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# Modulation and Simulation of Renewable Energy Source using MPPT Techniques

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**ABSTRACT**:This paper reviews output characteristics of Photo-Voltaic module supplying load with and without Maximum Power Point Technique (MPPT). Since the Photovoltaic array output is known to be affected by radiation of sun and the temperature, which makes is compulsory to find out an effective method to draw out maximum power from Photo-Voltaic cell/ modules. In this paper Perturb and Observe (P&O) algorithm is selected because of its easy implementation. A comparison has done in terms of I-V, P-V & Power verses time characteristics obtained from both the models from a 235W PV module.

**KEYWORDS:**Photovoltaic module, Solar cell modelling, PV power generation, MPPT Algorithm, Dc-Dc converter, Matlab, Simulation.

## I.INTRODUCTION

As we very well know that for social and economic development as well as for human activity energy is a basic need. Human life can be made better by the sufficient supply of energy. Now a day's global warming is occurring due to the nonstop combustion of fossil fuels all over the world, creating environmental hazards and reducing conventional energy sources, this scenario is contributing to the need to search for an energy source, which is clean and available in excess. Due to the huge impetus in the government policies on the development of solar energy, it is acting as a main alternative renewable energy source. PV cells/modules is used for the generation of DC voltage and can be given to buck converter, boost converter etc. based on the requirement. The converter output is given to the battery and via inverter it can be converted to AC and can be given to the AC grid. The solar energy is popular due to easy maintenance, cleanliness, sustainability, and zero noise characteristics. [1-3]

Because of expensive PV manufacturing process and relatively low energy conversion efficiency [4,5] the MPPT technique is very crucial to find out the optimum operating point or maximum power that is to be extracted from PV array. There are a lot of published literatures and papers related to solar MPPT techniques [6].The generation from PV is reliable and it involves no moving parts due to this the maintenance and operating costs are very low [7]. PV cells/ modules are the cores of the solar photovoltaic power generation unit. The cells of a solar PV system generate electricity from solar energy on the basis of photoelectric effect. Solar energy is directly converted into electricity by PV systems. The PV cell is the basic building block of photovoltaic system and it is a semiconductor device that converts the energy from solar to direct current (DC). The PV system is typically rated up to 50 W to 300 W. The PV systems are highly modular type and the modules may be connected together for providing power from few watts to megawatts.

The output from solar module is in the form of DC and due to this conditioning of power is required to convert the DC to AC via power electronic circuits either for standalone or for grid interface applications. In this physical process of conversion the major losses are involved within the cell and due to this solar PV energy conversion process is a low efficient. Because of this high loss in energy conversion the output energy has to be dealt with maximum care to utilize it to the greatest extent. In this situation, the analysis and modeling of the solar cell has become very essential and important. Long time ago the solar cell mathematical model had been developed. The analysis of the PV based generating system can be done correctly and its performance may be studied accurately in a realistic way due to the recent surge in the use of various simulation software such as MATLAB, SPICE etc.

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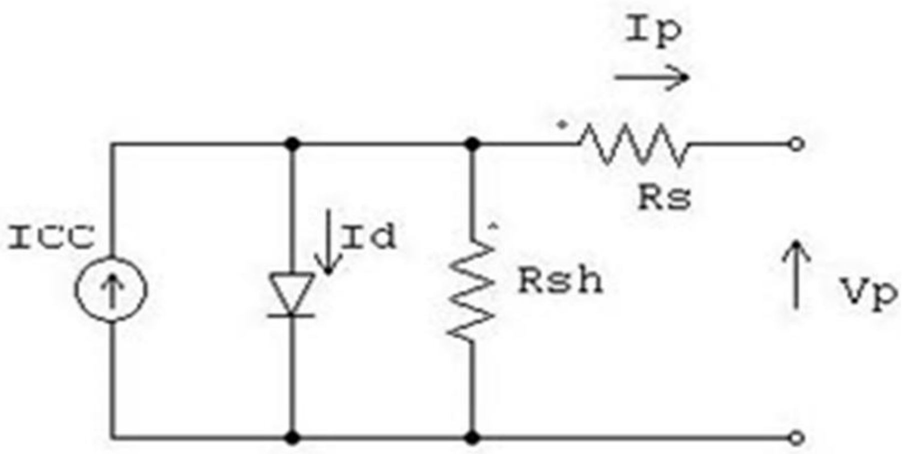


