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MATLAB Simulation of Perturb and Observe (P&O) Method of Maximum Power Point Tracking (MPPT) in Solar Photovoltaic System (SPV)

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Abstract: As compare to fossil fuels solar power is everlasting supply of energy whereas fossil fuels and traditional sources of power are restricted. currently solar power or solar photovoltaic's (PV) gaining a lot of attention of the researchers and market players of this field. Maximum power point tracking (MPPT) is that the optimum answer to extract maximum SPV generated power. MPPT is nothing but the tracking of maximum available power of an SPV system by means of the DC-DC converter. Presently so many methods are available for MPPT operation of solar photovoltaic (SPV). In this paper simulation of SPV along with the Perturb and Observe (P&O) method of MPPT is presented. The mathematical modeling of SPV array and the most popular MPPT technique that is P&O and its implementation is presented in this paper.

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I. INTRODUCTION

A SPV power generation system consists of numerous components like cells, electrical connections and power conditioning unit to regulating and/or changing the electrical outputs. These systems are rated in peak watts (Wp) which is an amount of electrical power that a SPV system can deliver at standard test conditions (STC). Photovoltaic comprises the technology to convert sunlight directly into electricity. The term photo means light and voltaic electricity. A PV cell, also known as solar cell is a semiconductor device that generates electricity when direct or indirect solar radiation falls on it.

II. MODELING OF PV SYSTEM

The output of PV cell is a function of photon current that can be also determined by load current depending upon the solar insolation during its operation equation [2].

$$I_{pv} = I_{ph} - I_s\left[\exp\left\{\frac{V_{pv}+I_{pv}R_s}{N\times V_T}\right\}-1\right] - I_{s_2}\left[\exp\left\{\frac{V_{pv}+I_{pv}R_s}{N_2\times V_T}\right\}-1\right] - \frac{V_{pv}+I_{pv}R_s}{R_{sh}} \quad \ldots(1)$$

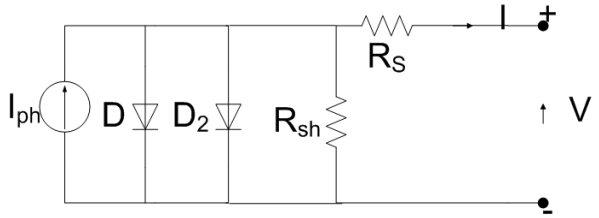

Fig. 1. Equivalent circuit of a two diode model of a PV cell [1-2].

Where:
I_{ph} is the solar induced or photon generated current:

$$I_{ph} = I_{ph0}\frac{I_r}{I_{r0}} \quad \ldots\ldots\ldots (2)$$

I_r is the irradiance (light intensity or insolation) in W/m2 falling on the cell.
I_{ph0} is the measured solar-generated current for the standard irradiance $Ir0$.
I_s is the saturation current of the first diode.
I_{s2} is the saturation current of the second diode.

V_T is the thermal voltage,
V_T=kT/q
k is the Boltzmann constant.
T is the solar cell operating temperature.
q is the elementary charge on an electron.
N is the quality factor (diode emission coefficient) of the first diode.
N_2 is the quality factor (diode emission coefficient) of the second diode.
V_{pv} is the voltage across the solar cell electrical ports.
The PV panel output is also dependents on solar insolation and temperature. A solar array modeled on the basis of two diode model has been given in MATLAB. Solar array given in MATLAB library is used for modeling and simulation. Fig. 2 shows the solar array available in MATLAB.

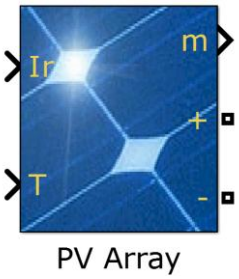

Fig. 2. Solar PVarray available in MATLAB.

The solar PV array given in MATLAB database is model Tata Power Solar Systems TP235MBZ; 10 series modules; 33 parallel strings. Its parameters are given in Table-I.

Table no 1: Parameters of Solar Module used for Simulation in MATLAB

Simulation data: Performance at standard test conditions, STC: 1000 W/m^2, 25 °C.	
Nominal Power P_{MPP} of module	234.4 W
Short Circuit current Isc of module	8.74 A
Open Circuit Voltage Voc of module	36.3 V
V_{MPP} of module	29.3 V
I_{MPP} of module	8 A

Current vs. voltage (I-V) characteristics obtained and power vs. voltage (P-V) characteristic is shown in Fig. 3 at standard test conditions, STC: 1000 W/m2, 25 °C. Parameters obtained from the simulation of the array are given in the table II below.

