Effect of MPPT on Performance of PV System

Dhiraj Singh, Satish Kumar Jangid, Atul Dadhich, Neeraj Sharma

Abstract- **In this paper, the effect of MPPT on PV System performance has been evaluated. In simple terms, the objective is to obtain maximum possible power all of the time &it will be possible when the panel has access to the maximum amount of solar irradiance possible resulting in its output voltage and current being at their maximum possible values. This study consists of examining solar energy as a viable option and obtaining the maximum amount from the 'green' energy source, this means getting the maximum power from a solar array at any given time. This is obtained by keeping the solar array at its Maximum Power Point (MPP) continually. It has been found that some major factors come into account when the MPP is trying to be located continually. This study looks at effects of Maximum Power Point Tracking (MPPT). For this Incremental Conductance (IC) MPPT method has been developed and tested. Also this paper gives details on the direct relationship between power output and sunlight and temperature levels.**

Index Terms-PV System, MPPT, Incremental Conductance

I. INTRODUCTION

In recent times the global energy demand has increased due to global growth and technology advances. This as well as the depletion of natural energy resources, such as fossil fuels, has resulted in the cost of energy becoming much more expensive and the increase in energy consumption has resulted in an increase in greenhouse gas emissions. As result of this, countries are been forced to look at employing more effective ways to generate energy which costs less and also reduces the country's carbon footprint. Ireland has a number of 'green' energy options available to it; these include wind generation, tidal power and solar energy or photovoltaic energy.

Improvements in Photovoltaic (PV) technology in recent times has resulted in solar energy prices becoming near levels in which it can compete effectively with widely used fossil fuel energy sources [1]. Solar power's extraordinary energy potential has been recognized and for solar energy to become a major player in the energy sector in the near future, further improvements need to be made. This study concentrated on coming up with a system which stabilizes the power output of solar energy in a PV system and making the power output easier to predict [2].

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The characteristics of a solar panel show that when power is plotted against voltage there is a voltage value corresponding to the MPP and normally this point is a function of the solar light level. The maximum power [2,3] transfer theorem shows that the maximum power is transferred when the load resistance matches the output resistance of the panel [3]. A DC-DC converter usually in the form of a buck converter is used to match the impedance of the load to the panel by varying the duty cycle; this is MPPT. The duty cycle is the ratio of output voltage to input voltage.This is a method used in Solar PV arrays to expose uniform solar irradiance and maintain a maximum power output for a period of time. In the characteristics the maximum power output can clearly be seen at the 'knee' of the curve. This is the position that is most sought after and is achieved when maximum voltage and maximum current are achieved at the same time. MPPT is a method to ensure that maximum voltage and maximum current is reached as much as possible and overall to make maximum utilization of PV modules and minimize the power failure due to environmental conditions [4,13]. This is done by having the solar array track the path of the sun and also by making sure that none of the solar array becomes partially shaded at any stage due to cloud, branches of trees etc., and if this does occur a system is in place to adjust the panel and get it back to output the maximum current and voltage and hence the maximum output power. If irradiance levels differ throughout the solar array, this results in multiple local maxima points being produced. This results in nonlinearity of the PV characteristic curves, which means there is more than one 'knee' in the P-V curve [5,6,7]. Multiple local maxima are not good for tracking as it reduces the effectiveness of the tracking system, and these results in overall loss in power output [8,9,10].

Further the paper is structured with PV system modeling, MPPT modeling and simulation results and discussions followed by conclusion.

II. PV SYSTEM MODELLING

Photovoltaic effect is a phenomenon in which solar energy is converted directly into electrical energy through the use of a solar cell [7, 11, 12]. A PV cell is made of silicon, which is purified, melted and then crystalized. The majority of the cell has a slightly positive electrical charge, with a thin layer, at the top, having a slightly negative charge. A thin grid of metal is placed on the top of the cell which allows adequate amounts of sunlight to be admitted but also had the ability to carry electrical energy. Sunlight, sometimes described as particles called 'photons', hits the PV cell and move into the cell [13, 14]. Photons strike electrons and dislodge them, these then become loose and start to move to the top of the cell. The greater the amount of photons that are admitted by the cell results in a greater flow of electrons towards the top of the cell. These then flow into the external electrical circuit through the grid of metal placed on top of the cell. The electric fields in the solar cell put these free electrons in directional current, from which the metal contacts on top of the cell can generate electricity [14].