Fig 1: Equivalent Solar Cell Model

In typical solar MPPT system, switching DC-Dc convertor is the mandatory element for tuning the PV output power towards its maximum peak level, by changing the duty cycle D. Buck converters and the boost converters are the most popular circuits, among the DC-DC converters, and both are mostly used in solar Maximum Power Point Tracking system because they are less expensive and more simple compared to the buck- boost and CUK converter. Boost converter is more favorable than Buck converter for MPPT application, because most of the solar PV module output voltage would be lower than the required external load voltage. Moreover, the switching component in Buck converter is placed at the Input side and series with input voltage, which will discontinue the current flow within the system. This will definitely result in energy losses during the power generation process. Hence Boost converter provides greater benefit in terms of cost saving and higher efficiency. [8-12]

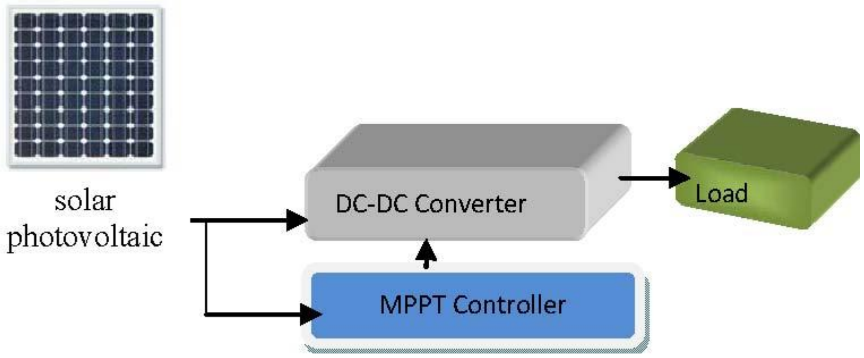


Fig 2: Equivalent Solar Cell Model

## II.SYSTEM MODEL AND ASSUMPTIONS

Fig 3 and Fig. 4 show the output characteristic of a particular solar cell at different cell temperature and solar insolation, denoted as V-I and V-P curves. These figures indicate that the PV cell's nonlinear characteristic is highly influenced by temperature and sun-irradiation. Through MPPT system maximum peak operating points ($P_{mpp}$, $I_{mpp}$ and $V_{mpp}$) are the desired parameters that need to be tracked all the time.

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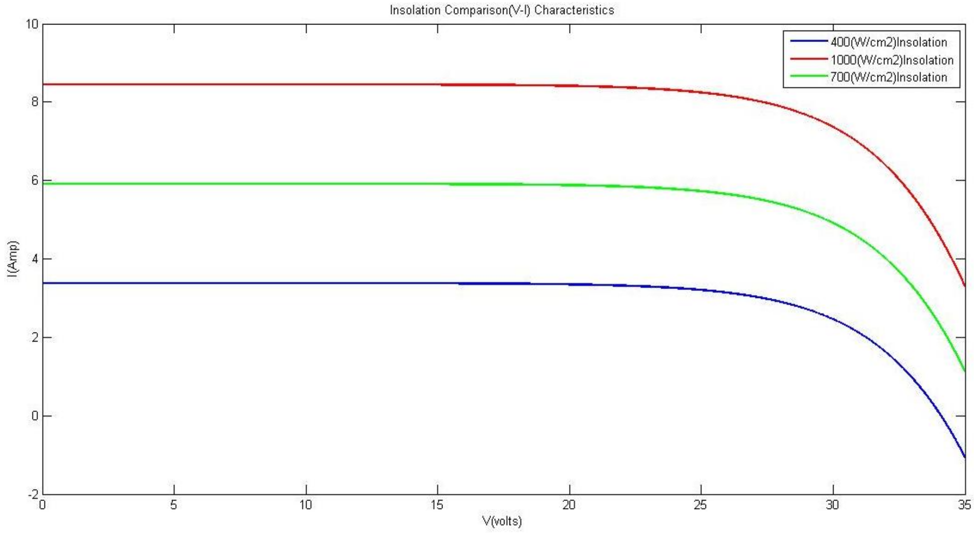


Fig.3 I-V Curves of different Sun Irradiation

Fig. 4 describes the effect of cell temperature and irradiance towards P-V curves. In contrast to the influence of sun irradiance, the cell temperature significantly affects the PV voltage. The temperature is inversely proportional to the PV voltage, at which the increment of temperature will eventually decrease the level of PV maximum power point and output voltage.