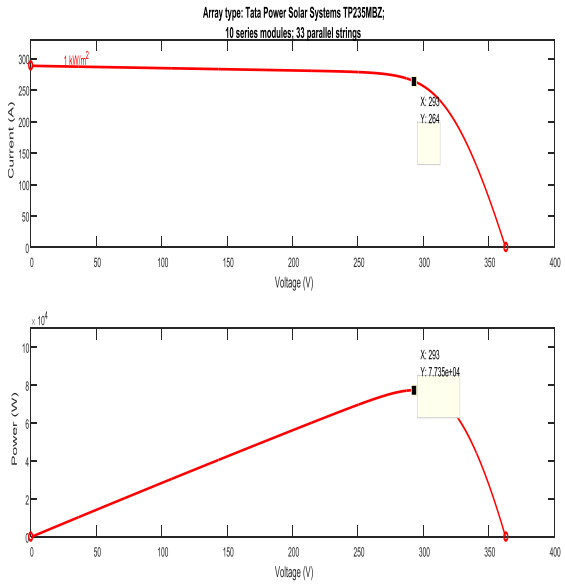

Fig. 3. I-V and P-V characteristics of solar array at 1000 W/m^2 insolation and 25$_0$C temperature.

Table 2: Parameters of Solar Array Obtained from Simulation.

Simulation data: Performance at standard test conditions, STC: 1000 W/m2, 25 °C.	
Nominal Power P_{MPP} of array	77.35 kW
V_{MPP} of array	293 V
I_{MPP} of array	264 A

III. MAXIMUM POWER POINT TRACKING

I-V and P-V characteristic shown in Fig 3 shows that the maximum available power of a solar PV system can only deliver to a particular voltage i.e. 293 Volt (V_{MPP}), also with changing environmental condition this point of voltage (V_{MPP}) vary. There is number of methods or algorithms have been developed for the MPPT over the past decade. They differ from each other on the basis of variable used for developing MPPT methods. Commonly used variables in MPPT algorithms are: PV current, PV voltage, output current, and output voltage. Based on these variables, there are various methods of MPPT as listed below:

Constant voltage

a. Constant Current
b. Curve fitting
c. Pilot cell
d. look up table
e. P&O
f. Incremental conductance
g. Temperature based
h. Beta
i. DC link capacitor droop control
j. Current Sweep

Commonly used method is found to be Perturb and Observe (P&O) method P&O algorithms are widely used in MPPT because of their simple structure and the few measured parameters which are required. The algorithm or principal of this method for finding the MPPT is developed by analysing the P-V characteristics of Solar PV array. In this method, the array terminal voltage is perturbed i.e. incremented and decremented and the power output of the array is observed. If the power output of the PV array is increased with the increment in the voltage that means the array is reaching towards the MPP and the perturbation is continued in the same direction, otherwise the perturbation direction will be reversed, hence array terminal voltage is perturbed every MPT cycle; therefore when the MPP is reached, the P&O algorithm will oscillate around it resulting in a loss of PV power, especially in cases of constant or slowly varying atmospheric conditions.. The operation explained in Table I.

Table 3: Methodology of P&O method

Perturbation	**Change in power**	**Next perturbation**
Positive	Positive	Positive
Positive	Negative	Negative
Negative	Positive	Negative
Negative	Negative	Positive

IV. SIMULATION OF P&O METHOD OF MPPT IN SOLAR PV SYSTEM

MATLAB simulation of the system presented in this paper is shown in Fig. 4.

