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PHOTOVOLTAIC SYSTEM MODELLING USING MAXIMUM POWER POINT TRACKING CONTROL MECHANISM

Harkiranjot Singh[*1] & Simarpreet Singh [2]

[*] Department of Electrical Engineering, Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib, Punjab, India, Country

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ABSTRACT

The conventional energy sources are depleting day by day, so the choice of solar energy as the future energy source is most prominent and secure as it is abundant. The non-linear I-V characteristic of Photovoltaic (PV) array and dependency of output power on external environmental conditions like temperature and irradiance affects the PV array efficiency. The maximum power point tracking (MPPT) mechanism is deployed along with the PV array so that maximum power can be extracted. In this paper, a PV system is modeled which incorporated the MPPT control mechanism and a boost converter to step up the voltage magnitude to the desired level. The algorithm applied for MPPT is Perturb and Observe (P&O); a generalized algorithm and is easy to model. The results are carried out in MATLAB/SIMULINK.

KEYWORDS: PV array, MPPT, Perturb and Observe (P&O), Boost converter.

1. INTRODUCTION

Renewable energy technologies (RETs) are playing a vital role in securing sustainable and affordable energy, which is accessible to a large part of society. In recent years, the growth in generation using RETs is unprecedented, and solar energy is the prime source among all RETs [1]. Figure 1 depicts the global renewable energy investment made over the decade (2010-2019) in billion dollars ($bn).

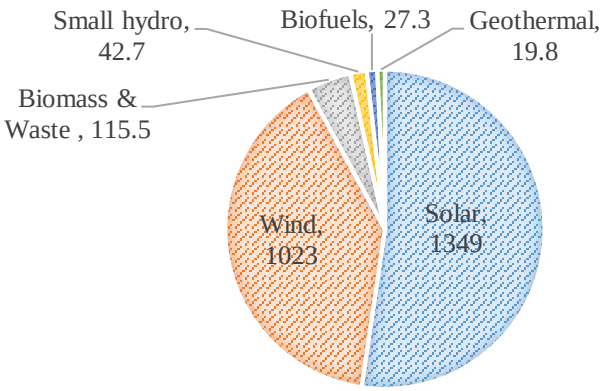

Figure 1: Global renewable energy investment over the decade (2010-19) in $bn

The popularity of the solar system is because of the abundant availability of the sun's energy. The PV (solar) system can be used as a standalone or grid-tied. The standalone system is well-suited for rural areas where there is no grid nearby. The reliability of such a PV system depends on various environmental conditions, mainly like irradiance level and temperature [2]. The effect of irradiance and temperature can be seen in figure 2, portraying the I-V characteristics. At a particular value of voltage, the PV system produces maximum power called a maximum power point (MPP), see figure 2. The maximum power point tracking (MPPT) mechanism make certain the PV array should operate at MPP, and extract the maximum available power.

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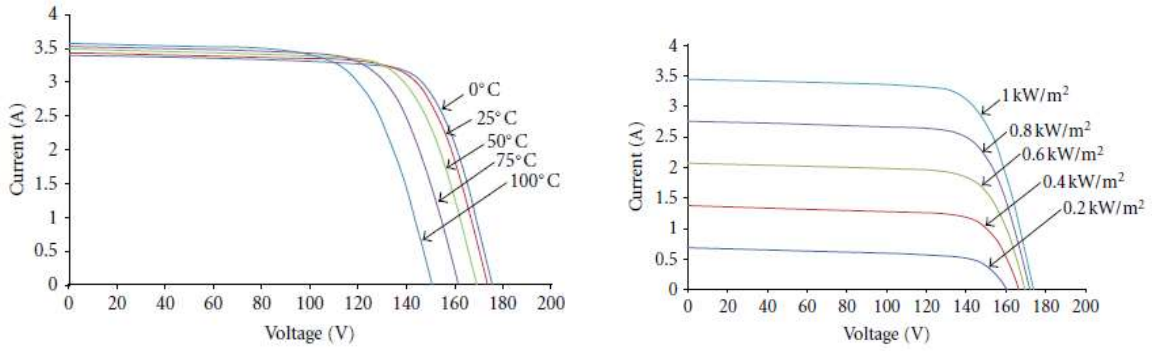

(a) *(b)*

Figure 2: The I-V characteristics of PV array portraying the effect of (a) change in temperature and (b) different solar irradiance

Over the years, many methods have been developed for MPPT like Perturb and Observe (P&O), incremental Conductance (I_C) and constant voltage method, etc. [1]–[6] In this paper, the most common MPPT algorithm P&O is used to analyze the performance of PV array. The remaining paper is arranged in following sequence: section 2 presents the mathematical modeling of PV array. The PV array incorporating the MPPT mechanism is modeled in section 3. The results simulated in MATLAB/SIMULINK are presented in section 4 followed by conclusion and future trends in section 5.