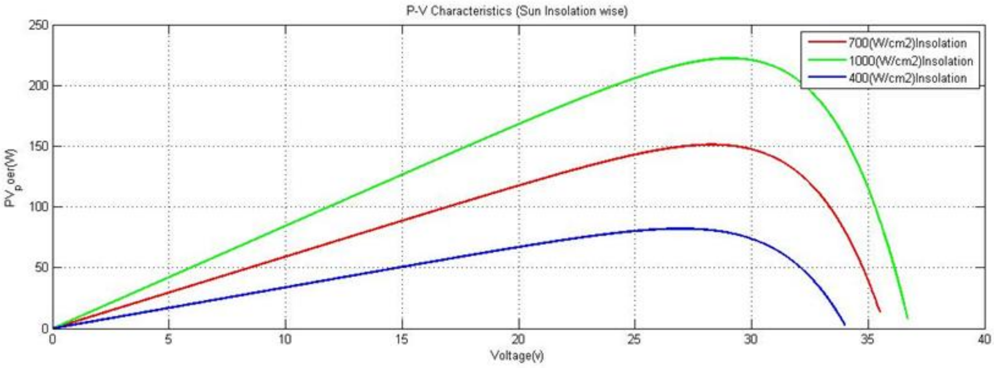


Fig. 4 P-V Curves of Different Sun Irradiation

Considering all well-established PV cell modeling circuit from other literatures by [23, 24] the model of single diode in fig 5 is regarded as the most suitable model for MPPT research purpose.

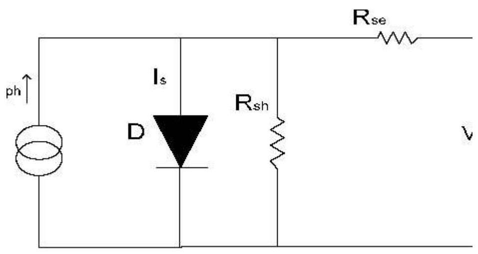


Fig.5 Solar Cell single diode model

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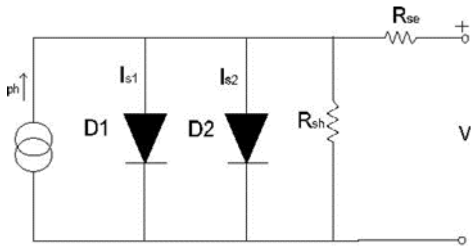


Fig.6 Solar Cell double diode model

Solar cells are made up of a p-n junction fabricated in a thin layer of a semiconductor material. The solar cell has exponential current-voltage output characteristics, which is similar as of a diode [13]. When solar cell has been hit by the photons from the solar energy, with the energy, which is higher than the band gap energy of the semiconductor material, electrons are knocked loose from the atoms in the material and create electron and hole pairs. Due to the internal electric field of p-n junction these charge carriers are swept apart and current is being created which is directly proportional to the incident radiation. When we short circuit the cell, the generated current flows in the external circuit, and when the terminals are open circuited, the current is shunted internallyby the intrinsic P-N junction diode. The open circuit voltage characteristic of cell is being set up by the characteristic of the diode. As silicon cells are the building block of PV modules and the Si solar cells give voltage output of approximately 0.7 V in open circuit condition. The operation of the solar P-V cell [14] is described by the double exponential equation of the solar cell which is being derived from the physics of the p-n junction and can be modeled into current source having two parallel diodes, a series and shunt resistance as indicated in Fig. 6.

$I = Iph - Is1\,[e^{q(V+IRse/kT}-1] - Is2[e^{q)V+IRse)/AkT}-1] - (V+IRse)/Rsh$ (1)

However the model shown in figure 6 can again be simplified by removing the current Is2, the reverse saturation current of diode D2 can be neglected, as the amount of recombination is negligible and less. Under STC conditions this assumption is very much acceptable and generates error only at very low values of irradiation such as 100 W/m2 [18]. Hence finally the solar cell generalized model with minimum complexity is developed, as shown as in Fig 5.Where:

| | |
|---|---|
| Iph | Solar cell generated photo diode current which depends on temperature and irradiance |
| Is1 | Saturation current which is generated by diffusion mechanism of diode D1 |
| Is2 | Saturation current generated by the recombination in space charge layer |
| Rsh | Shunt resistance which represents shunt current leakage to the ground |
| Rse | Series resistance which represents contact resistance |
| K | Boltzmann's constant , (1.38x10(-23)J/K) |
| Q | Electron charge, 1.6x 10(-19)C |
| V | Terminal voltage of solar cell. |

However the model shown in figure 6 can again be simplified by removing the current Is2, the reverse saturation current of diode D2 can be neglected, as the amount of recombination is negligible and less. Under STC conditions this assumption is very much acceptable and generates error only at very low values of irradiation such as 100 W/m2 [18]. Hence finally the solar cell generalized model with minimum complexity is developed, as shown as in fig 5.After the assumptions the single diode model equation is:

$I = Iph - Is\,[e^{q(V+IRse)/AkT}-1] - (V+IRse)/Rsh$ (2)

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## III.MODELLINGAND SIMULATION OF THE SET-UP

A solar cell module of 235 W capacity is being selected for analysis and modeling in this study. In table 1the detailing of solar cell is given. For successful design and development simulation is the starting point to get the result satisfactorily in the work before going to the implementation. In MATLAB there are many solar PV cell models developed which have been reported in lots of papers [15-18, 19-21].

