Simulation and Modelling of Photovoltaic Power Conversion System

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ABSTRACT
Fossil fuels energy consumption leads to the major global problems such as shortage of energy and the climate changes and these problems can be solved by efficient use of renewable energy resources. Photovoltaic power generation is expanding rapidly because of the growing interest in the renewable energy resources. In this paper, detailed photovoltaic system is designed using MATLAB/SIMULINK. The combination of the PV array, dc-dc converter, and single phase dc-ac inverter is designed for the power generation. The battery bank or the other sources will be connected as a backup for the emergent situations. The main aim is to design such a system which provides constant supply to the ac load by considering various changes in the operating conditions of the PV array by SimPower system toolbox of the SIMULINK/MATLAB software.

Keywords
Photovoltaic PV system, boost converter, inverter, matlab simulations.

1. INTRODUCTION
Increasing electricity demand, minimal reserves of fossil fuels and global environmental concerns are the main factors which motivate the use of renewable energy in India. Solar energy is available in profusion but the high initial investment and non-uniformity are the disputed points associated with the solar energy. Solar Photovoltaic is a field of solar energy utilization by which solar radiation is converted into electricity or electrical energy through photoelectric effect. Solar cells must be connected in series to form a solar module and these modules are further connected either in series or parallel to form an array of photovoltaic [1] as shown in fig1. Photovoltaic technologies use both direct and scattered sunlight to create electricity. The solar energy across much of the world is energy of future and it contributes to the ecology and economy. However, the amount of power generated by a photovoltaic system at a particular site depends on how much of the sun's radiation reaches that area and this metrological data can be estimated by knowing the latitude and longitude of that particular site. As a stand-alone system, photovoltaic will not provide continuous power because of the intermittent nature of the sunshine. Therefore, it is necessary that solar must be combined with an energy storage system or another energy production technology allowing it to ride through periods of low solar activity. The main reason for the deployment of the renewable energy system are their benefits, such as supply security, reduced carbon emission, and improved power quality, reliability and employment opportunity to the local people.

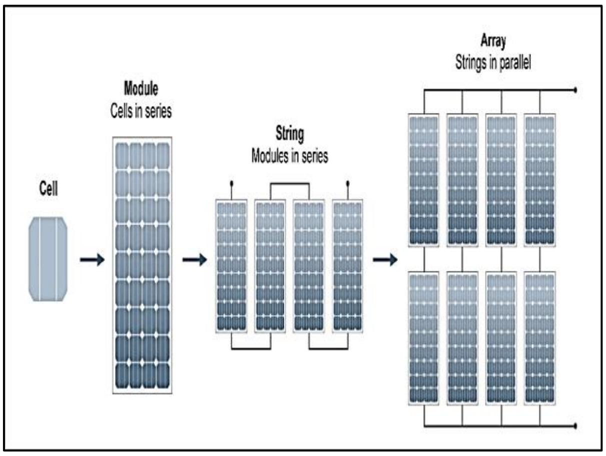

Fig1: cell-module-array

In this paper, renewable energy based power generation system consist of PV array, dc-dc boost converter, dc-ac single phase inverter, battery, filter and load as shown in fig2. However, the main drawback is the intermittent nature of solar radiation and in that case MPPT make the PV system achieving its maximum power [2] [4]. This paper discuss the detailed study of the PV array which is connected to the local loads through the boost converter to step up the PV output and DC/AC inverter to convert the DC output of the PV array into the AC supply to the local utilities. The output of the inverter is connected to filter for the pure sinusoidal supply. The entire components of the model are formulated under MATLAB/SIMULINK software. The simulated results show the validity of the model.

