Comparison of Solar Panel Power under Varying Load and Irradiance Conditions

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Abstract- ***As*** **the electric power supplied by Solar array depends on insolation, temperature and array voltage, it is important to track the maximum power point of Photovoltaic panel. There are different types of Maximum Power Point Tracking (MPPT) control. In the proposed paper, Modified Perturb and Observation MPPT Control method is used to track maximum power point. Solar panel output is connected with the boost converter [6] and the switching of the boost converter is controlled to achieve MPPT. The major difference between the proposed algorithm and other techniques is that proposed algorithm is able to control the power of the PV array directly. The proposed MPPT has several merits such as simplicity, high convergence speed and independent of PV array characteristics.**

Keywords: Photovoltaic, MPPT, Perturb and Observe, insolation.

INTRODUCTION

RENEWABLE sources of energy acquire growing importance due to its enormous consumption and exhaustion of fossil fuel. Also, solar energy is the most readily available source of energy and it is free. Moreover, solar energy is the best among all the renewable energy sources since, it is non-polluting. Energy supplied by the sun in one hour is equal to the amount of energy required by the human in one year. Photo voltaic arrays are used in many applications such as water pumping, street lighting in rural town, battery charging and grid connected PV systems.

As known from a Power-Voltage curve of a solar panel, there is an optimum operating point such that the PV delivers the maximum possible power to the load. The optimum operating point changes with solar irradiation and cell temperature. Therefore, maximum power point tracking is essential for PV panel. A variety of maximum power point tracking (MPPT) methods is available [1].

This paper deals with Modified Perturbation and Observation MPPT algorithm method due to its simple approach.

A. Photovoltaic Cell

Photovoltaic cell generates electricity from the sun. PV panel works under the phenomenon of photoelectric effect. It directly converts sunlight into electricity. The diagram of PV based system is shown in Fig. 1.

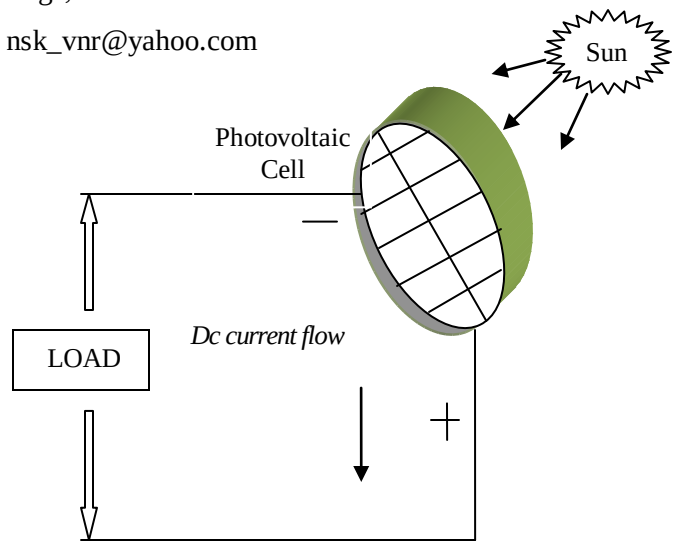

Fig 1: Photovoltaic Cell

B. PV Equivalent Circuit:

Solar cells are connected in series and parallel to set up the solar array. Solar cell will produce dc voltage when it is exposed to sunlight. Fig. 2 shows the equivalent circuit model for a solar cell. Solar cell can be regarded as a non-linear current source. Its generated current depends on the **characteristic of material**, age **of solar cell, irradiation and cell temperature.**

Fig. 3 and 4 shows the P-V and V-I characteristics of solar panel for various irradiance at a cell temperature of 25˚C.