In the Matlab the available inbuilt model for solar cell is based on double diode equation model [14]. In this paper, an attempt using Matlab as a tool has been made to develop a model for the solar cell supplying load with MPPT and without MPPT. The cell solar irradiance and temperature are used as inputs and the output is the cell current, which is based on its operating voltage. With the help of Simulink blocks the model has been developed by translating the mathematical equations directly in to a model. If there is a case of interfacing with power conditioning systems, the physical parameters are being converted into equivalent electrical parameters by making use of controlled sources. Further to find out the comparison of the output characteristics of PV module with and without MPPT the models in Matlab have been made as shown in Fig. 7 and Fig 8.Perturbation and observation algorithm is used in this study due to its easy implementation. This method is also known by the name of hill climbing method [25]. Its working principle is based on making small active voltage perturbation in a certain working voltage of PV cells and then observing the change of direction of power output. The perturbation in the same direction is kept when the output power increases; otherwise the perturbation, which is against the original direction, is kept.

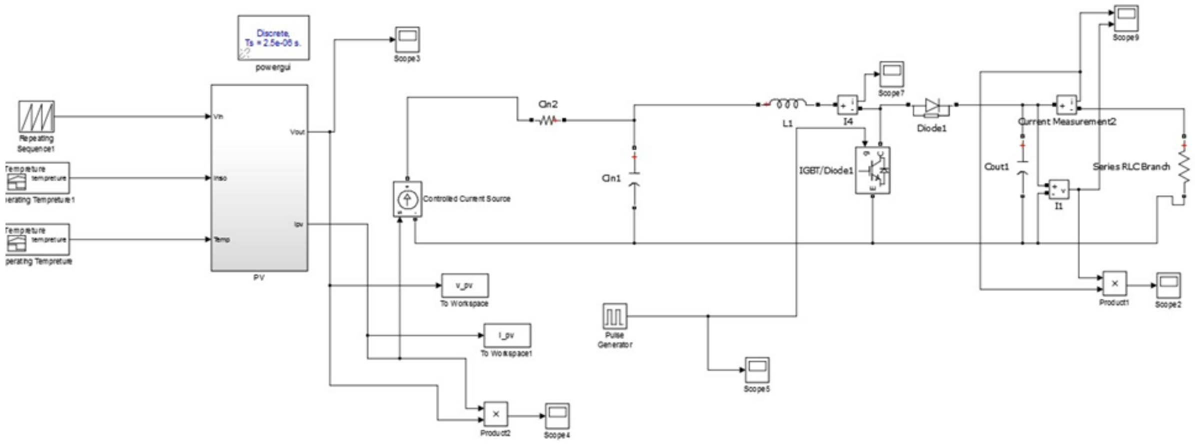


Fig: 7 Model of PV system without MPPT algorithm

In the fig 7, it shows the model ofPV system without MPPT, simulated in Matlab, which is used in this study.

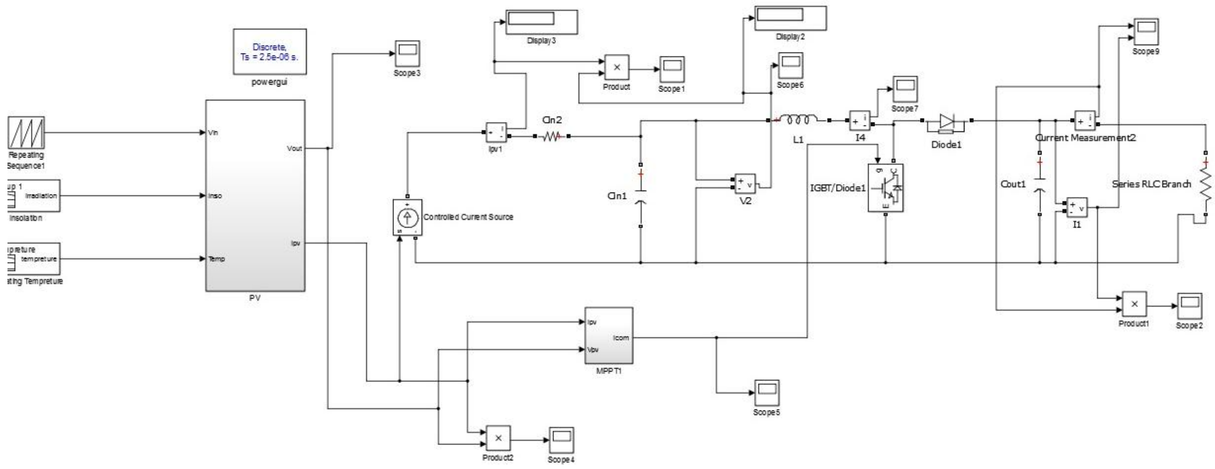


Fig: 8 Model of PV system with MPPT algorithm

In the fig 8, it indicates the model simulated in Matlab using MPPT technique used for the plotting of output power.