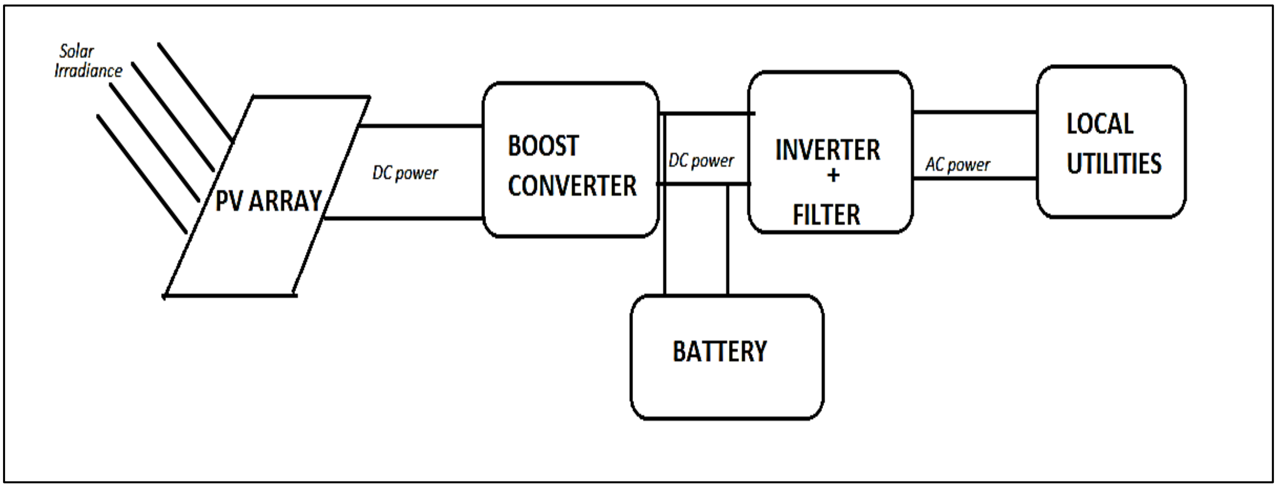

Fig2: Basic model of photovoltaic power generation

2. SYSTEM MODELLING

2.1 Modeling of PV Array

Several models have been proposed by the researchers in the MATLAB/SIMULINK. In some cases irradiance and the cell temperature are considered as the input parameters and some proposed a model of PV array based on the basic electrical circuit of the solar cell considering the effects of various parameters [3][7]. In this, the design of the model is based on the equivalent circuit of the solar cell and the basic circuit equivalent equation of the parameters including the irradiance effect on the characteristics of the solar cell.

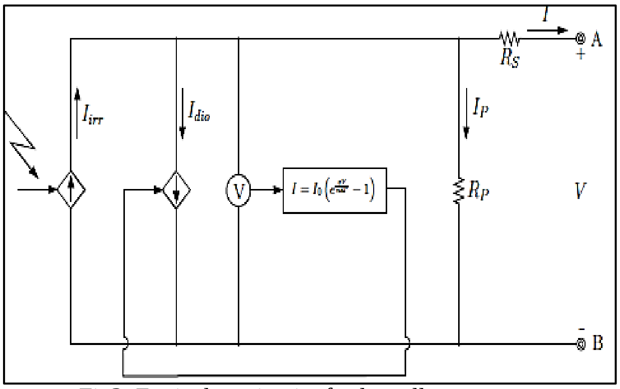

Fig3: Equivalent circuit of solar cell

In this paper, detailed I-V parameters are developed for a cell, a module and an array in series and parallel. The Simulink model predicts the I-V and P-V characteristics by considering the varying irradiance. The equivalent circuit of the solar cell comprises of a controlled current source, a diode, a series resistance (R_s) and a shunt resistance (R_p). The antiparallel diode is modified to an external controlled current source which is placed antiparallel with the original source [1] [5] [6].

According to Kirchhoff's current law,

$$I = Irr - Id - Ip$$

I-V relationship for a single solar cell is given by the equation:

$$I = I = Irr - Io[e^{\frac{q(V+IRs)}{nKT}} - 1] - \frac{V + IRs}{Rp}$$

where,

$I_{rr,}$ is the photocurrent or irradiance and it varies linearly with the radiations for certain cell temperature
$I_{0,}$ is the saturation current of antiparallel diode
n, is the ideality factor or the emissivity factor
Boltzmann constant (K=1.3806503 × 10^{-23} J/K)

$N_{S,}$ be the no. of cells connected in series to form a photovoltaic module and hence the equation thus obtained as:

$$Ip = Irr - Io[e^{\frac{q(V+IRs)}{Ns\, nKT}} - 1] - \frac{V + INs\ Rs}{Np\ Rp}$$

The above relation is not limited up to one module only because

No. of cells in series (N_s) =
No. of modules in series × No. of cells in series in each module [1].