The following section shows a detailed study into the output voltage vs. output current and output voltage vs. output power for solar radiation levels in Jaipur for the month of June-2017 as well as a study into the output voltage vs. output current and output voltage v/s output power for different solar irradiance levels and different temperatures. The solar panel used in these calculations is shown the data sheet for this PV module. The data sheet of PV Panel of 270 W parameters is given as follows:

Table 1: parameters of PV Panel

Q	Chargeon anelectron	q =1.6022 x10^{-19}C
K	Boltzmann constant	K=1.38*10^{-23}m².kg.s^{-2}°K
N	Idealityfactor	n=1.5
I	Output current	(to be calculated)
V	Output Voltage	(0 to Voc)
N_S	Number ofcells in series	100
R_S	Series resistance	Rs=0.004Ω
T_{cell}	SolarPanel temperature	25^0 C
Iscref*	Shortcircuitcurrentatstan dardconditions	8 Amp
S	Solar radiation	As per actual
Vocref *	Open circuit voltage atstandardconditions	48 V

Theoutputcurrent isgiven by:

$$I = I_{ph} - I_{sat}\left(e^{\left(\frac{q\,(V+I.R_S)}{n.K.T_{cell}.N_S}\right)} - 1\right)$$

Thephoto generated current$I_{ph}$is given by:

$$I_{ph} = I_{sref}.\frac{s}{s_{ref}}.[1 + \propto_{isc}(T_{cell} - T_{ref})]$$

Thesaturation current,I_{sat}, is given by:

$$I_{sat} = \frac{I_{ph}}{e\left[\frac{V_{oc}.q}{n.K.T_{cell}.N_s}\right] - 1}$$

Theopen circuitvoltage,V_{OC}, is given as:

$$V_{oc} = V_{ocref} + \propto_{voc}(T_{cell} - T_{ref})$$

Where $\square_{voc}$** is Opencircuitvoltagetemperaturecoefficient.

On the basis of these equations the modeling of PV Panel is being done as following figure:

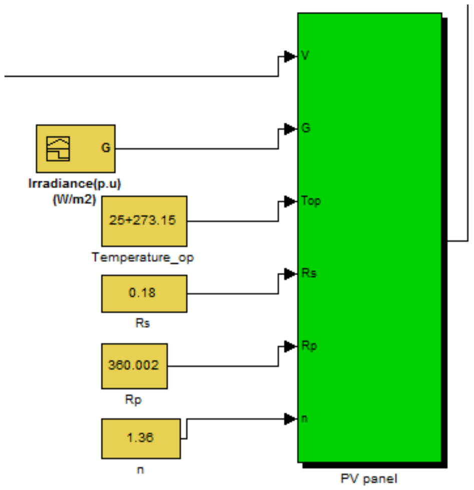

Fig.1. Matlab Model of PV Panel

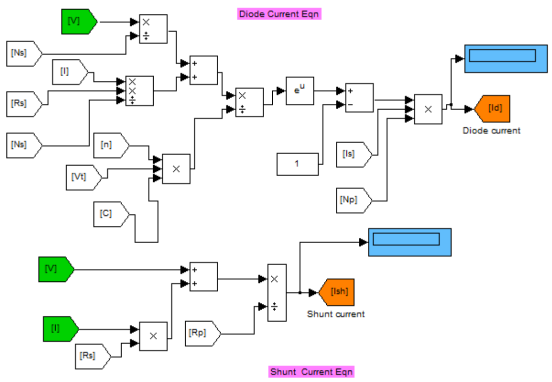

Fig.2.Modelling of current

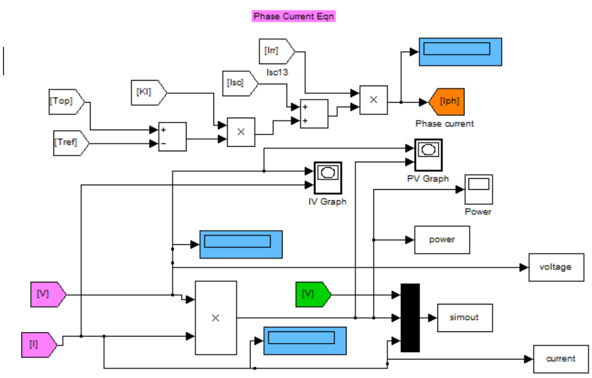

Fig.3.Modelling of load current

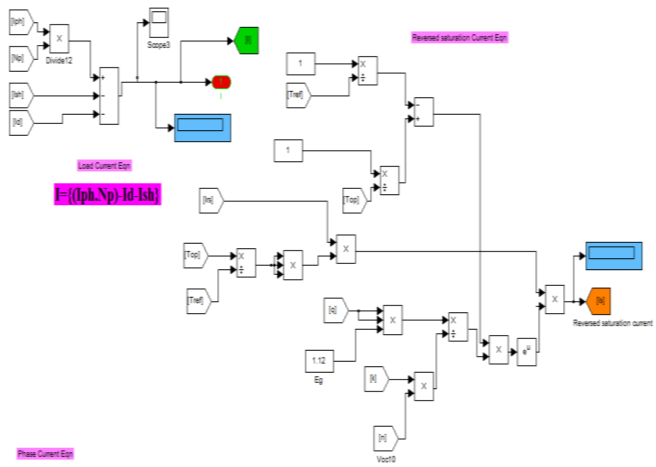

Fig.4.Modelling of saturation current

III. MPPT MODELLING

The creation of a MPPT system may be modelled using the MATLAB based simulator, Simulink. This is implemented using the SimPower systems toolbox of the MATLAB/Simulink model. A Simulink model of a PV system under different temperatures and irradiation is created in [6] by adjusting the duty cycle of the DC-DC converter. The purposed system in this paper discusses the implementation of an algorithm to find andmaintain peak power. The modified version of the IC method is used to do this, the system contains an internal regulator to minimise the error where the regulator output is equal to the duty cycle correction. The digital controller in the system can directly control the duty cycle of the converter current which makes it possible to find the MPP. This paper presents results which prove that the modified IC method of MPPT reaches the intended MPP. This is a representation that MATLAB/Simulink simulations can be accurately used to simulate the outcome of MPPT in a PV system.

Modelling the performance and output of a solar system is a very important procedure which allows the user to become familiar the system as well as interactions with utility grids. Models may be used to investigate the effects with the conditions which give out the best results and conditions which are best suited to of partial shading and module mismatching of a solar panel. Particular focuses are paid to the modelling and simulation of models in [26], with modelling approaches based on PSIM simulation circuit and MATLAB - SIMULINK based simulations being discussed. This paper shows the importance of detailed parameterization when trying to create a PV model or simulation. A generalized approach is needed to create a simulation which may be used for long-term operations of different PV systems.

This method always adjusts the array terminal voltage according to the MPP voltage. This method computes maximum power and directly controls the extracted power from the PV cell. This method uses a DC-DC converter which is controlled by an Incremental Conductance (IC) algorithm. This system offers great performance under quick changing circumstances and can be implemented using low cost microcontrollers. The method can track the maximum power points accurately at high speeds and greatly increase the power output of a solar array under Partially Shaded Conditions.