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Table 1: Technical Specs. of Solar Module

| Parameter @STC | Variable Parameter | Specification |
|---|---|---|
| Max. Circuit voltage in watts | Pm | 235W |
| Open circuit voltage in Volts | Voc | 54.2V |
| Short Circuit current in Amps | Isc | 6.2A |
| Voltage @max. Power | Vmp | 45.8V |
| Current @max. Power | Imp | 5.1A |
| Temperature Coefficients | Voltage | -(80±10) mV/° C |
| | Current | (0.065±0.15) %/°C |
| Type of cell | Mono Crystalline Silicon | |

The manufacture specification of the solar module used for this study is given in table 1 [22]. Most of the specifications of the manufacturer are valid at the STC conditions. However, the solar PV module is rarely operated at the STC conditions and these produce lots of uncertainties in terms of its power delivery capability. In this study the I-V and V-t curves are plotted in Fig.13& Fig.14 without MPPT and with MPPT respectively. Further Power (watts) curves with respect to time are plotted shown in Fig.7 & Fig.8 for the arrangement indicated in Fig: 7(without MPPT) and Fig: 8(with MPPT).

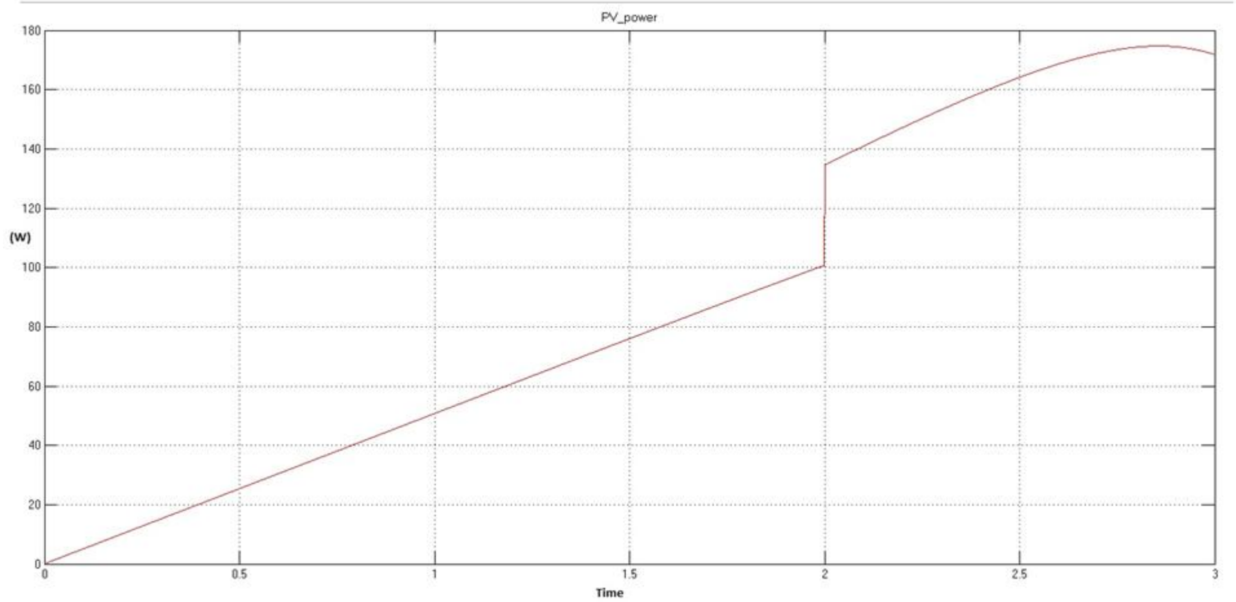


Fig 9: PV cell Power

Fig. 9 shows the graph of the PV cell actual power as per the insolation and the temperature shown in figures 10 and 11.

