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Implementation of MPPT Algorithm with Non-Uniform Irradiance in Solar PV System

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Abstract- The government focusing on deployment of solar energy as India is bestowed with large solar energy potential whereby about 5000 trillion kWh per year energy is incident over India's land area with most parts receiving 4-7 kWh per sq. m. per day with almost with more than 300 sunny days. Photovoltaic panel has very low efficiency. So, several methods are to be undertaken to match the generating source and load properly in order to increase the efficiency of system. Therefore, Maximum Power Point Tracking (MPPT) technique is used to obtain the maximum possible power from a varying source. The paper proposed the algorithm for MPPT to obtain the maximum available power from PV module by making them operate at the most optimal voltage. In photovoltaic systems the nature of I-V curve is non-linear; hence it might be difficult to be used to power a certain load end. This is done by utilizing a converter whose duty cycle is varied by implementing Perturb and Observer algorithm for MPPT algorithm controller with variable irradiance.

Keywords- solar, characteristics, MPPT controller, P&O.

I. INTRODUCTION

Solar energy technologies utilizes the energy and light from sun's to provide heat, light, electricity, and even heating and cooling, for homes, buildings, and industry. There are large numbers of technologies that have been developed for variety of applications in different areas by making an efficient utilization of solar energy. "Jawaharlal Nehru National Solar Mission" (JNNSM) has been launched by Government of India which aims at development and deployment of solar energy technologies in India. The mission targets of establishing 20 GW of Grid connected and 2 GW of Off-grid capacity by 2022 in three phases. The mission also includes implementation of 20 million solar lighting systems for rural areas by 2022. The main objective is to subsidize India's long term energy security and its sustainable ecological growth. The Prime Minister has emphasized the importance of the mission as: "The importance of this Mission is not just limited to providing large-scale grid connected power. It has the potential to provide significant multipliers in our efforts for transformation of India's rural economy. Already, in its decentralized and distributed applications, solar energy is beginning to light the lives of tens of millions of India's energy-poor citizens. The rapid spread of solar lighting systems, solar water pumps and other solar power-based rural applications can change the face of India's rural economy. We intend to significantly expand such applications through this Mission. As a result, the movement for decentralized and disbursed industrialization will acquire an added momentum, a momentum which has not been seen before [2]." But now the government is proposing an increase in the JNNSM target from 20 GW to 100GW by 2020 by introducing ultra-mega power projects of solar parks.

Several features of the photovoltaic are to be studied when the graph is plotted in between the current and the voltage generated. IV curve shown below clearly defines the various parameters that will affect the operating conditions of the solar cell and that we will discuss later in the next discussion. Here, We discuss the IV curve, short circuit current (Isc), open circuit voltage (Voc); fill factor (FF) and efficiency of the cell [10]. The IV characteristics of the solar cell are the superposition of the diode in the dark. Basically, a solar cell behaves same as diode in the absence of light. Whenever the light falls on the solar diode, the current starts flowing and hence the graph shifts as the cell starts generating power as shown in the fig 2. As the intensity of sunshine increases the curve start shifting. The equation for the IV curve is given as:

$$I = Irr - Io[e^{\frac{qV}{nkT}} - 1]$$

Where, K (K=1.3806503 × 10^{-23} J/K), is the Boltzmann constant

T is the absolute temperature, 25°C

q (>0) is the electron charge

V is the voltage at the terminals of the cell

Io is the diode saturation current

Irr is related to the light incident on the cell.

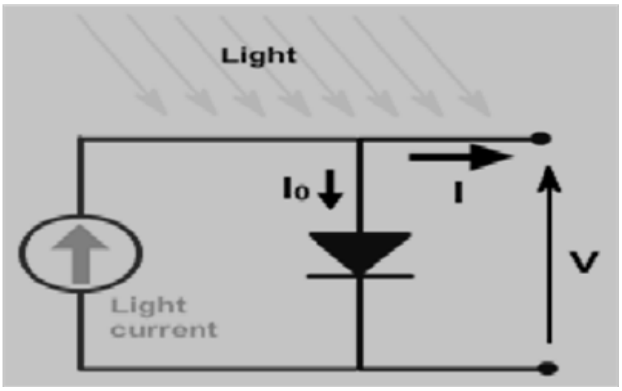

Fig 1: Solar Cell Equivalent

Some of the important characteristics of solar cell (short circuit current, open circuit voltage, fill factor, efficiency) from curve are as discussed -

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Short circuit current (Isc): The short-circuit current is the amount of current through the solar cell when the voltage across the solar cell is zero or when the solar cell is short circuit. The short-circuit current is denoted by I_{SC} shown on the IV curve.