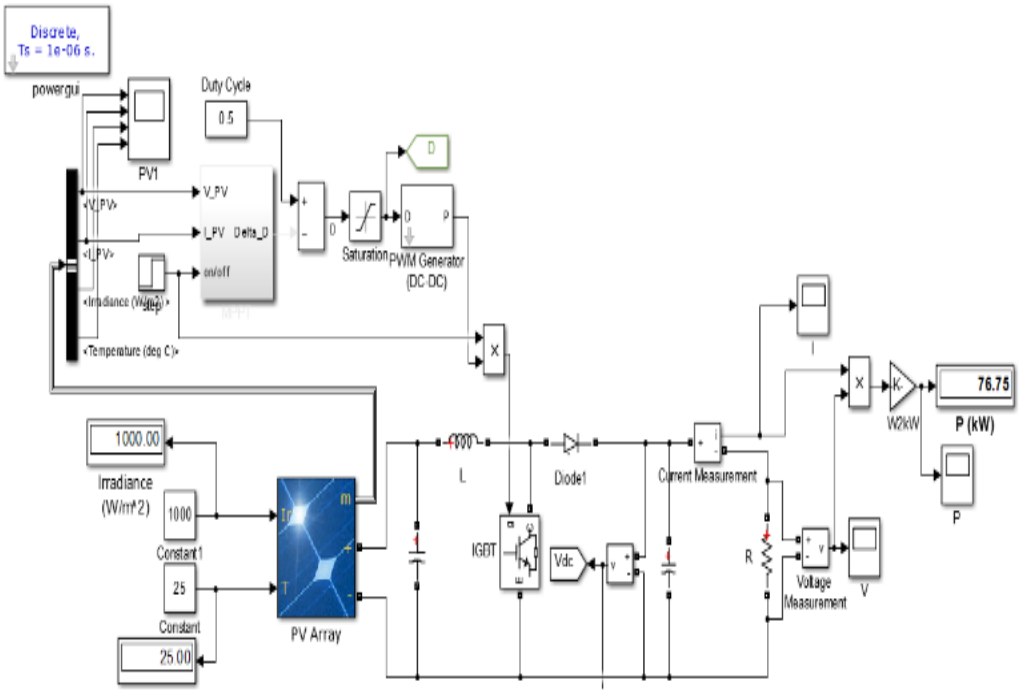

Fig. 4: MATLAB simulation of P&O MPPT algorithm applied to a standalone solar PV system

V. RESULT AND DISCUSSION

The simulated results are presented in this section. Simulation at fixed environmental conditions: The standard test conditions considered are i.e. 1000 W/m^2 insolation and 25^{0}C temperature. Fig. 5 shows the insolation falling on solar PV array with time. The operating temperature of solar PV array with time is shown in Fig. 6.

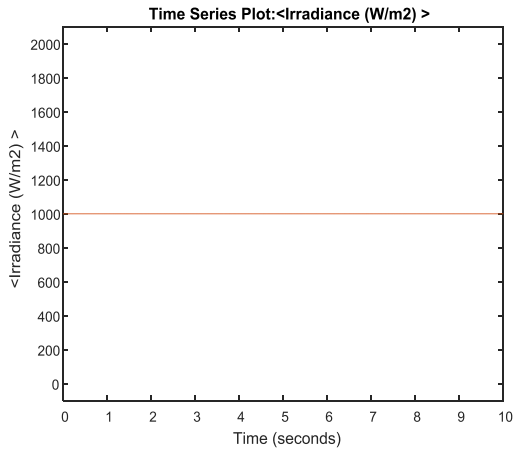

Fig. 5.Insolation on solar PV array with time

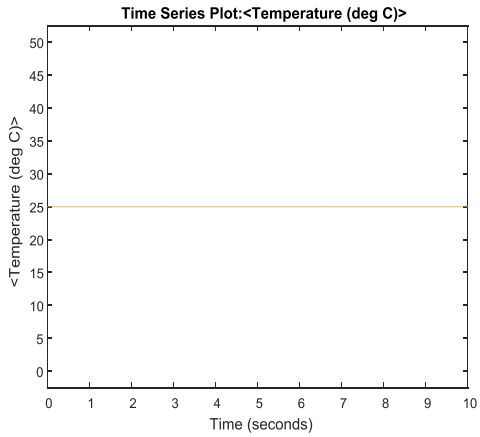

Fig. 6: Operating temperature if solar PV array with time

The power output from the array is measured in simulation as depicted in Fig. 7. and it is proved that the MPPT technique work properly as the output received by the load is equal to the maximum available power the source i.e. 77kW. The maximum available power at STC is 70 kW and the load receives the same amount of power.

Fig. 7 represents the variation in power output of the solar PV array with time.