2. MATHEMATICAL MODEL OF PV ARRAY

The solar cells are the building block of PV array (figure 3), which is essentially a p-n semiconductor junction. When the light falls upon it, a current is generated (DC in nature). The I-V characteristics for a PV array can be written as:

$$I_D = I_0\left\{exp\frac{[q(V+IR_S)]}{n*K*T}-1\right\} \quad (1)$$

$$I_{SH} = \frac{V+IR_S}{R_{SH}} \quad (2)$$

$$I = I_{SC} - I_D - I_{SH} \quad (3)$$

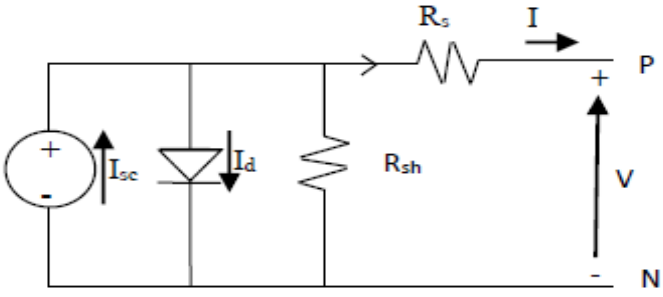

Figure 3: Equivalent circuit of a PV array

Where:

- V and I represent the output voltage and current of the PV, respectively.
- R_S and R_{SH} are the series and shunt resistance of the cell.
- q is the electronic charge.
- I_{SC} is the light-generated current.
- I_0 is the reverse saturation current.
- n is a dimensionless factor.
- K is the Boltzmann constant, and T is the temperature in ^oK.

3. MODELLING OF PV SYSTEM INCORPORATING MPPT MECHANISM

There are a lot of methods to improve performance of solar module. Maximum Power Point Tracking "MPPT" is one of these methods. The P–V characteristic curve of a PV array unveils a maximum power point "MPP"

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that varies due to the environmental condition, viz. temperature and solar insulation which impose a challenge for the maximum power tracking algorithms [7]. In this paper P&O algorithm is utilized which is modeled as:

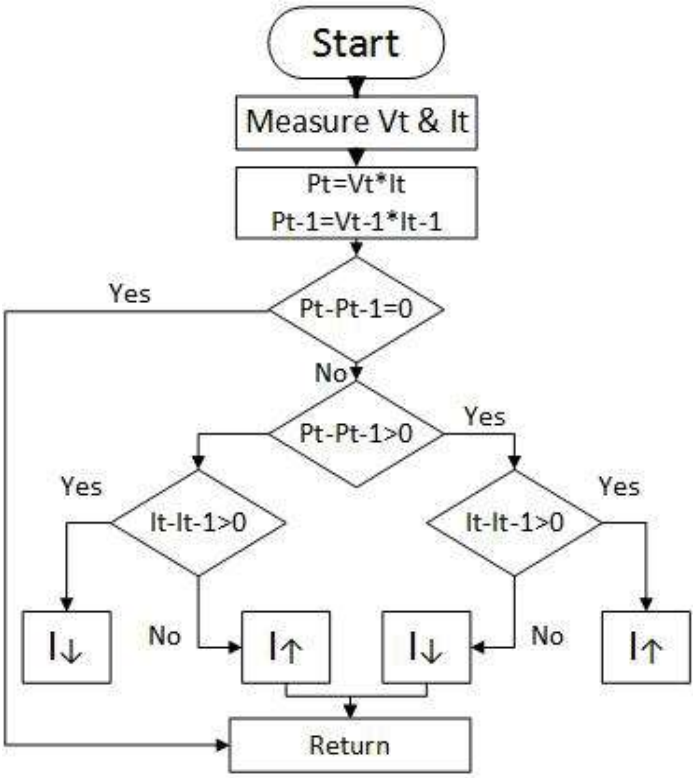

Figure 4: Perturb & Observe (P&O) algorithm

The perturb & observe "P&O" algorithm, works on "hill climbing" principle is a MPPT controller based on the voltage perturbation Vpv. A periodically perturbation is given to the module voltage and the corresponding output power is compared with that at the previous perturbing cycle [2]. In this algorithm a slight perturbation is introduce to the system so that the output power of the solar module varies. If the power increases due to the perturbation, then the perturbation is continued in the same direction. After the peak power is reached the power at the MPP is zero and next instant decreases and hence after that the perturbation reverses [8], as shown in figure 5.