Open circuit voltage (Voc)*:* The open-circuit voltage, V_{OC}, is the maximum voltage available from a solar cell whenever there will be no load across the cell or when there will be no current. The open-circuit voltage is denoted by Voc as shown on the IV curve.

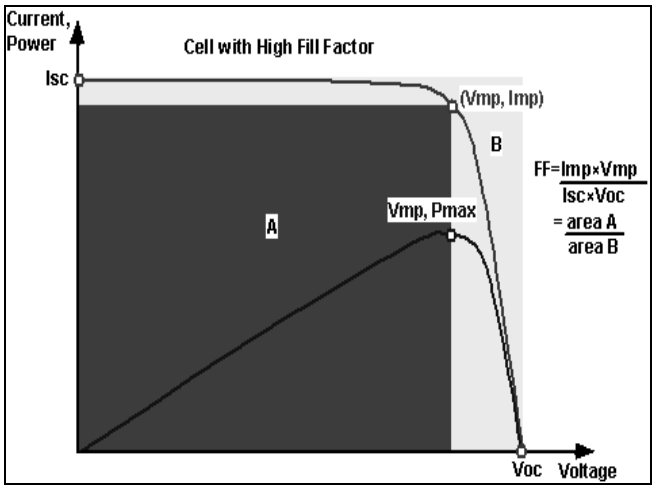

Fig 2: solar cell with fill factor (FF) [7]

Fill factor: Fill factor is the foremost important factor for determination of the capabilities of the solar cell. It describes the ideality of the solar cell. The fill factor (FF) may be defined as the ratio of maximum generated power to the actual maximum power to be generated. The factor is graphically shown in the graph 1 and mathematically is calculated as:

$$\text{Fill factor (FF)} = \frac{\text{Imp} \times \text{Vmp}}{\text{Isc} \times \text{Voc}}$$

Where, Vmp, Imp are the parameters for maximum power point

Efficiency: The efficiency of a photovoltaic cell depends upon the intensity of the light incident on the cell and the temperature. The efficiency of a solar cell is determined as the fraction of incident power which is converted to electricity and is defined as [7]:

$$\text{Pmax} = V_{OC} I_{SC} \text{ FF}$$

$$\text{efficiency} = \frac{V_{OC} I_{SC}}{\text{power input}} \text{FF}$$

Solar energy technologies utilizes the energy and light from sun's to provide heat, light, electricity, and even heating and cooling, for homes, buildings, and industry. There are large numbers of technologies that have been developed for variety of applications in different areas by making an efficient utilization of solar energy. These technologies use the solar energy to heat either water or a heat-transfer fluid in collectors generally mounted on a roof top. The sun rays penetrate through the glass and fall on the absorber. The heat of the sunrays is absorbed by the cold water inside the absorber thereby increasing its temperature. Solar thermal technologies can be used for Heating, cooling and ventilation of buildings.
S fibers, holographic tuning [6] are the new emerging solar technologies that will improve the amount of electricity that it's possible to generate from much smaller panels by holographic tuning and in S fibers, instead of using silicon like with solar cells these use a solar tape which is made out of titanium dioxide.

II. IMPLEMENTATION OF MPPT CONTROLLER ALGORITHM

Photovoltaic panel has very low efficiency. So, several methods are to be undertaken to match the generating source and load properly in order to increase the efficiency of system. Therefore, Maximum Power Point Tracking (MPPT) technique is used to obtain the maximum possible power from a varying source [6]. The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient voltage (maximum power point) [3]. In photovoltaic systems the nature of I-V curve is non-linear; hence it might be difficult to be used to power a certain load end. This is done by utilizing a converter whose duty cycle is varied by using an MPPT algorithm [8]. A converter is connected on the load side and power to this converter is through a solar panel. There are various algorithms used for maximum power point tracking

- Fractional Open Circuit Voltage algorithm
- Fractional Short Circuit Current algorithm
- Perturb and Observe algorithm
- Incremental Conductance algorithm

Perturb & Observer (P& O) method is the commonly used MPPT algorithm and is also known as hill-climbing algorithm [6]. In this algorithm, the panel voltage is periodically perturbed with small change in the voltage and the corresponding output power is observed and compared with the previous perturbing cycle. Due to perturbation, the operating point oscillates around the MPP. Depending on the sign of observed power, further perturbation will be given to voltage. During the process, the change in the sign is also observed. If dP/dV is positive, then the algorithm increases the voltage value towards the MPP until $dP/dV$is negative. This process is repeated at each MPP tracking step until the MPP is reached. Practically, the voltage never reaches an exact value but perturbs around the maximum power point (MPP) [4] [9]. The algorithm is defined clearly through flow chart given below in the fig.3