Now, for a PV array in which N_s be no. of cells in series and N_p be the no. of strings in parallel, then the I-V relationship thus obtained as:

$$Im = Np\ Irr - Np\ Io[e^{\frac{q(V+IN'Rs)}{nN'KT}} - 1] - \frac{V + IN'Rs}{N'Rp}$$

Where,

$$N' = Ns/Np$$

The model for the PV system was designed in the Matlab/Simulink based on the equivalent circuit given in the fig4. In this, I_m is the input parameter applied to the current source and can be estimated by the I-V relation of the array given in the above equation.

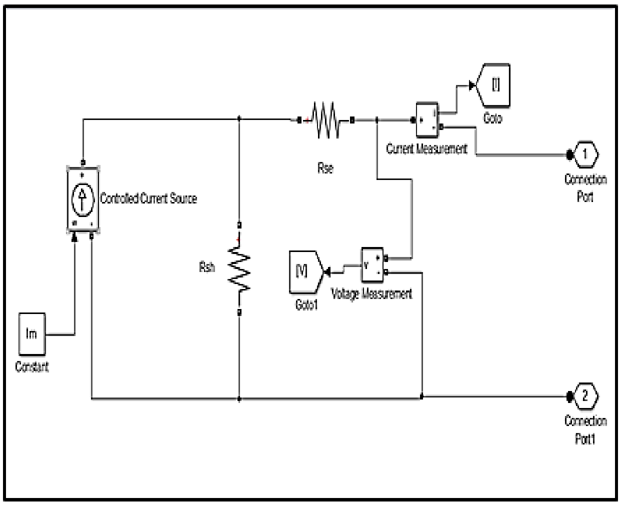

Fig4: Equivalent circuit of PV system in the Simulink with Im as input port and the output ports connected to the subsystem

2.2 DC-DC Boost Converter Model

The basic circuit diagram for the DC-DC boost converter as shown in the fig5. A DC to DC converter is required for changing the input resistance of the panel to match the load resistance by varying the duty cycle. DC-DC converters can be used as switching mode regulators to convert an unregulated dc voltage to a regulated dc output voltage. Diode in the circuit is to avoid the back flow of current. The PWM is for regulation at a fixed frequency and the switching device is generally MOSFET as shown in the fig5.

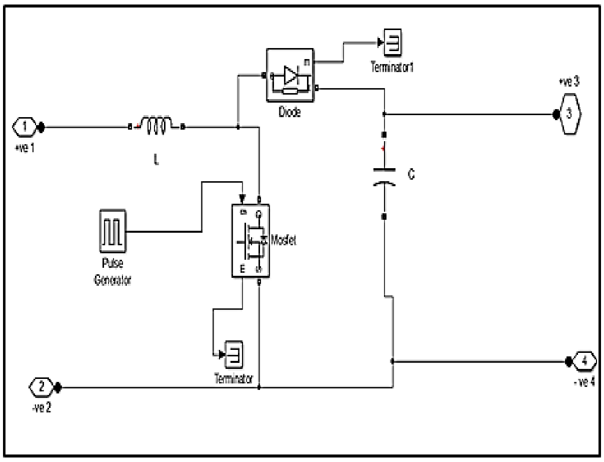

Fig5: Basic circuit of boost converter

When the boost converter operates in the continuous mode the value of the inductance L, is:
inductance L, is:

$$Lmin. = \frac{D(1-D)2}{2f}$$

The minimum value of the capacitor C, filter is given by:

$$Cmin. = \frac{DIo}{Vo\ f}$$

Where, D and V_0 are the duty cycle and output voltage respectively [2].