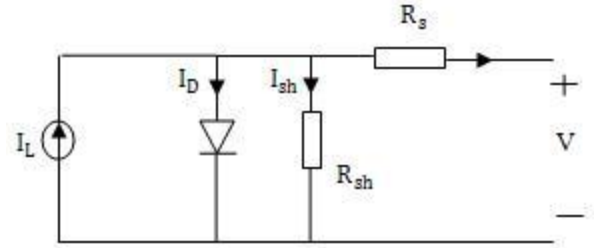

Fig. 2: Equivalent circuit of solar panel

Equation (1) describes the I-V characteristics of the PV model,

$$I = I_L - I_0\left(e^{\frac{q(V+IR_S)}{KT}} - 1\right) - \frac{V+IR_S}{R_{sh}} \quad (1)$$

Where:
I is the cell current (A).
I_L is the light generated current (A).
I_o is the diode saturation current.
q is the charge of electron = 1.6 x 10^{-19}(coulomb)
K is the Boltzmann constant (j/K).
T is the cell temperature (K).
R_s, R_{sh} are cell series and shunt resistance (ohms).

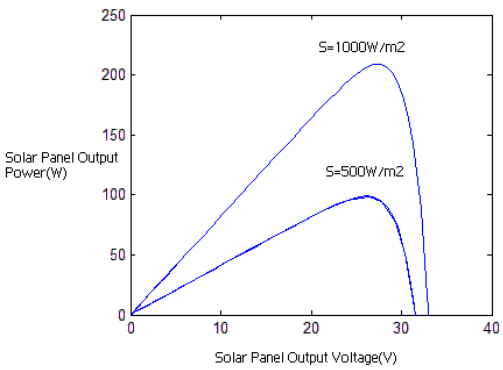

Fig. 3: P-V characteristics of solar panel for various Irradiance S at a temperature of 25°C

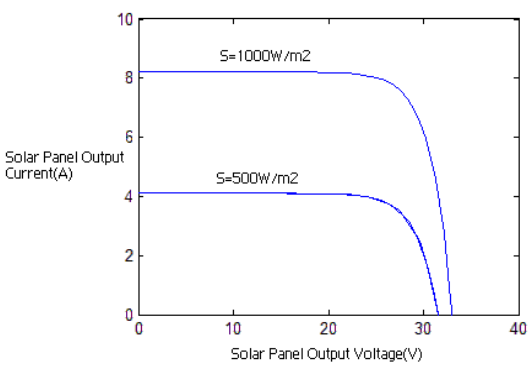

Fig. 4: I-V characteristics of solar panel for various Irradiance S at a temperature of 25°C

C. *System Description:*

The MATLAB simulation circuit diagram of Photovoltaic system [7],[8] is shown in Fig 5. The PV system is modeled using Power System Block set under Matlab Simulink. The MPPT algorithm is modeled using embedded matlab function block.

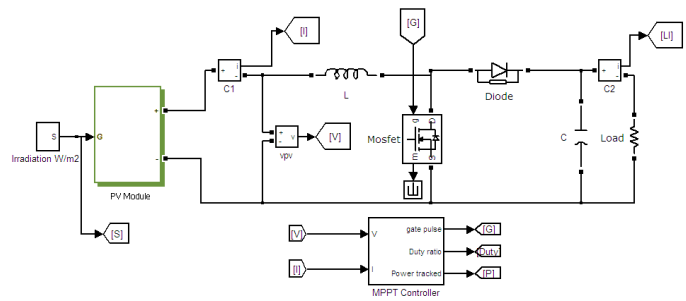

Fig. 5: Photovoltaic System

Table I
Simulation Parameters

Switching frequency of converter	20 kHz
C	470µF
L	100mH
Boost chopper switch	MOSFET
Load resistor, R	100Ω

Table II
Key specifications of Solar Panel

Maximum Power P_{max}	200.1430W
Maximum Voltage V_{max}	26.3V
Maximum Current I_{max}	7.61A
Short Circuit Current I_{sc}	8.21A
Open Circuit Voltage V_{oc}	32.9V

D. *Commonly Used MPPT Methods:*

MPPT methods are used to track the voltage Vmax or current Imax at which a PV module delivers a maximum power under a given insolation and temperature [9], [10]. The commonly used MPPT methods are fractional open circuit voltage, fractional short circuit current, Perturb and Observe and Incremental conductance MPPT methods.