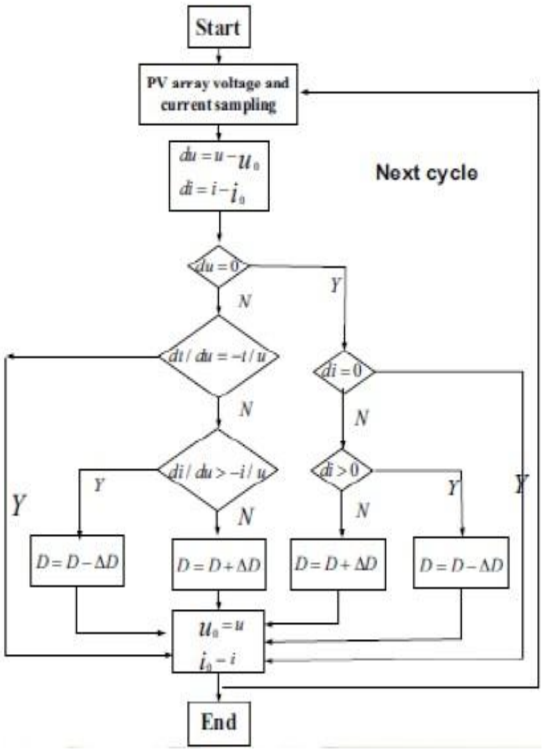

Fig.5. Flow chart of IC method

Figure shows the IC MPPTalgorithm in the form of a flow chart. It can be seen from this that the algorithm is much more complex than the P&O algorithm. If this MPPT method was used in this study, a complex microcontroller would be required to implement the algorithm.

This method computes the maximum power point by comparing (ΔI/ΔV) (Incremental conductance) to (I/V) (array conductance) [13]. Figure 15 [12] shows the basic idea of the IC method on the P-V curve, the MPP occurs when the slope of the curve is zero, with the slope becoming greater than zero to the left and less than zero to the right hand side of where the slope is equal to zero. Therefore the aim of the algorithm is to keep the slope of the curve at zero all of the time. Simulation results are given in [12] for this algorithm, where the tracking efficiency is calculated to be 96.8%. This method of MPPT is a digital method of medium complexity [12].the matlab modeling is shown as follows:

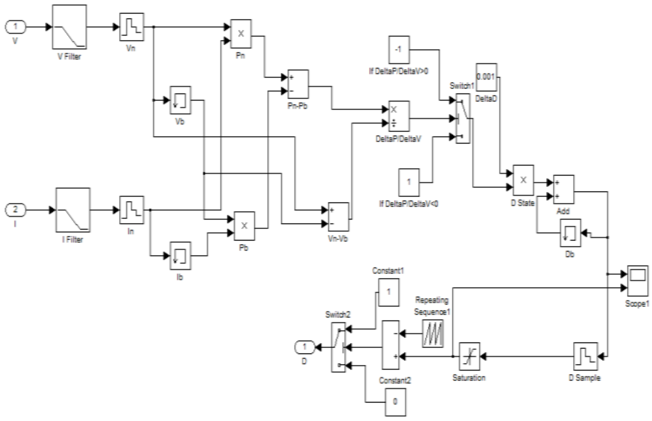

Fig.6. MPPT Modelling in MATLAB

IV. BOOST CONVERTER

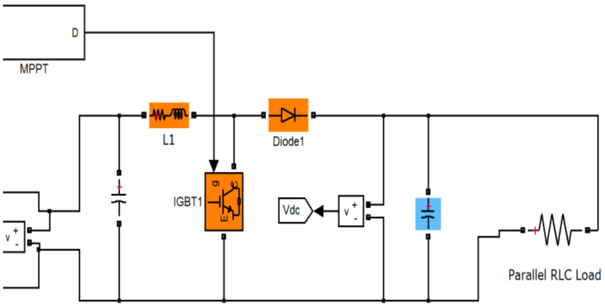

Fig.7. . Boost Converter

A DC-DC converter usually in the form of a boost converter is used to match the impedance of the load to the panel by varying the duty cycle of MPPT. The duty cycle is the ratio of output voltage to input voltage.This is a method used in Solar PV arrays to expose uniform solar irradiance and maintain a maximum power output for a period of time. In the characteristics the maximum power output can clearly be seen at the 'knee' of the curve. The main function of boost converter is increase the voltage level to feed the dc output to load. In this system we are using the IGBT switch which operate the output pulse of MPPT, and boost the voltage level. MPPT is track the best combination of current and voltage to get the maximum power output of PV panel. If we do not use the MPPT technique to trigger the IGBT switch just use the random pulse the it does not find the best combination of current and voltage, then we will not track the maximum power from PV panel. For a example here we using the 280 watt panel if use the MPPT technique (Incremental Conduction) we find the 270 watt power output from solar panel, the combination of voltage(39 volt) and current(6.9 amp). But we use random pulse the combination of voltage and current is not best here we find the voltage(47 volt) and current(3.8amp) output power is 178 watt. so here is loss of power that's why we use the MPPT technique with Buck/Boost system to improve the efficiency of panel.

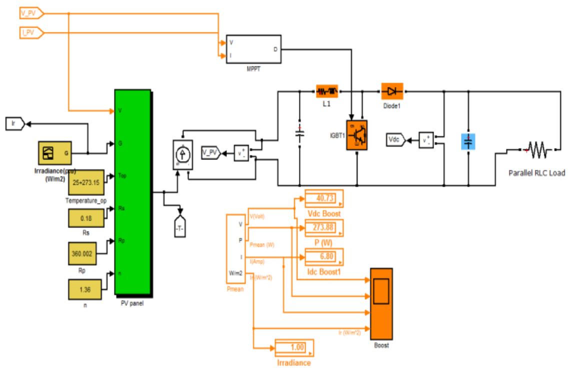

Fig.8. PV Panel with MPPT & Boost Converter

V. RESULTS AND DISCUSSION

In this section different results of PV panel with and without MPPT have been discussed. The results are shown as follows:

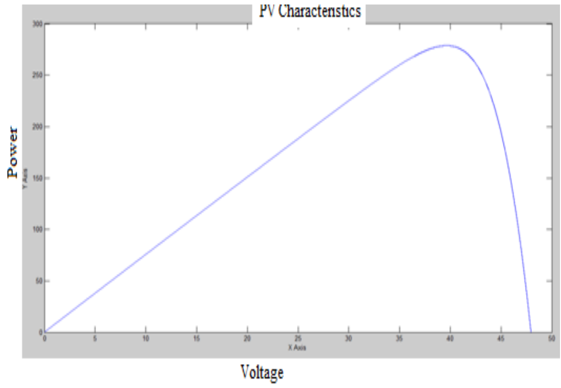

Fig.9.. Output of PVcharacteristics

Fig. 9 shows the PV characteristics of PV panel with 1000 W/m^2 radiation and 25 ^{0}C Temperature. Similarly Fig. 10 shows the IV characteristics of same PV panel with 1000 W/m^2 radiation and 25 ^{0}C Temperature. Further the study of PV panel is done with different irradiation and different Temperature level. The Fig. 11 and fig. 12 show the PV characteristics and IV characteristics of PV Panel at different irradiation level (1000 W/m^{2,} 800 W/m^{2,} 500 W/m^{2,} 200 W/m^2) at constant temperature (25 ^{0}C). From the figures it is clearly shown that as radiation level decreases the output voltageof PV panel will also decreases.