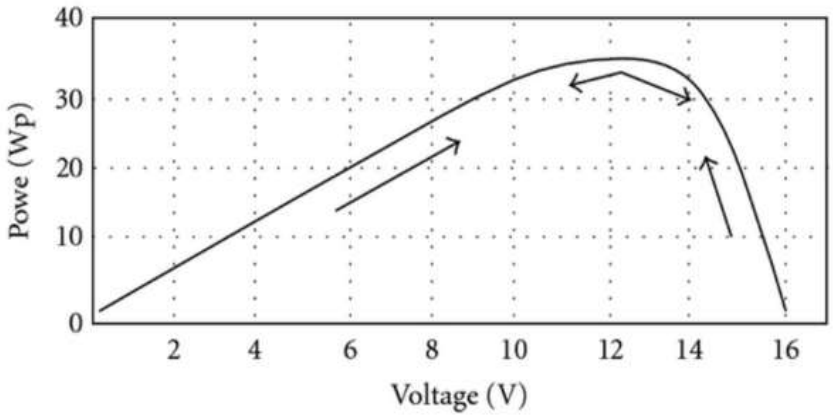

Figure 5: Power vs Voltage graph for P&O algorithm

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4. SIMULATION RESULTS AND DISCUSSION

The models considered in paper were simulated using MATLAB/SIMULINK. The simulation results for boost converter has been recorded and presented here. Results portrayed below include output voltage, current and output power.