E. *Proposed Modified Perturb and Observe MPPT Algorithm:*

Most MPPT techniques attempt to find the PV voltage that result in the maximum power point V_{mpp}, or to find the PV current I_{mpp} corresponding to the maximum power point. The proposed algorithm tracks neither the V_{mpp} nor the I_{mpp}. However, it tracks directly the maximum possible power P_{max} that can be extracted from the PV. The flowchart of the proposed MPPT method is shown in Fig: 6.

The proposed modified Perturb and Observe MPPT [2] algorithm starts by setting the computed maximum power P_{max} to an initial value (zero or any other value). Actual PV

voltage and current are measured [3]. Then the instantaneous value of PV power P_{act} is computed. The error between P_{max} and P_{act} is the duty cycle of boost converter. The output of the MPPT controller is used to drive the power transistor of the Boost Converter such that the P_{act} tracks P_{max}. Till now, the real maximum power is not tracked. To track the maximum power, the error between P_{max} and P_{act} is checked. If the error is lower than a certain upper limit (0.5 Watt), this means that the Power drawn from the PV is within allowable value, so we can increment P_{max} by a certain step size. This new value of P_{max} is stored and used to control the actual power of the PV to track this new value. Then the algorithm is repeated again. When the error between P_{max} and P_{act} exceed the upper limit it means that the PV is no longer able to deliver this value of P_{max}. Therefore, we have to decrement of P_{max} by a certain step size (0.5Watt).