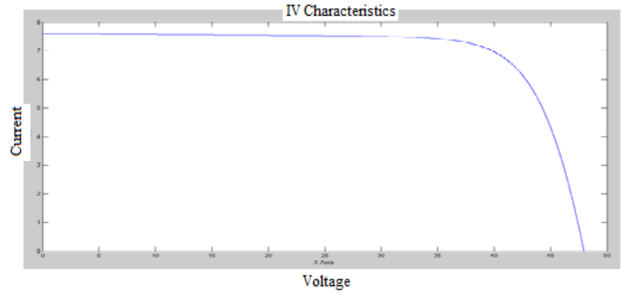

Fig.10.. Output of IVcharacteristics

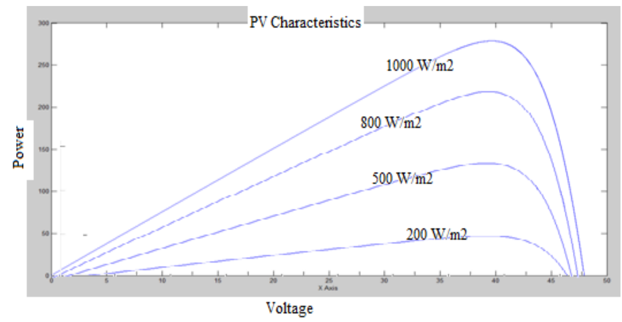

Fig.11.. Output of PVcharacteristics at different Irradiance

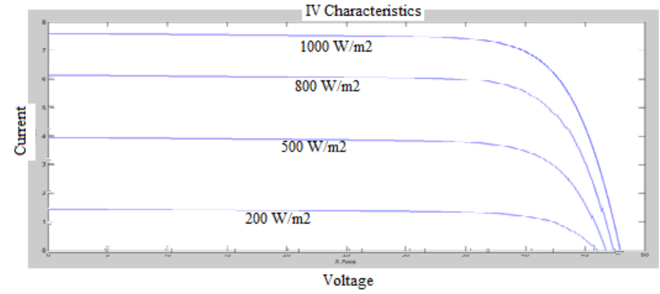

Fig.12.. Output of IVcharacteristics at different Irradiance

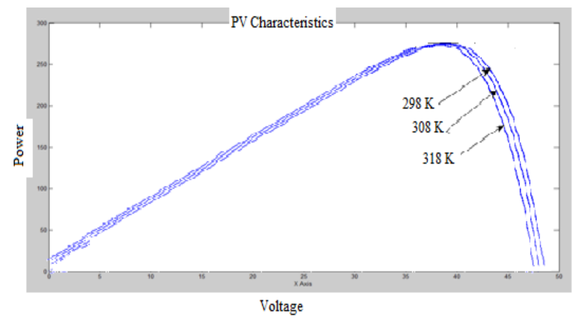

Fig.13.. Output of PVcharacteristics at different Temperature

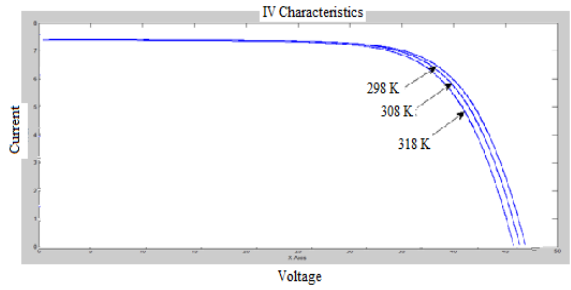

Fig.14.Output of IVcharacteristics at different Temperature

Similarly the Fig. 13 and fig. 14 show the PV characteristics and IV characteristics of PV Panel at different Temperature level (25^{0}C, 35^{0}C, 45^{0}C) at constant irradiation (1000 W/m^2). From the figures it is clearly shown that as Temperature level increases the voltage of PV panel will decreases in a very small manner.

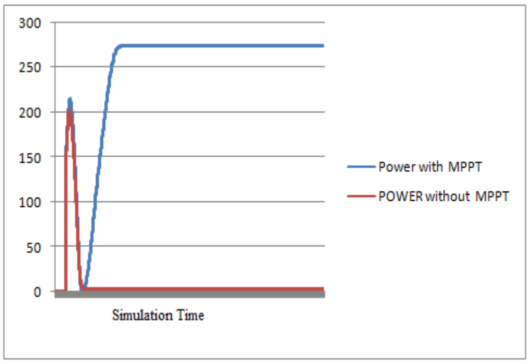

Fig.15. Output of Power

Further Fig. 15 and Fig. 16 will show the compared results of output power and voltage with respect to simulation time (at constant irradiance) respectively with and without MPPT modeling. From the figures it is clearly visible that the power output in the case of MPPT is maximum because in MPPT mode PV panel is tracking best combination of current and voltage.