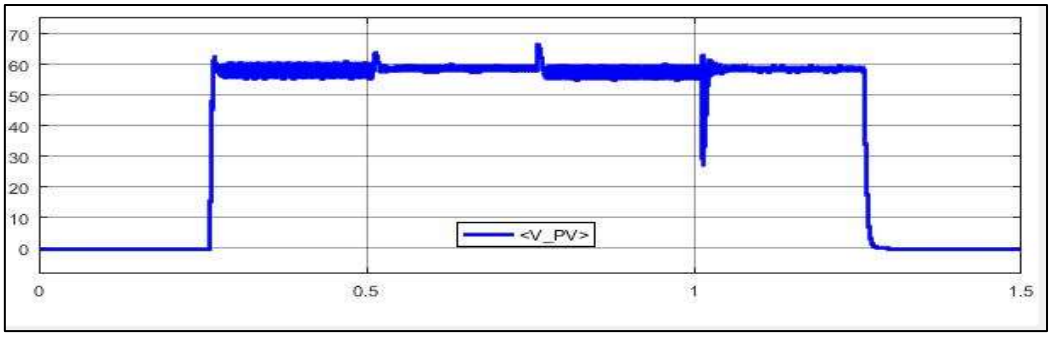

Figure 6: Voltage characteristics of PV panel

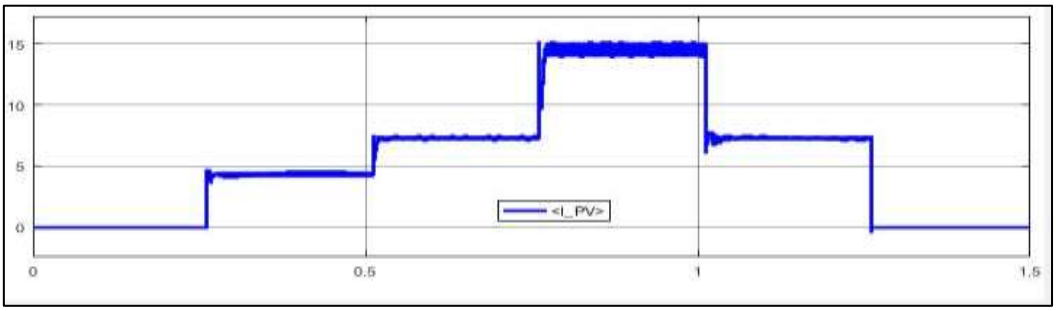

Figure 7: Current characteristics of PV panel

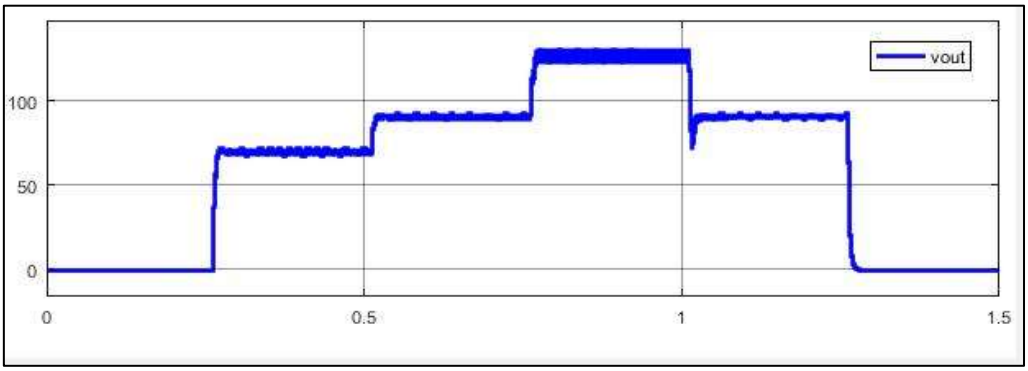

Figure 8: Output voltage of Boost converter with P&O algorithm

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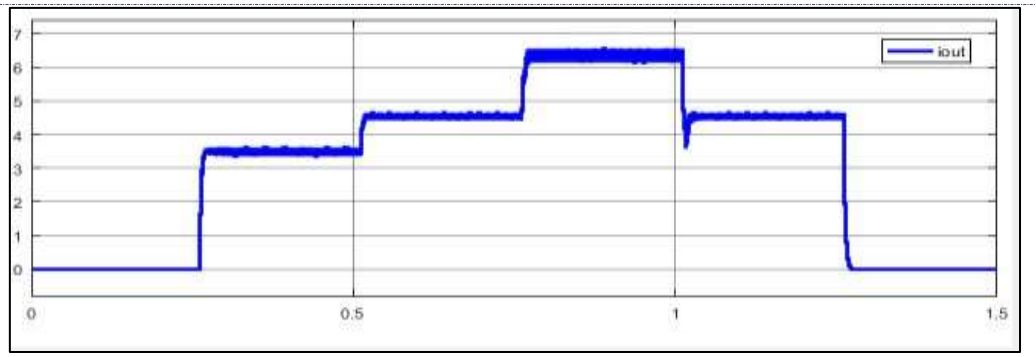

Figure 9: Output current of Boost converter with P&O algorithm

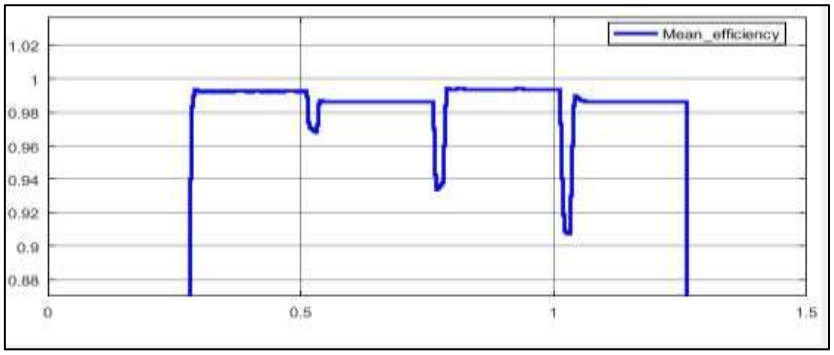

Figure 10: Mean efficiency graph (about 98%)

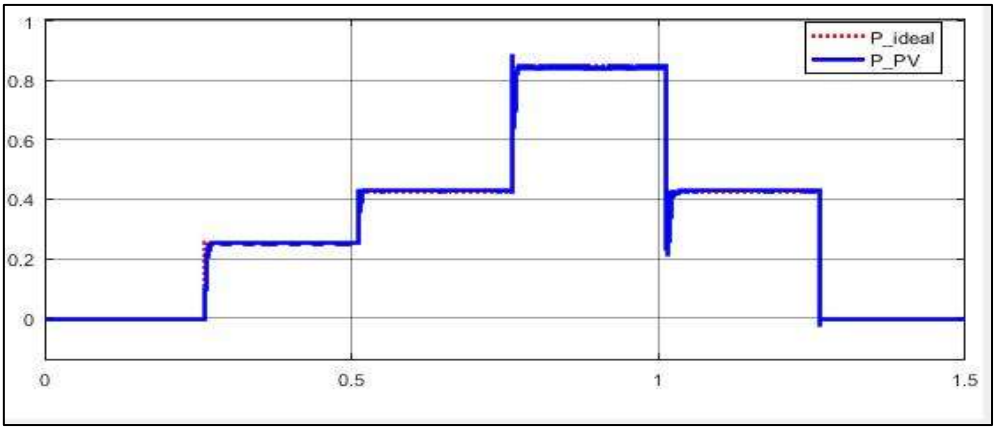

Figure 11: Output power for PV panel and ideal output power

In Figure 11, the simulation results of the output power of the PV panel using Perturb an Observe method controller is reported, so we can say it is shown that the P&O method, when properly optimized, leads to an efficiency which is equal to 98 % as shown in Fig. 10.

5. CONCLUSION

A mechanism for extracting maximum power from PV panel is presented in this paper. Firstly the PV system characteristics and mathematical model are presented. The MPPT strategy based on Perturb & Observe method is presented. The results obtained from simulation using P & O approach show the effectiveness despite the variation in environmental changes, i.e. change in irradiance or temperature level.

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