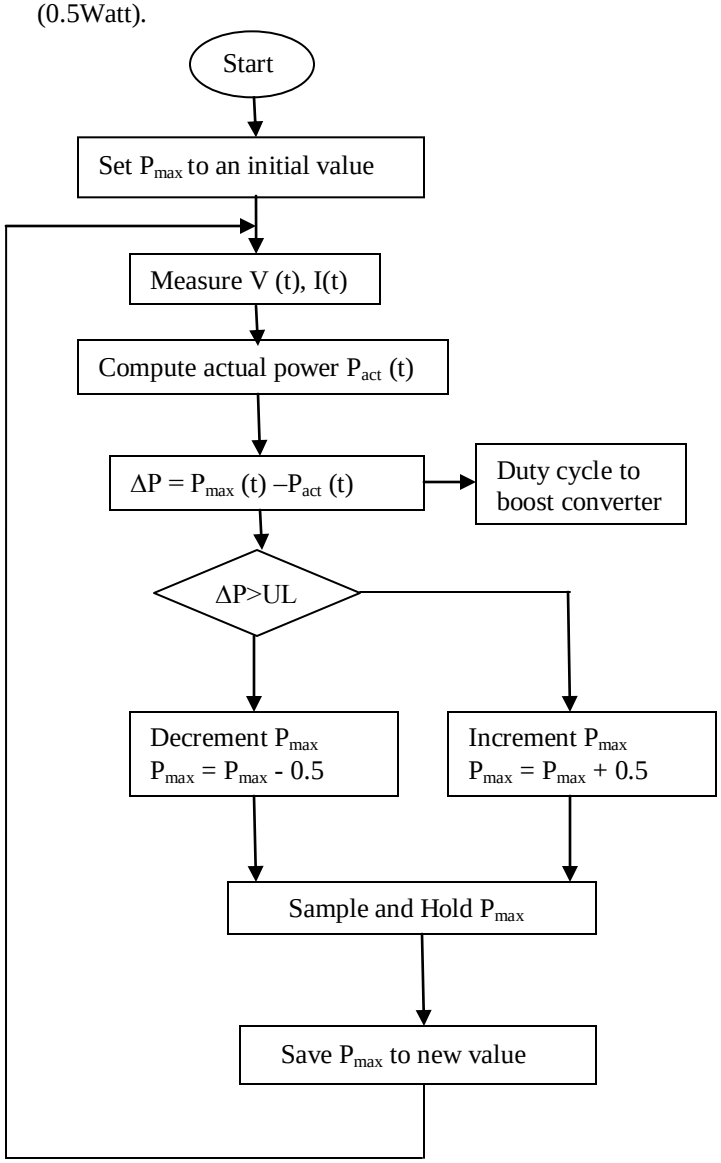

Fig. 6: Flowchart of the proposed MPPT Algorithm

F. Simulation Results:

Fig. 7 the shows the power of the photovoltaic panel under varying insolation and load conditions in open loop. The maximum power obtained at 1000W/m^2 insolation was 139W in the open loop condition. The Fig. 8 shows the maximum power tracked under varying insolation and load conditions [4] using MPPT controller in closed loop which is implemented using embedded matlab function. Here the insolation is varied from 600W/m^2 to 1000W/m^2. According to the results, computed Pmax is 169W, while the theoretical value is 200W at 1000W/m^2. So the tracking efficiency is 84.5%.

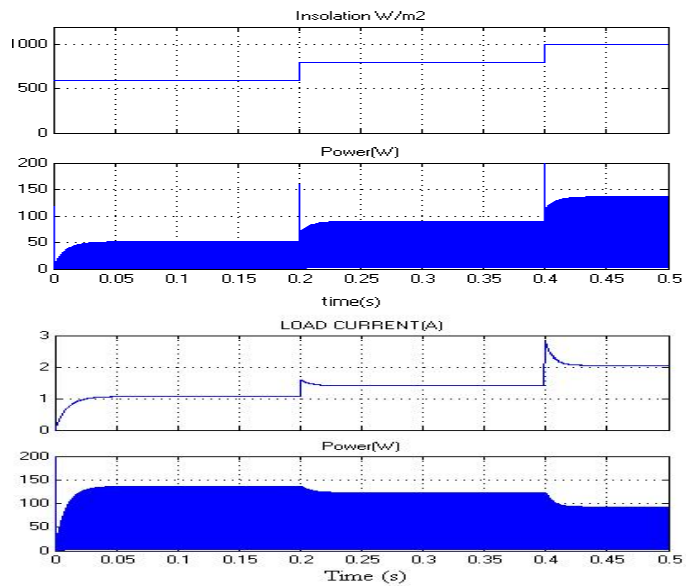

Fig. 7: Open Loop Waveforms for Varying Irradiance and Load Conditions

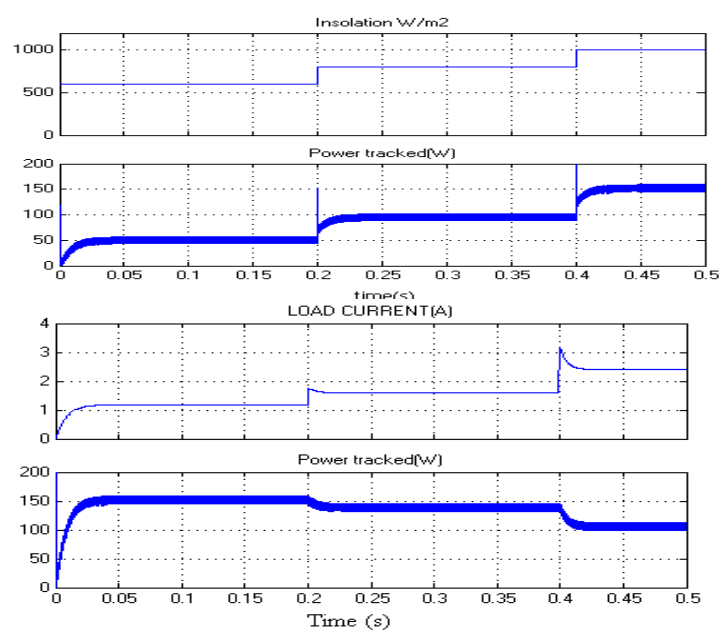

Fig 8: Closed Loop Waveforms for Varying Irradiance and Load Conditions

G. Conclusion:

The paper proposes a simple MPPT method that requires only measurements of PV voltage and current. The proposed MPPT algorithm is called Modified Perturb and Observation Method. However, the major difference between the proposed method and any other MPPT method [5] is that the proposed method attempts to track and compute the maximum power and controls directly the extracted power from the PV.

The proposed method offers different advantages which are: good tracking efficiency, relatively high convergence speed and well control for the extracted power.

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