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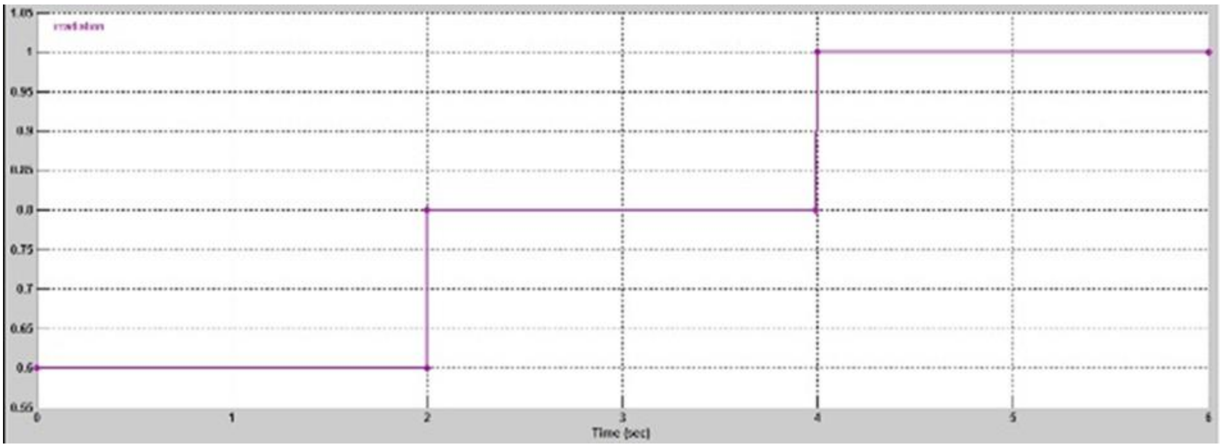


Fig10: Insolation with respect to Time

Fig. 10 indicates the insolation level w.r.t. time for which the Fig.9 power of PV cell is plotted, in the plotting of power the same insolation level is used throughout the time.

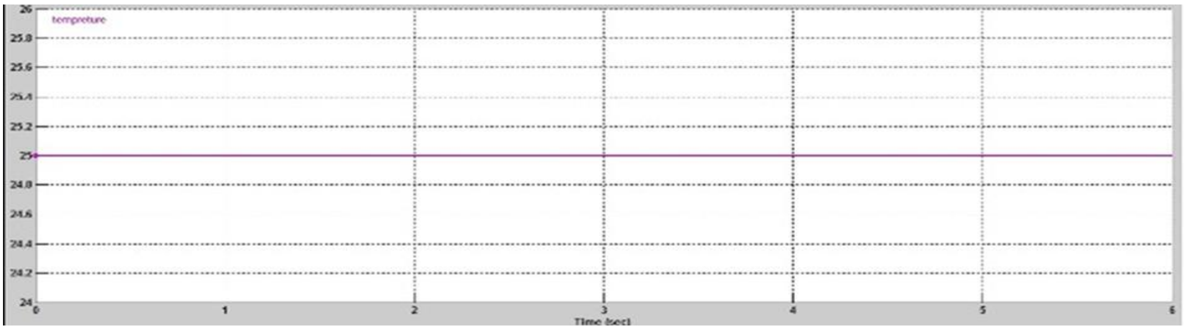

Fig11: Temperature w.r.t. time

Fig. 11 represents the temperature which is being used for the plotting and it can be seen that it remains constant at 25 deg. C. The plotting of power in Fig. 9 is done in this fixed temperature.

