Comparative Analysis and Simulation of PV Array Maximum Power Point Tracking Techniques in a PV generation systems

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Abstract
PV generation system is one of the best methods to get clean energy. But to generate maximum power we adopt some techniques through which generation efficiency increases. Maximum Power Point Tracking (MPPPT) techniques are engaged in PV systems to make maximum utilization of PV array generated output power which directly depends on solar irradiation and temperature. In recent times, many MPPT control and MPPT algorithms methods of PV system have been projected, but due to various control methods and various controller parameters it provide different output efficiency P-V and I-V relation Curve and vibrant response. The MPP directly depends on solar irradiance conditions, the module temperature, and the load connected. Therefore, in this paper, we use Poly 60 Wp 36 cells solar PV sell and look through existing methods by doing their analysis probable solution is to use MPPT Technique. In this method, we take a proposed model and simulate it against a user-defined module of the PV array to get its intrinsic characteristics with the basic measured data provided by manufacture. In this paper, we also evaluate the pros & cons. of the existing MPPT control Algorithms by simulation.

Keywords: Solar PV Cell, I-V Characteristics, MPPT Algorithms, MPPT Controllers, P & O method, Inc Conductance Method, PV Conversion.

1 Introduction
As the energy reserves are depleted at very rapid rate, the importance of Solar Photovoltaic based power generation plant has been promising as an alternative to energy resources. Since it is pollution free, neat, and inexhaustible, many researches on the PV power generation system got attention on global level. To mitigate the problem of GHG emission and other harmful gases Solar PV technology emerges as one of the promising technology for future energy demand. MPPT (Maximum power point tracing) is one of the well-known and important problem for all solar PV based power plant. An efficient MPPT algorithm is needed for solar PV industry to increase efficiency of PV system. Existing analysis and possible solutions to the MPP problem is the P&O (Perturb and Observe technique). It became noticeable that the perturb and observe (P&O) technique is widely used for its simplicity of realization. It is based on the condition that: if the working voltage of the PV array is perturbed in a any direction and if the power drawn from the PV array increases, it simply mean that the operating point of PV array has stimulated toward the MPP therefore, the operating voltage should be promote perturbed in the same direction. Or else, if the power drawn from the PV array decreases, the operating point has moved away from the MPP and, as a result, the direction of the operating

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voltage perturbation must be reversed. The Basic methods of the MPPT algorithms, are Constant Voltage Tracking (CVT) method, Fraction Open Circuit Voltage (FOCV) method, Fractional short circuit Current(FSCC) method, Current Sweep method, Hill climbing and Perturb and Observe (P&O) method, Incremental Conductance (INC-CON) method. Both P&O and INC-CON method are example of hill climbing methods, Variable Step Size (VSS) method based on INC-CON method, and hybrid method which combined above algorithms are introduced. Some MPPT methods based on Fuzzy logic control and neural networks were introduced to improve the power generation efficiency of the solar PV plant. Solar PV Curve measurement plot for different temperature and solar insolation values Fig [1].

Figure 1 I-V and P-V characteristic curves of the PV array

(1) P-V curves at constant temperature T=298.15 K;
(2) I-V curves at constant insolation/solar Irradiance (G) =1000 W/m²;
(3) P-V curves at constant insolation/solar Irradiance (G) =1000 W/m²
(4) I-V curves at constant temperature T=298.15 K;

2 System Overview

The following materials were required to set up a minimal working solution for MPPT Technique: solar panel, current sensor, voltage sensor, BUCK/ BOOST, DC-DC converter, digital controller, and the logic/circuitry to connect everything collectively.

2.1 PV Array Characteristic and modelling

Solar PV cell is working on the principle of photovoltaic effect of semiconductor PN junction. It behaves as basic a PN junction diode under dark test condition. (i.e. no light condition) The equivalent electrical circuit shown in Fig.2 can represent the typical model of a PV module.

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The basic structure of a cell model or solar cell is analogous to that of a photodiode, of silicon, intended to maximize the inclusion of photons from the sun light and minimize reflection from module surface. When it receives an incident light falling to surface it act as a current source, which increases in inverse proportion of the light incident upon it. The building block of PV array is the solar cell, which is a p-n junction semiconductor junction that directly converts light energy into electricity.

2.2 Manufacturer Specification for Poly 60 Wp 36 cells

Table: 1 Table for Solar PV Module Specification

<table>
<thead>
<tr>
<th>GRef w/m²</th>
<th>Isc (A)</th>
<th>Voc (V)</th>
<th>Imp (A)</th>
<th>Vmp (V)</th>
<th>Temp. Coeff</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>3.800</td>
<td>21.10</td>
<td>3.500</td>
<td>17.10</td>
<td>25 °C</td>
</tr>
<tr>
<td>800</td>
<td>2.750</td>
<td>22.30</td>
<td>2.500</td>
<td>19.20</td>
<td>25 °C</td>
</tr>
<tr>
<td>600</td>
<td>1.850</td>
<td>23.45</td>
<td>1.945</td>
<td>17.10</td>
<td>25 °C</td>
</tr>
</tbody>
</table>

The load current \( I_L \) is given by the expression:

\[
I_L = I_{SC} - I_D - I_{SC} \tag{1}
\]

\[
I_L = I_{SC} - I_D \left[ \exp \left( \frac{V + iR_S}{\eta V_T} \right) - 1 \right] - \frac{V + iR_S}{R_{SH}} \tag{2}
\]
Where,

$I_{SC}$ - is the Short-circuit current of module in presence of solar irradiance and temperature.