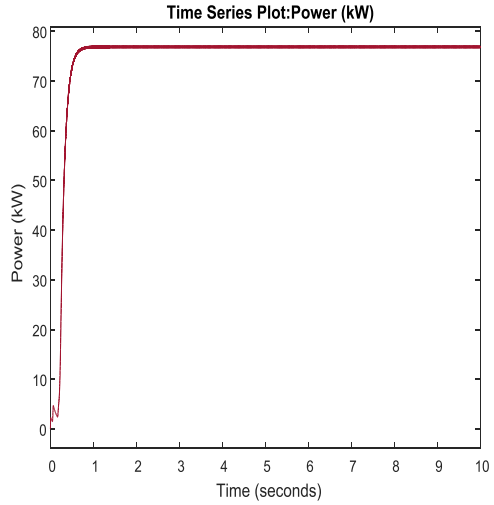

Fig. 7: Output power of solar PV array with time

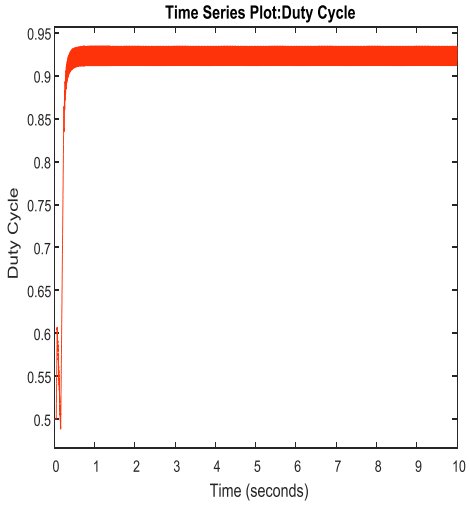

Fig. 8: duty cycle of solar PV array with time

According to the P&O operation the duty cycle increases upto the maximum power point after that it oscillate around the point of maximum power. Fig. 8 shows the relation between duty cycle and time and it is clear from the figure that the duty cycle oscillates once the maximum power achieved. Fig. 9 shows the terminal voltage of solar PV array and it is clear from the figure that the voltage of array settled down around the V_{MPP}. Fig. 10 shows the output current of solar PV array and it is observed that the current of array settles down around I_{MPP}.

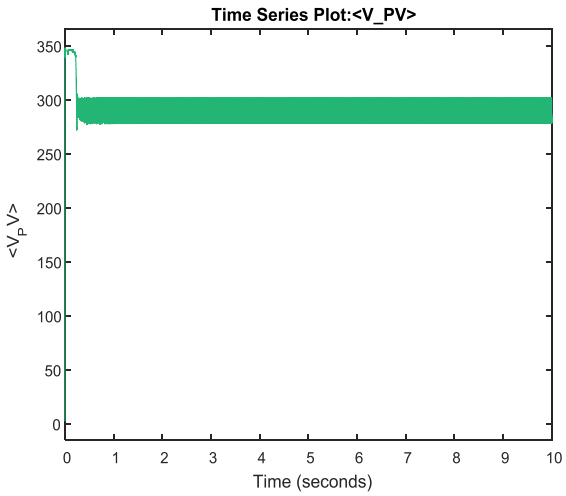

Fig.9: Voltage of solar PV array with time

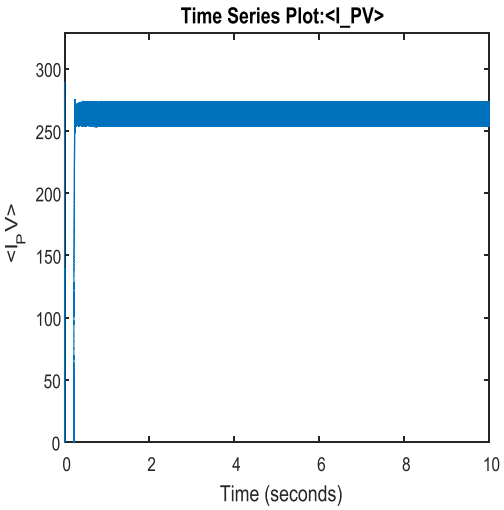

Fig. 10: Current of solar PV array with time

VI. CONCLUSIONS

This paper concerns with implementation of MPPT algorithm in MATLAB, for maximum power extraction. The input voltage is settled near to V_{MPP} where solar PV delivers maximum power. With the help of duty cycle driven by the P&O is kept corresponding to maximum power point and results show that the MPPT operation is achieved successfully under fixed as well as varying environmental conditions.

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