Comparison of Different MPPT Algorithms for PV System

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Abstract

This paper helps us analyze three different MPPT techniques like Perturb and Observe, Incremental Conductance and Particle Swarm Optimization method. As the output characteristic depends on temperature and irradiance, therefore the maximum power point (MPPT) is not always constant. Hence it is necessary to ensure that the PV panel is operating at its maximum power point. There are many different MPPT techniques but, the confusion lies in selecting which MPPT technique is best as every algorithm has its own merit and demerit. In order to extract maximum power from PV array arrangement, PSO algorithm is proposed. Algorithms are implemented using the DC-DC converter as well as SEPI converter. Results of simulations are presented in order to demonstrate the effectiveness of PSO algorithm, when compared to Perturb and Observe (P&O) and Incremental Conductance (INC). To simulate the proposed system MATLAB/SIMULINK power system tool box is used.

Keywords: Maximum power point tracking, photovoltaic (PV) system, Single-ended primary inductor (SEPIC) converter

1. Introduction

The demand for power has increased in today’s generation. Renewable energy is having more advantage than non-renewable energy as they are present abundant in nature and is pollution free. All these advantages have to lead the researchers to shift their attention toward renewable energy as the solution to problems created by non-renewable energy. Although there are many limitations in renewable energy like the capital cost is high and it depends on temperature, irradiance, and other natural factors. In present PV system is gaining more popularity in this field of generating electricity. PV system has the capability to replace the conventional energy in future. Moreover, it does not emit pollution and has no moving part which very well reduces the cost of its maintenance [1, 2].

The output characteristics of PV system depends on the temperature and irradiance hence it does not operate on its Maximum Power Point (MPP) always. To obtain Maximum Power Point (MPP) several Maximum Power Point Tracking (MPPT) has been developed. They may involve simple method or it may be complex. In this paper, the Perturb and Observe (P&O), the Incremental Conductance (INC) and Particle Swarm Optimization (PSO) Maximum Power Point Tracking (MPPT) techniques are compared. Perturb and observe (P&O) based MPPT algorithm is efficient but is not suitable for PV array arrangement as it has an unstable operating point. Sensing parameter of Incremental Conductance is voltage and current. Incremental Conductance has good efficiency but is generally not used because of its complexity. For multi-junction PV cell system Particle Swarm Optimization (PSO) technique is implemented. The purpose of MPPT techniques is to have constant output irrespective of power produced by PV system.

2. Methodology

Different types of Maximum Power Point Tracking (MPPT) Algorithm:

a. Perturb and Observe (P&O)

This algorithm requires perturbation in the system, because of this perturbation, the power of the module changes[3]. If the power is improved due to this perturbation, then the perturbation is continued in name direction. Otherwise, the perturbation is reversed. This is how maximum power point is attained. The power keeps oscillating near the Maximum Power Point (MPP) and fails to attain exact Maximum Power Point (MPP). Therefore this algorithm is not suitable for rapid fluctuations of irradiance. Among different algorithm Perturb Observe (P&O) is a simple method and is cost effective. Incremental Conductance is the advance version of (P&O) and is designed to overcome all the (P&O) algorithm drawbacks. To have better output, the previous output is continuously compared.
b. Incremental Conductance (INC)

Two voltage and current sensors are used in Incremental Conductance (INC) to get the desired output voltage and current from the PV array. The slope at Maximum Power Point (MPP) of PV curve is zero.

\[
\frac{dP}{dV}|_{\text{MPP}} = \frac{d(VI)}{dV}
\]  

(1)

\[
o = I + \frac{V}{dI/dV}|_{\text{MPP}}
\]  

(2)

\[
dI/dV|_{\text{MPP}} = - \frac{I}{V}
\]  

(3)

Tracking efficiency of Incremental conductance (INC) is good but complexity level is high in comparison to Perturb Observe (P&O)[4].

c. Particle swarm optimization (PSO)

There are multiple peaks in the power-voltage characteristic curve of the photovoltaic (8V) arrays, therefore the conventional control methods of Maximum power point tracking (MPPT) will not work efficiently. Whereas, the Particle swarm optimization (PSO) algorithm works very efficiently and can solve multiple extreme optimizations[5-8]. Particle swarm optimization (PSO) technique is based on the movement and intelligence of swarms. Social interaction in the key concept applied to solve the problem. But the solution is achieved by the use of a number of particles (agent). Each particle keeps tracking the solution and when they have achieved it, it becomes its personal best. One more value is tracked by Particle swarm optimization (PSO) i.e., global best which is the best value among all personal best.

3. Boost Converter

A boost converter is one among different types of the DC-DC converter and it is used to step up the output voltage.

Four different topologies of DC-DC regulators: buck converter, a boost converter, buck-boost converter and buck converter. Here the project deals with the boost converter whose operation is boosting up the voltage level.

d. 1st mode of operation:

When the MOSFET switch is ON current flows from the positive terminal to the negative terminal through an inductor, thus forming a short circuit current. In the remaining circuit there is no flow of current.

e. 2nd mode of operation:

When the MOSFET switch is OFF there is a sudden drop in current which causes inductor to produce a back emf in opposite polarity to that of inductor during ON period.