$I_D$ - is the diode current

$R_S$ - is the series resistance (resistance due to material)

$R_{SH}$ is parallel resistance

$I$ - is the output terminal current,

$I_0$ - is the diode saturation current [A],

$V$ - is the terminal voltage of a module [V].

$n$ - is the ideal constant of diode,

The characteristics of a PV module are nonlinear and each curve has only one Maximum Power Point (MPP). Furthermore, the output current of a PV module is mostly affected by change in solar irradiation, whereas the output voltage of module is mostly affected by change in temperature. The effect of temperature variations somehow less venerable then the solar irradiation value that is why the main factor of output power variation.

3 MPPT METHODS

- Perturb and observe method
- Incremental Conductance Method
- Variable step Size Method
- CVT Method
- FOCV Method

3.1 MPPT Controller

A Dc-to-Dc converter is an electronic circuit arrangement, which converts a direct source of current from level of voltage to another. It is a type of power converter. Electronic switch-mode dc to dc converters operate by storing the input energy temporarily and then releasing that energy to the output at a different voltage and current. Basic arrangement of MPPT controller is shown in fig below.

![Solar PV Module](image1)

**Figure: - 3 Mppt Controller**
MPPT Controllers typically trail one method to optimize the generated power output of a solar array out of the three. Maximum power point trackers use different algorithms and switch among them based on the working conditions of the array. MPPT controller changes the input energy into a different impedances level. So the output voltage level, the output power all comes from the input, there’s no energy manufactured inside the converter. Due to this reason DC-DC converter essential for MPPT. The converter provides an electrical load to solar PV module that varies as the output voltage of controller varies. This load variation in turn causes changes in operating point (i.e. voltage and current characteristics) of the panel.

4 MPPT Techniques
(a) P&O METHOD
The basic concept behind P&O technique is to get maximum power by adjusting the operating voltage or current, of solar PV module. This method is also known as “hill climbing method. P&O can be implemented by apply perturbations to the mentioned current or the voltage signal of the solar module. A flowchart illustrating this method is shown below in [Fig 4].The main aim of this method is to pushing the referenced voltage to perturb near the Vmpp; as a result generated output power will approach to MPP.

The solar panel voltage varies by applying small and constant perturbation on a step by step manner in order to change the system operating point. At every change in perturb change in power output variation is measured. If variation in output power is positive, generated power will approach MPP.

(b) Incremental Conductance
The incremental conductance (Inc Cond) method employs the slope of the PV array power characteristics to track MPP. This method is based on the fact that the gradient of the PV

![Figure 4: Perturb & Observation Method for MPPT](image_url)
The array power curve is zero at the MPP. For output power smaller values than MPP slope is positive, and negative for values greater than MPP of output power.

The MPP is obtained by comparing the immediate conductance ($I/V$) to the incremental conductance ($\Delta I/\Delta V$). For very first time the system find MPP it repeatedly maintain this power point if there is any variation in V or I occurs, if this happens algorithm will find new MPP. The main advantage of this algorithm that it maintains MPP automatically without losing energy by making oscillation around this point. If the environmental conditions change rapidly this algorithm, more accurately find MPP than P&O method.

The maximum power output is given by eqn:-

$$P_{MPP} = V_{MPP}I_{MPP}$$

(3)

It is obtained by differentiating the PV output power with respect to voltage and equating the equating with zero.

$$\frac{\Delta P}{\Delta V} = 1 + \frac{V\Delta I}{\Delta V} = 0$$

(4)

This gives us

$$\frac{\Delta I}{\Delta V} = -\frac{I_{MPP}}{V_{MPP}}$$

(5)

From these equations, one can easily infer that whether the given system is operating near MPP or not.

Fig:-5 Incremental conductance method
\[ \frac{\Delta P}{\Delta V} = 0 \]
\[ \frac{\Delta P}{\Delta V} > 0 \rightarrow \begin{cases} \frac{\Delta I}{\Delta V} = -\frac{l}{V} \text{ at MPP} \\ \frac{\Delta I}{\Delta V} > -\frac{l}{V} \text{ Left of MPP} \\ \frac{\Delta I}{\Delta V} < -\frac{l}{V} \text{ Right of MPP} \end{cases} \] …… (6)

(e) Variable Step Size Method

The step size method is basically a constant method. The output power drawn from PV array with large step size adds faster dynamic but excessive steady state oscillations, resulting in a comparatively low efficiency. This situation is reversed while the MPPT is running with relatively small step size. MPPT with fixed or constant step size provide satisfactory trade off between the dynamics and oscillations. Such a problem can be solved by the method of variable step size method. It offers fast response time and better steady state performance.

In variable step size method large step size is used to move the PV system to the MPP quickly when the solar irradiation changes abruptly. Step size will be small to decrease power variation when module oscillates around MPP.

5 Simulation and Results

![MPPT Curve for solar PV Cell](image)

**Figure: - 6** MPPT Curve for solar PV Cell

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The MPPT control methods use in above discussion has been tested and simulated. From simulation result we say that the perturb and observation method, Incremental conduction method are similar characteristic performances and response time. They are superior to some of existing methods for calculation of MPPT. Variable step size method shows improved response time and increased output power generated compared to P&O method and incremental conductance method. One drawback is that it takes more time to provide stable state when MPP reached.

Figure: -8 - Voltage, current and power under irradiation ramps

6 Conclusion

Various MPPT methods taken from the previous literature are discussed and analyzed, with their merits and demerits. Most of the MPPT methods are able to take maximum power output from solar PV module. Methods based on artificial intelligence are shown better result for MPP. It is shown that there are several other MPPT techniques than those commonly included in literature reviews. The final review and result paved new way and serve as a useful guide for opting correct and easy MPPT method for particular PV systems for generation of maximum output power.
7 References