2.3 Single Phase DC-AC Inverter

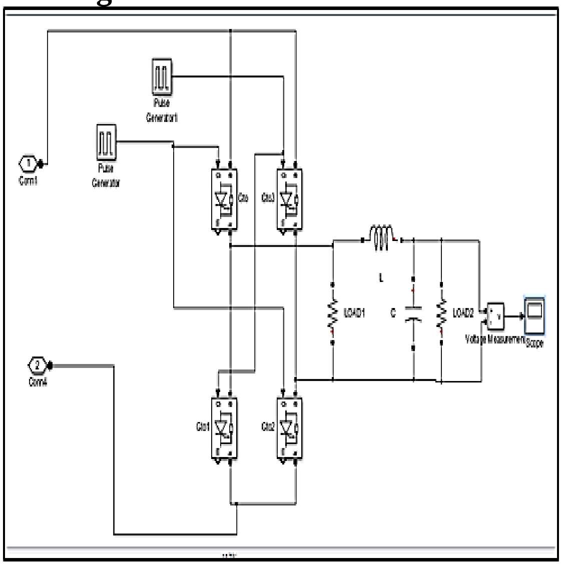

Fig6: Simulink model of the single phase inverter

The output dc power of boost converter input to single phase inverter and then to filter and ac loads. The configuration of the single phase full bridge voltage source inverter is shown in the fig6 [7]. It comprises of a dc voltage source and four switching blocks. These switching blocks are semiconductor switches (GTO) and antiparallel diodes. Pulse width modulation (PWM) is applied for proper gating signals to the switches. PWM function is to control the amplitude of output voltage and fundamental frequency. The output of the inverter is then input to the filter for obtaining pure sine wave without any harmonic component.

The detailed Simulink modelling of the photovoltaic power conversion from DC power generation to AC power supply to local utilities is depicted in the figure7. The detailed description of each circuit had been already discussed before through Simulink model. The proposed model entirely simulated under Matlab/Simulink.

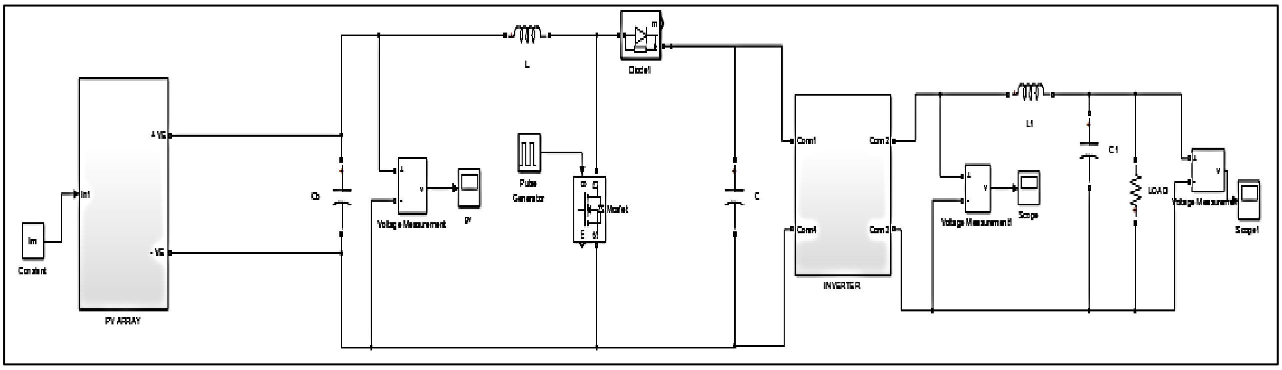

Fig7: Simulink modelling of PV based power conversion

3. SIMULATION RESULTS AND DISCUSSIONS

Figure8 and figure9 shows the P-V and I-V characteristics of the photovoltaic module by varying the irradiance parameter at certain temperature in the Simulink. These curves define the performance of the module, the short circuit current, the open circuit voltage and the maximum power point (MPP). The MPP is the point on the curve at which the module operates with the efficient output power and for the efficient operation of the system; it is required to make the operation of the system at this point. We analyzed from the I-V characteristics that as the irradiance decreases the value of the short circuit current and the open circuit voltage goes on the decreasing but also the decrease in the value of the open circuit voltage is less as compared to the short circuit current. Solar irradiance, atmospheric temperature and the electrical load operating conditions are the main factors which affect the performance of the photovoltaic system [4] [11].