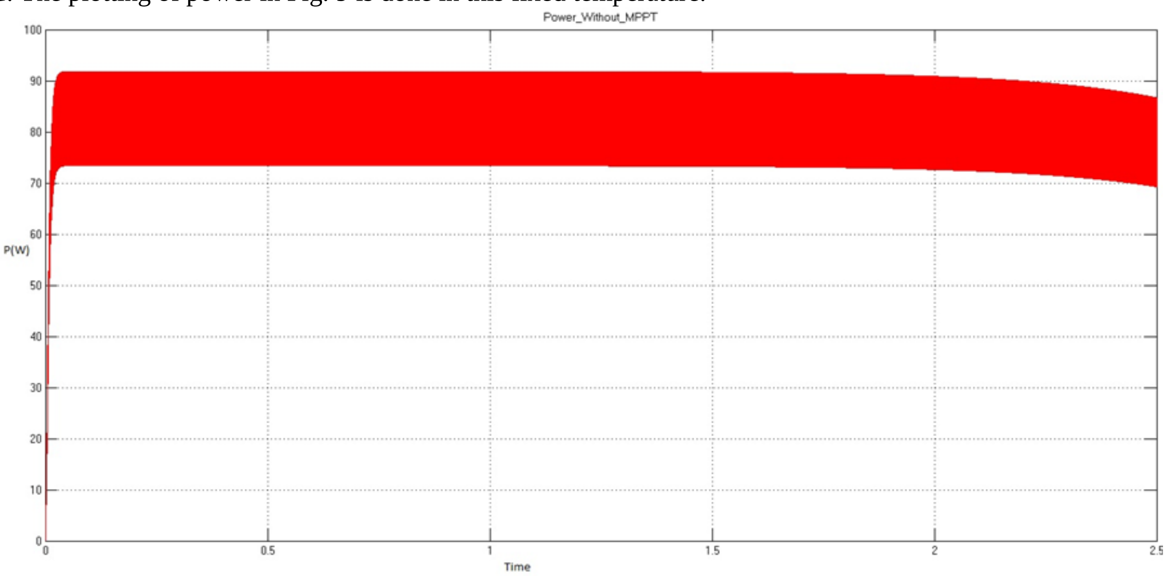


Fig.12, Graph between output power (watt) & time (second) of module at load terminals without MPPT

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In the above shown Fig.12 it is clearly visible that the power from PV module using PWM technique is variable and not maximum.

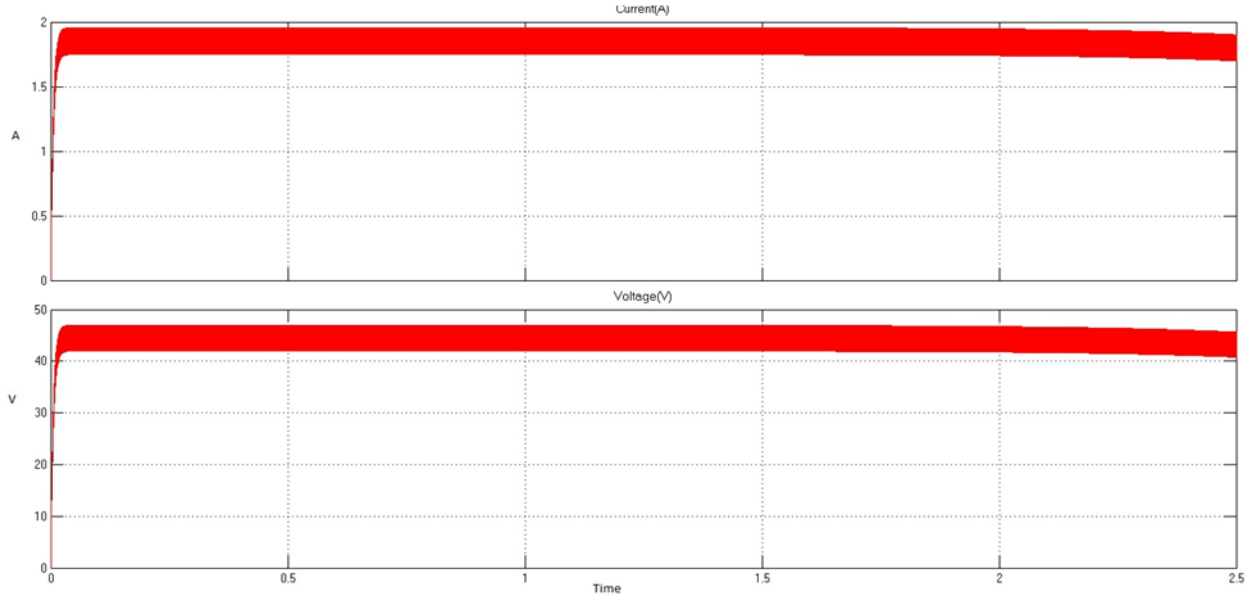


Fig13: Graphs for Voltage –Current & Voltage-time for without MPPT model

In the above Figs, graphs are plotted between V-I & V-t for the model shown in Fig.7.These graphs are plotted for insolation level and temperature as indicated in Figures 10 &11.