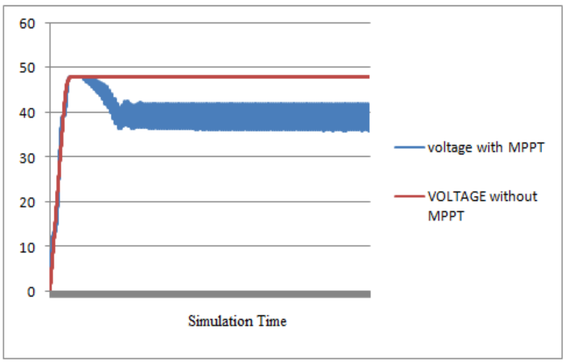

Fig.16. Output of Voltage

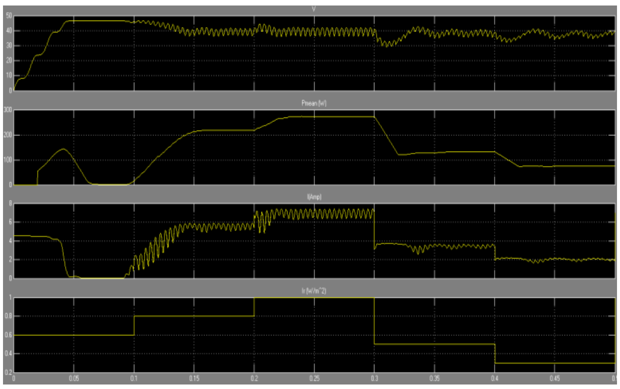

Fig.17. Output of Voltage Power Current with MPPT

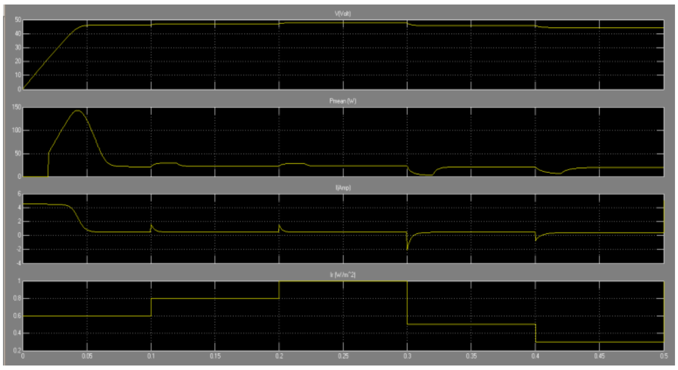

Fig.18.Output of Voltage Power Current without MPPT

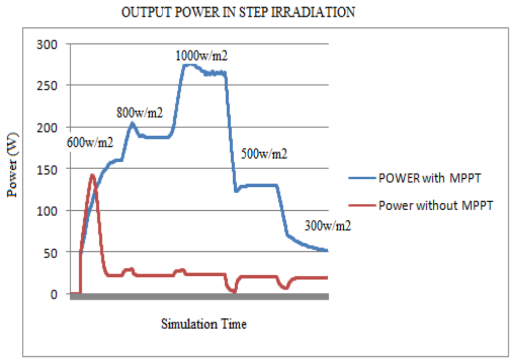

Fig.19. Output of Power in step Irradiace

Further Fig. 17, Fig. 18 and Fig. 19 will show the compared results of output power, current and voltage with respect to simulation time (at step irradiance) respectively with and without MPPT modeling. From the figures it is clearly visiblethat the power output in the case of MPPT is maximum because in MPPT mode PV panel is tracking best combination of current and voltage. Fig. 19 shows the comparison of output power of panel at step irradiance (600w/m2, 800w/m2, 1000w/m2, 500w/m2, 300w/m2).

VI. Conclusion

In this study, the effect of MPPT on PV System performance has been evaluated. In simple terms the objective is to have a solar panel outputting its maximum possible power all of the time, this occurs when the panel has access to the maximum amount of solar irradiance possible resulting in its output voltage and current being at their maximum possible values.

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