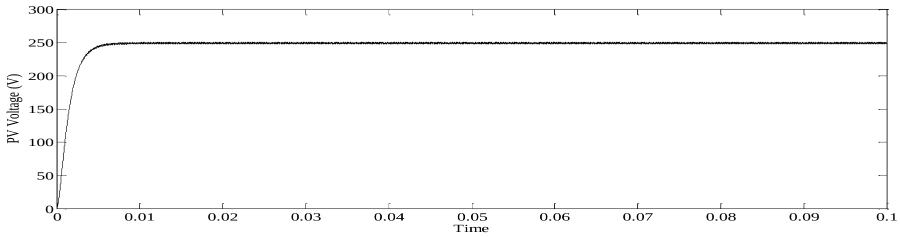

Figure 15. Output voltage waveform of PV panel

The current drawing by the load from PV panel is varied in a range, and the PV panel output power is also monitored for the perfect system health. That power graph should be in a well planed shape, which is given in Figure 16.

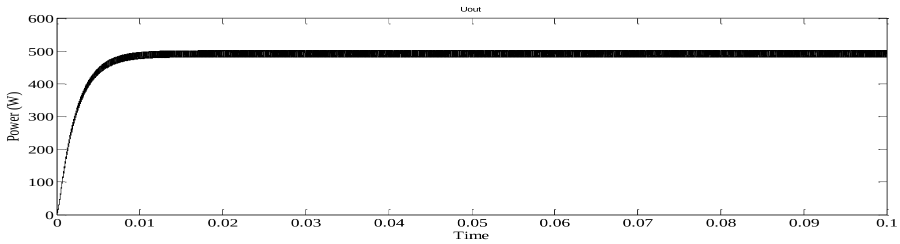

Figure 16. Waveform of output power for PV panel

At every step of the system, there is a voltage change according to the converter used. Like the voltage between boost converter and inverter is DC link voltage. This voltage is given as in Figure 17.

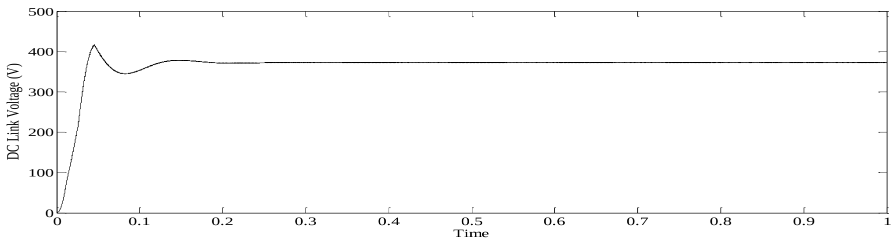

Figure 17. Waveform for DC Link Voltage

At the end of the system, a load is connected to handle the supply power. And the load current is shown below in figure 18. This current depends upon the load connected.

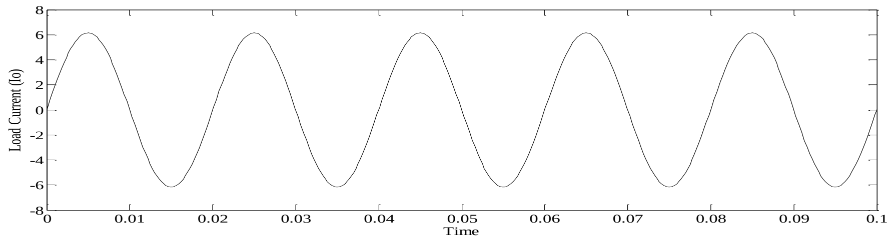

Figure 18. System Load Current waveform

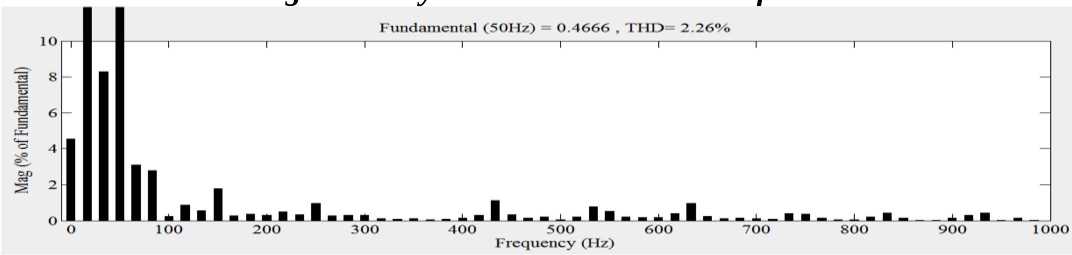

Figure 19. Total harmonic distortion in load current

THD analysis of inverter output current of the developed system has been done and it is found 2.26%, which is in permissible limit.

V. CONCLUSION

The objective of this project is to design, modeling and simulation of standalone PV system. Modeling & simulation of the proposed system has been done using MATLAB/SIMULINK platform. Standalone SPV system consists of solar PV array, DC/DC boost converter with MPPT controller and a single phase H-bridge inverter. P-V and I-V characteristics are obtained for the developed PV array (1000W) with different solar irradiance and temperature conditions. The simulated results for single phase standalone PV system clearly shows the ability of the proposed control schemes to track MPP power from the PV module. The current controller provides robust controlling method for the inverters as well as protects the PV system. The implemented schemes derive the advantage of simplicity and are capable of delivering power effectively.

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