![Fig 1: Flowchart of Perturb and Observe algorithm](image-url)
4. Single-Ended Primary Inductor Converter (SEPIC)

There are many limitations of conventional boost converter like the output is inverted, the input current is found pulsating and is unsuitable for a wide range of operation due to high voltage stress. Therefore Single ended primary inductor converter (SEPIC) converter is used to overcome this problem [9, 10]. The boost converter is used to step the output voltage whenever buck converter is used to step down voltage. The advantage of Single ended primary inductor converter (SEPIC) converter over there two conventional converter is that it can both step up and step down voltage [11-14]. There it helps to reduce the problem of using both buck and boost converts for any application. Single-ended primary inductor converter (SEPIC) is a DC-DC converter whose output voltage is positive. It is used as buck and Boost converter. The output is varied by varying duty cycle of the gate signal. It will step up if the duty cycle is more than 50% and it will step down if the duty cycle is less than 50%. Hence, it functions similarly like a buck and Boost converter.

5. Simulation Results

Here in this project work, a real-time organization is taken for analysis and comparison of different MPPT techniques. A 150KW off-grid solar power plant is taken for case study and a sample of 1.2KW panels are implemented in MATLAB/SIMULINK software. The power generated is fed to Resistance load for analysis. All the three i.e. Perturb & Observe, Incremental Conductance and Particle Swarm Optimization MPPT techniques are compared with Boost and Single Ended Primary Inductor converters in SIMULINK. The switch of two different converters is controlled by three different MPPT algorithms. The harmonic content is also reduced. The output graph is shown below for analysis. The power obtained on DC and AC side is tabulate below with different MPPT techniques for comparison. It is observed that the PV generation is improved with Particle Swarm Optimization algorithm using Single-Ended primary Inductor Converter. Particle Swarm Optimization (PSO) algorithm is fastest of all the three algorithms. At lower irradiance the efficiency of PSO is higher than P&O and INC algorithms. The Perturb and Observe (P&O) tracking algorithm is poorer than Incremental Conductance (INC) algorithm. According to simulation result, the maximum power point is tracked correctly by Particle Swarm Optimization MPPT technique under all conditions. It has advantages over other two methods such as it has simple structure, implementation is easy, efficiency of tracking is very high, and the desired solution is attained fast due to high convergence speed. PSO technique has turned out to utilize the PV array most efficiently and this technique can also be used in partial shading conditions.

6. Simulation result of PSO algorithm with Boost Converter
It has been observed that the voltage and current waveform is sinusoidal.
Fig 8: DC Output Voltage

The output voltage on DC side is observed to be 240 V in PSO MPPT algorithm by using SEPIC.

Fig 9: THD Analysis

Above FFT Analysis states that for the frequency of 50Hz the Total Harmonic Distortion is 2.16%. Hence by using SEPI converter, THD is decreased.

8. THD Calculation

<table>
<thead>
<tr>
<th>SNO</th>
<th>MPPT</th>
<th>CONVERTER</th>
<th>DC (W)</th>
<th>AC (W)</th>
<th>EFFICIENCY (%)</th>
<th>THD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P&amp;O</td>
<td>BOOST</td>
<td>689.5</td>
<td>560</td>
<td>46.6</td>
<td>3.32</td>
</tr>
<tr>
<td>2</td>
<td>INC</td>
<td>BOOST</td>
<td>717.7</td>
<td>581.8</td>
<td>48.4</td>
<td>2.81</td>
</tr>
<tr>
<td>3</td>
<td>PSO</td>
<td>BOOST</td>
<td>726.2</td>
<td>612.9</td>
<td>51.7</td>
<td>2.56</td>
</tr>
</tbody>
</table>

From the above tabular column, it can be observed that the output from PSO MPPT technique is more efficient than P&O and Incremental Conductance MPPT technique.

<table>
<thead>
<tr>
<th>SNO</th>
<th>MPPT</th>
<th>CONVERTER</th>
<th>DC (W)</th>
<th>AC (W)</th>
<th>EFFICIENCY (%)</th>
<th>THD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P&amp;O</td>
<td>SEPI</td>
<td>703.3</td>
<td>570.9</td>
<td>47.5</td>
<td>3.14</td>
</tr>
<tr>
<td>2</td>
<td>INC</td>
<td>SEPI</td>
<td>732.2</td>
<td>589</td>
<td>49.1</td>
<td>2.73</td>
</tr>
<tr>
<td>3</td>
<td>PSO</td>
<td>SEPI</td>
<td>744</td>
<td>639</td>
<td>53.5</td>
<td>2.16</td>
</tr>
</tbody>
</table>

From the above tabular column, it can be observed that the efficiency of PSO MPPT techniques is highest whereas the outputs and THD value has decreased by using SEPI converter.
9. Conclusion

By observing the above table it can be clearly concluded that the SEPI converter with PSO MPPT technique gives increased output compared to other two MPPT techniques like P&O and INC with a combination of the BOOST converter. The harmonic quantity is also reduced with PSO and SEPI converter. Hence the PV generation system is proved to be more advantageous with PSO and SEPI converter.

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