Table 1: Comparison of MPPT Algorithms

MPPT algorithm	*Time response*	*Accuracy*
Fractional open circuit voltage	Fast	low
Perturb & Observer	faster	high
Incremental Conductance	Slow	higher

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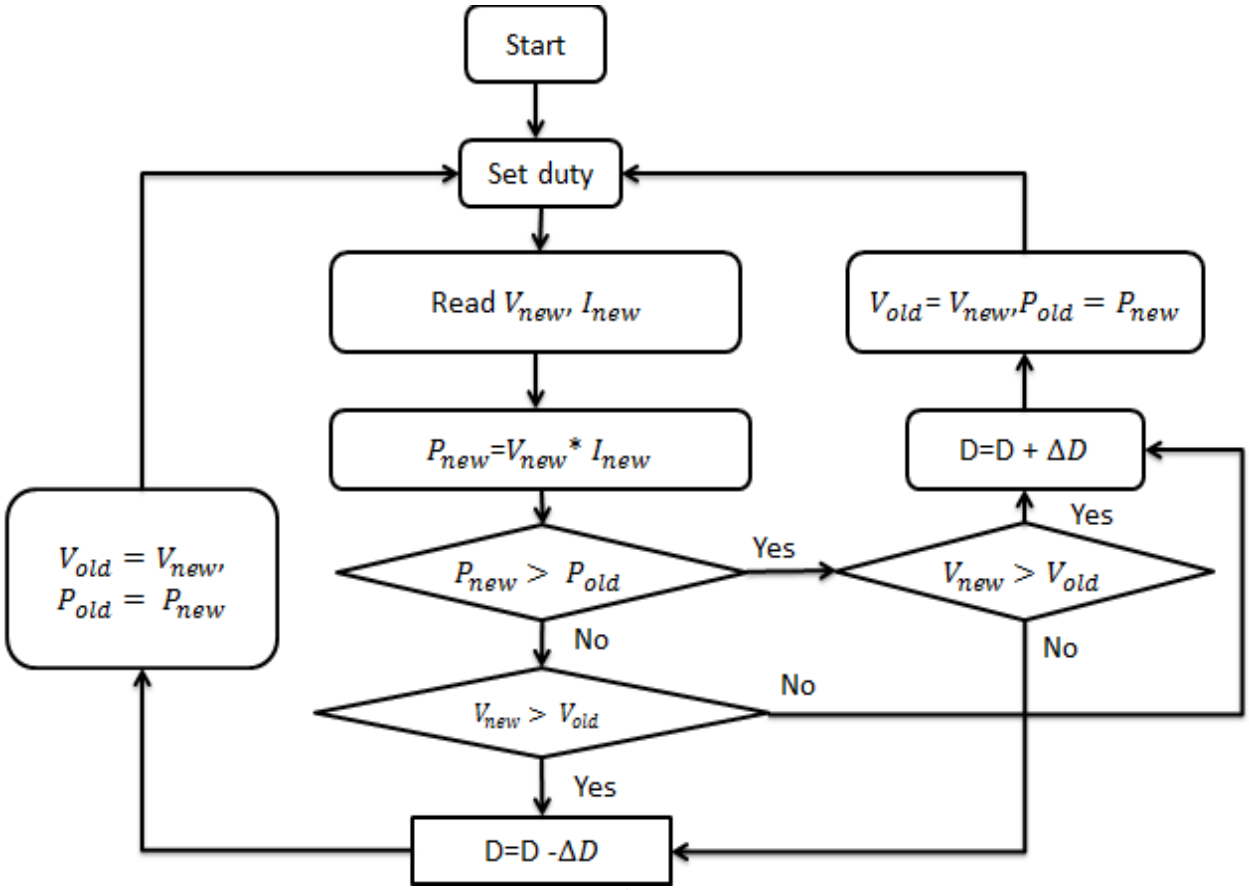

Fig 3: Flow chart for P&O algorithm

III. RESULTS

V-P and V-I characteristics graph results of the photovoltaic module by varying the irradiance parameter at certain temperature is shown in fig 4(a) and fig 4(b). 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 V-I and V-P 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. Fig 4(c) results into output parameters of the solar photovoltaic panel with respect to variable radiations under different atmospheric condition while implementing the proposed controller algorithm. Solar irradiance, atmospheric temperature and the electrical load operating conditions are the main factors which affect the performance of the photovoltaic system [1] [5].

