Maximum Power Point Tracking of PV Array at Partially Shaded Conditions using Matlab

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ABSTRACT
A PV array is a nonlinear power source. The output power induced in the photovoltaic modules depend on solar radiation and temperature of the solar cells. The selection of converter is important for MPPT operation. A boost converter (step-up converter) is a Dc to Dc power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). The MPPT algorithm represents optimal load for PV array, producing opportune voltage for the load. Perturbation and Observation (P&O) method has a simple feedback structure and fewer measured parameters. It operates by periodically perturbing (i.e. incrementing or decreasing) the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle.

Keywords— PV Array; MPPT, Boost Converter

I. INTRODUCTION
Photovoltaic cell is an electrical device that can generate electricity when it is exposed to light by the principle of photovoltaic effect. Solar power is the renewable source of energy which has become increasingly popular in modern times. The electricity production by PV cell has superior advantages over the non-renewable energy sources like coal, diesel etc and the energy production by this way is clean and silent [1].

The DC output of solar array used in standalone as well as in grid connected applications. The performance of a PV module depends on the solar irradiation and the cell temperature. So in order to extract the maximum power from the solar array MPPT controllers are used[2]. In general a PV source is operated in conjunction with a DC–DC converter by using MPPT control algorithms like P&O, Incremental conductance methods, ripple correlation control fractional open circuit voltage method, fractional short circuit current method etc.

Actually the MPPT controllers adjust the equivalent load resistance across the PV module[3] to an optimum value, where it can drawn maximum power from PV array. The conventional MPPTs are very effective in uniform illumination condition. But, they are failing to operate to in partial shading condition of an array due to the multiple peaks in power voltage characteristics. The conventional MPPTs may get struck at the local maxima power points instead of global maximum power point due the multiple peaks in P-V characteristics [4]. Number of modification on conventional MPPT methods is proposed over the years. From most of the literature, the modification had done on the method of finding initial scanning point and step size of conventional MPPT algorithms. Fuzzy logic and neural network method are also used in MPPT control application and they are also affected by the partial shading condition.

II. PV CELL
The equivalent circuit of a PV module is shown in below figure 1, while typical output characteristics are shown in fig 2 and 3. The characteristic equation for this PV model is given below

![Fig.1. Equivalent circuit of PV cell]
where

\[ I_0 = DT_c^3 \exp \left( \frac{-qG}{A_k} \right) \]

\( G \): Irradiance (W/m²),
\( G_{ref} \): Irradiance at STC = 1000 W/m²,
\( \Delta T = T_c - (T_c)_{ref} \) (Kelvin),
\( (T_c, ref) \): Cell temperature at STC = 25 + 273 = 298 K,
\( ISC \): Coefficient temperature of short circuit current (A/K), provided by the manufacturer,
\( (I_{ph})_{ref} \): Photocurrent (A) at STC.

The variation of the output I-V characteristics of a commercial PV module as function of temperature and irradiation is shown in fig 2. It is seen that the temperature changes affect mainly the PV output voltage, while the irradiation changes affect mainly the PV output current. The intersection of the load line with the PV module I-V characteristic, for a given temperature and irradiation, determines the operating point. The maximum power production is based on the load-line adjustment under varying atmospheric conditions.

III. P&O MPPT

Here, the solar array voltage is periodically incremented or decremented, till MPPT is operated. If a given perturbation leads to an increase (or decrease) in the array power, the subsequent perturbation is made in the same (or opposite) direction. In this manner, the peak power tracker continuously hunts or seeks the peak power conditions. The conventional P&O MPPT flow chart by varying duty cycle as shown in Fig.4.

![Fig.4. Flow Chart of P&O MPPT](image)

IV. BOOST CONVERTER

A boost converter (step-up converter) is a DC to DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load)[5]. It is a class of Switch Mode Power Supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). Below figure shows the circuit diagram of boost converter.

![Fig.3. PV power - voltage characteristics at different irradiances](image)
V. PV SYSTEM WITH BOOST CONVERTER

The below figure shows the PV system with boost converter and MPPT technique. Here the output current and output voltages of PV cell are given as inputs to the MPPT controller. The MPPT controller generates the duty cycle for the boost converter. Employing this will result in the increase of efficiency of the system when using without the MPPT technique.

VI. EXPERIMENTAL SETUP AND RESULTS

PV Cell Specifications:
Maximum Power = 100 watts
Open –circuit Voltage = 21.6V
Short-circuit Current = 6.43A
Maximum Voltage = 18.1 Volts
Maximum Current = 5.5 Amps

In this paper, comparison has been made between PV cell without MPPT and with MPPT with irradiations of 1000 and 800 for load of 15ohms. Corresponding waveforms are shown below from Fig.7 to Fig.14.
C. Output waveforms of Voltage and Current of PV system

![Output Voltage of PV Cell](image1)

![Output Current of PV Cell](image2)

D. Boost Converter output Power and Voltage Waveforms

![Boost Converter Output Power](image3)

![Boost Converter Output Voltage](image4)

### TABLE I

<table>
<thead>
<tr>
<th>Irradiation</th>
<th>Without MPPT</th>
<th>With MPPT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Power (W)</td>
<td>Voltage (V)</td>
</tr>
<tr>
<td>1000</td>
<td>40.34</td>
<td>24.6</td>
</tr>
<tr>
<td>800</td>
<td>30.89</td>
<td>21.53</td>
</tr>
</tbody>
</table>

From the above table we can observe that power profile of the PV system with MPPT technique has increased when compared the system without MPPT technique.

### VII. CONCLUSION

The step-by-step procedure for modeling the PV module is presented. This mathematical modeling procedure serves as an aid to induce more people into photovoltaic research and gain a closer understanding of I-V and P-V characteristics of PV. Implementing of P&O MPPT technique has helped to increase the efficiency of the system. The Boost converter is used to step up the pv cell output voltage.

### REFERENCES

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