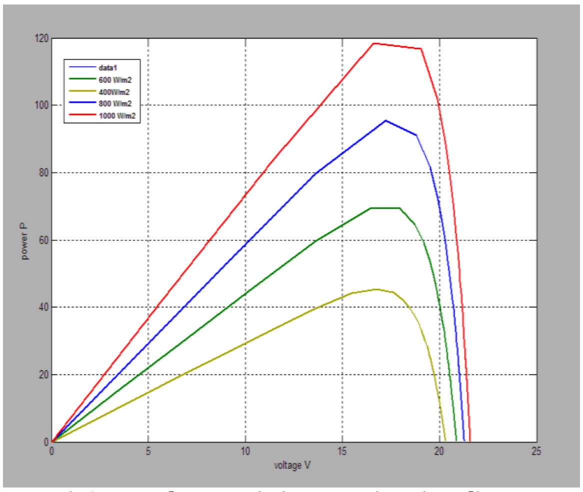

Fig8: P-V characteristics at various irradiance

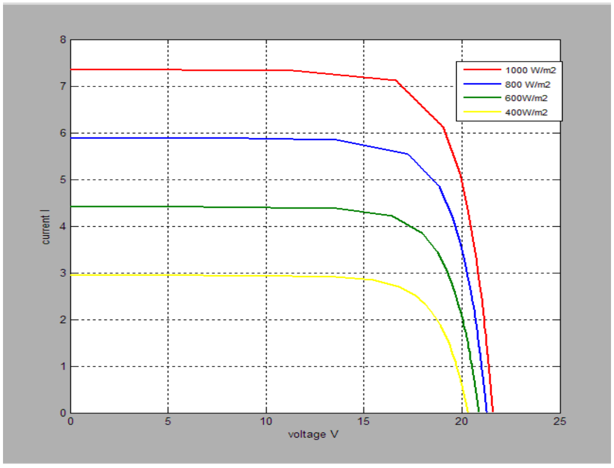

Fig9: I-Vcharacteristics of array at various irradiance

Figure10 shows the non sinusoidal output from the inverter connected after the dc converter. The inverter converts the DC output voltage from the converter to the AC for the local utility.

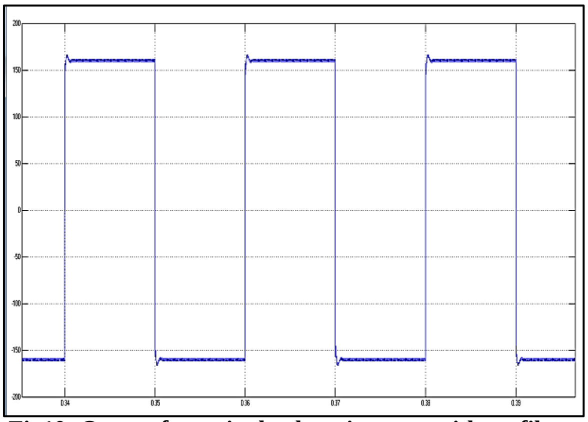

Fig10: Output from single phase inverter without filter

Figure11 shows the sinusoidal output from the inverter when it is connected with the filter. The capacitor in the filter circuit eliminates the harmonic components from the output for the smooth supply to the local load.

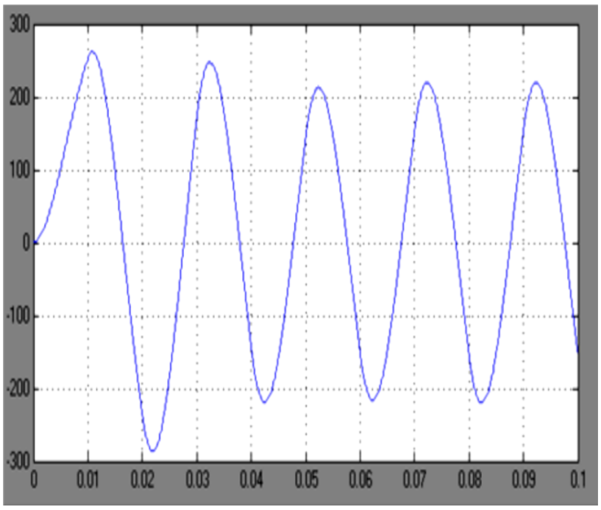

Fig11: output from inverter with filter

4. CONCLUSION AND FUTURE SCOPE

In this paper, the simulating model is developed by integrating the variable PV array with the DC-DC boost converter, single phase inverter and filter in the MATLAB/SIMULINK software with the help of SimPower system toolbox. Environmental condition like temperature, insolation affects the performance of the PV and could be analyzed through the characteristics of the module. The working of the photovoltaic array in the MPP mode maximize the use of the solar energy but due to the fluctuating nature of the input parameter, performance of the system degrades and hence for that different type of controllers with the converter will be implement in future for leveling the variable supply. A Photovoltaic system not only consist of PV modules but also involves good deal of power electronics as an interface between PV modules and load for effective and efficient utilization of naturally available Sun power.

5. REFERENCES

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