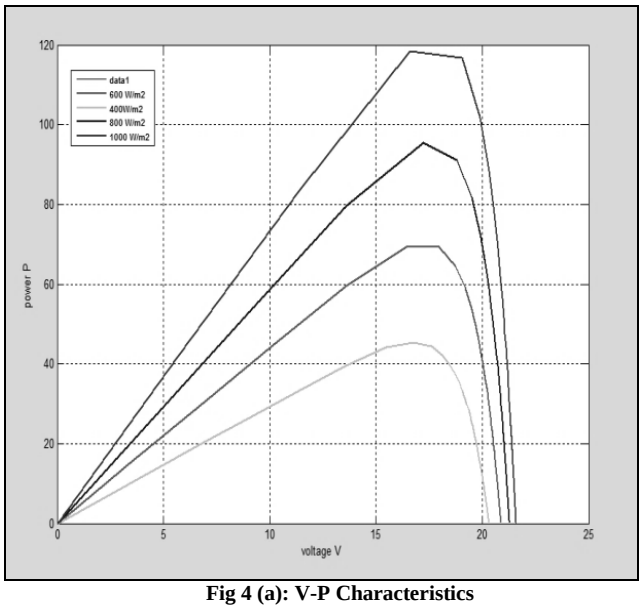

Fig 4 (a): V-P Characteristics

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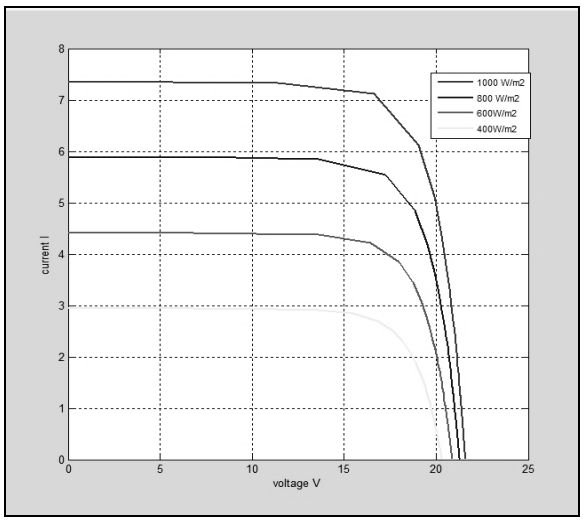

Fig 4 (b): V-I Characteristics

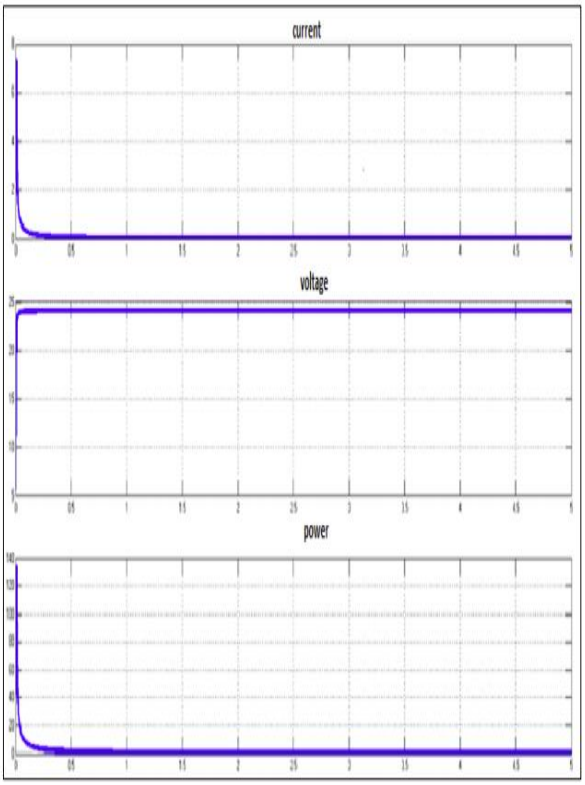

Fig 4 (c): output current, voltage and power

IV. CONCLUSION

The proposed algorithm of MPPT shows the effects of the non-uniform irradiance on the PV module performance. Inspection of accuracy and precision of the model is implemented in Matlab/ Simulink using electric parameters of solar panel. A comprehensive simulation of PV module equivalent electric circuit was also performed as the initial step in improving the photovoltaic power systems which can be used in all the PV systems. 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. Eventually closed loop simulations show that P&O method can track the MPPs with high accuracy and exploit full utilization of PV modules irrespective to environmental conditions. Solar irradiance, atmospheric temperature and the electrical load operating conditions are the main factors which affect the performance of the photovoltaic system. This P&O Algorithm for MPPT controller is simple and Easy to implement on hardware as well as software.

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