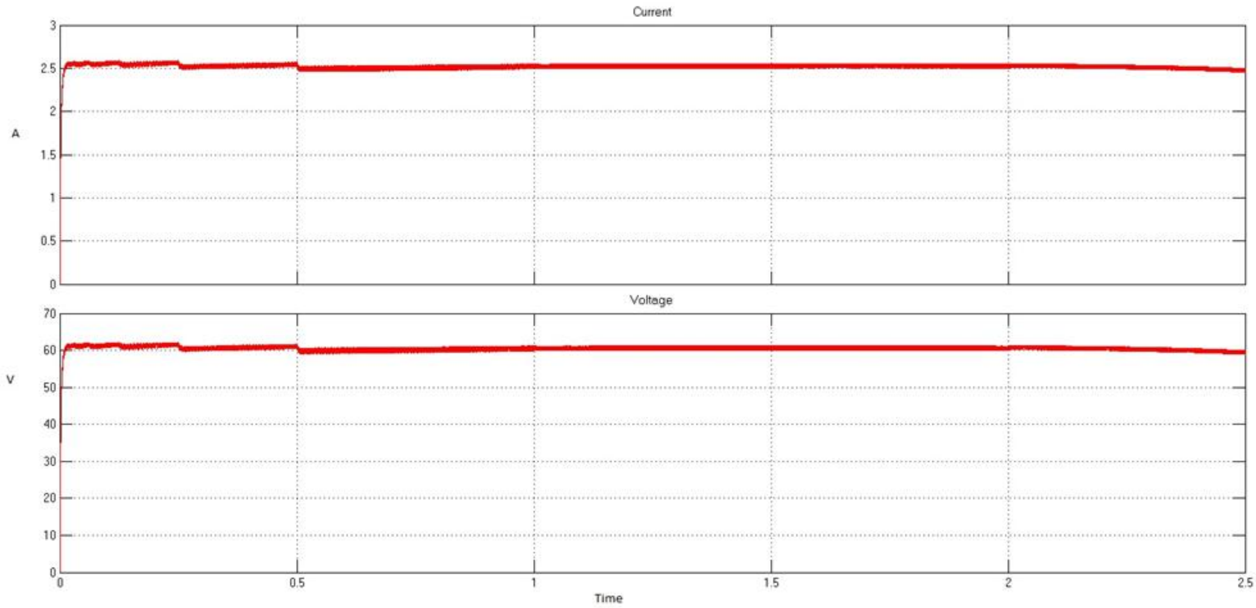


Fig14: Graphs for Voltage-Current & Voltage-time for MPPT model

In the above figs, graphs are plotted between V-I & V-t for the model shown in Fig.8.These graphs are plotted for insolation level and temperature as indicated in fig. 10 &11.

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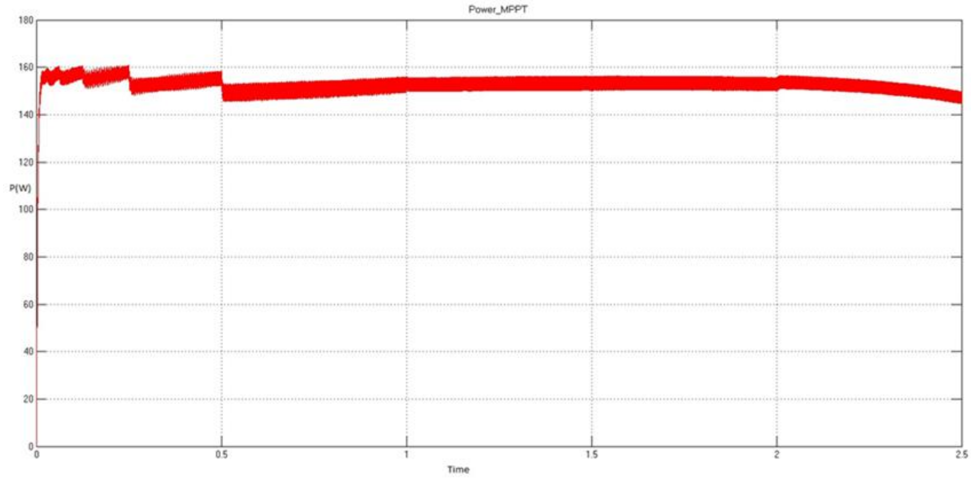


Fig15: Graph between output power (watt) &time (second) of module with MPPT

Fig.15 displays the power extracted from the PV module using MPPT algorithm, now if we compare the power with and without MPPT as indicated in Fig.15 & Fig.12 respectively, power obtained after implementation of MPPT algorithm is much higher and constant as compared towithout MPPT algorithmfrom PVmodule.

## V. RESULT AND DISCUSSION

The V-I & and V-t Characteristics as indicated in Fig.13 & Fig. 14, of the models of solar cell supplying the load have been obtained and plotted. The Power vs. time characteristics is obtained for both the conditions i.e. without MPPT and with MPPT scheme as shown in Fig.12and15 respectively. The above plots for both the models of Fig.7 & Fig.8, explain the Voltage –Current, Voltage-time& Power-time characteristics and it's been found that the efficiency increased drastically in the model with MPPT.

## VI.CONCLUSION

In this paper an attempt is made to develop a model for PV cell with MPPT and without MPPT in Matlab to find out the increase in efficiency using MPPT.The output characteristics obtained from both the models are verified. The models are compared and the P-V and I-V characteristics generated for the models. The model proposed in this paper using Matlab performs well for developing model for solar PV systems with MPPT.

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