Efficiency Improvement of Photovoltaic by Using Maximum Power Point Tracking based on Particle Swarm Optimization Algorithm under Normal and Partial Shading

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Abstract—Photovoltaic (PV) is a device which is capable to converts solar irradiance into Direct Current (DC) electricity energy. To increase the power result of PV, it needs a method to track the Maximum Power Point (MPP) which is usually called Maximum power Point Tracking (MPPT). So that, the power result increased with low cost. The purpose of this research is to conduct MPPT modeling by Particle Swarm Optimization (PSO). The proposed method is implemented in DC to DC converter. This research used SEPIC converter. The purpose of using SEPIC converter is in order the output of current and voltage have smallest ripple. The modelling system is conducted by using MATLAB 2016b software to find out performance of PSO and SEPIC converter. The evaluation of PSO and SEPIC converter performance has been done. The simulation result shows that the proposed system has been working very well. The PSO has good accurateness in tracking and capable to to track the power produced by PV with velocity around ±4.2 seconds when in conditions STC, ±9.2 seconds when in conditions partial shading, despite a fluctuating irradiance change. While in SEPIC converter is able to reach efficiency of ≥ 80%.

Keywords—Photovoltaic (PV); Maximum Power Point (MPP); MPPT; Particle Swarm Optimization (PSO); STC; Partial Shading; SEPIC Converter.

I. INTRODUCTION

At this time the need for electric power is growing with a population with, in this case both the industrial sector as well as households. On the research of utilizing the energy of alternative, one of which was from photovoltaic (PV). Utilizing its own PV energy source of the Sun which is then converted into a voltage. [1] the performance of the photovoltaic (PV) is influenced by temperature, insulation, and the configuration of the direction. System resources I-V on PV is non-linear and point a unique maximum power on P-V curve varies with temperature and insulation, which at that point solar cells work at maximum efficiency and power output of the so-called Maximum Power Point (MPP). [2] the location of the point of maximum power is unknown, but can be searched by using a tracking algorithm.

Maximum Power Point Tracking (MPPT) is a system to find the point of maximum power at PV. This research proposed a method for tracking the maximum power point of a PV module is in a State of normal irradiance and partial shading using Peturb techniques and Observe (P&O) and Particle Swarm Optimization (PSO) in the PSO method based on the algorithm used to find optimal solutions globally[3].

II. RESEARCH METHOD

Modeling on a system built is shown in the block diagram in Figure 1. Weights used in this experiment is a 1 ohm in accordance with the results of the planning calculations

![Figure 1. Block diagram of the MPPT System PSO using SEPIC Converter](image-url)

A. Photovoltaic (PV)

Modeling and simulation using the PV model already available in MATLAB simulator 2016a. PV modules composed of solar cells in parallel and series equivalent physical model of a solar cell can be seen in Figure 2.
Figure 2. Equivalent circuit of a physical model of solar cell

The equation of the above can be seen as the equivalent equation (1) to the equation (7).

\[ i = i_{ph} - i_d - i_r \]  
\[ i_{ph} = I_{sc0} \cdot \frac{S}{S_0} + C_t (T - T_{ref}) \]  
\[ i_d = I_0 \cdot \left( \frac{e^{\frac{qV}{nkT}} - 1}{T_{ref}} \right) \]  
\[ i_r = \frac{V_d}{R_s} \]  
\[ v_d = \frac{V_{oc}}{n_s} + i \cdot R_s \]  
\[ T = T_a + k_s \cdot S \]

Where \( q \) is the electron charge (\( q = 1.6 \times 10^{-19} \)), \( k \) is the Boltzmann constant (\( k = 1.3806505 \times 10^{-23} \)), \( S \) is the input light intensity, \( T_a \) is the input temperature, \( v \) is the voltage across the solar modules, and \( i \) is the current out of the positive terminal of the module. Parameters that will be used as input in the PV modules adapted to the parameters that are contained on the PV type Sunpower SPR-X20-250-BLK on table 1.

<table>
<thead>
<tr>
<th>PV SunPower SPR-X20-250-BLK</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Pm )</td>
</tr>
<tr>
<td>( Voc )</td>
</tr>
<tr>
<td>( Isc )</td>
</tr>
<tr>
<td>( Vmp )</td>
</tr>
<tr>
<td>( Imp )</td>
</tr>
<tr>
<td>Maximum System Voltage</td>
</tr>
<tr>
<td>Dimension</td>
</tr>
<tr>
<td>Test Condition</td>
</tr>
</tbody>
</table>

The above parameters obtained from the curve characteristics of the PV as in Figure 3.

B. Modeling SEPIC Converter

the SEPIC converter consists of a switch (S) with the duty cycle \( D \), a diode (D), the two inductor (L1 and L2), two capacitors (C1 and C2), and a load resistor (R). For more simply, load R here used as per application to the required load can vary and response can be obtained. All element is assumed to be ideal and conduction is assumed to be continuing. The circuit shown in the picture can be seen in Figure 4.

![Figure 4 Circuit SEPIC Converter](image)

While the equation on SEPIC converter from image above can be viewed as equations (8) up to equation (13).

\[ V_{out} = \frac{V_{in} \cdot D}{(1-D)} \]  
\[ \Delta IL1 = \text{lin} 10\% \]  
\[ L1 = L2 = \left[ \frac{n \cdot D}{f_s \Delta l_1} \right] \]
\[ \Delta V_o = 0.1\% V_o \]  \hspace{1cm} (11)

\[ R = \frac{V_{Out}}{I_{Out}} \]  \hspace{1cm} (12)

\[ C_1 = C_2 = \frac{Out_D}{R \Delta V_o fs} \]  \hspace{1cm} (13)

### C. Particle Swarm Optimization Algorithm

PSO algorithm consists of members who are called particulate matter, which can be a candidate solution. Each particle contains a prospective solution called the particle solution, and move the direction of the particle filter is called the speed of the particle. The speed of the PSO are constantly updated based on the experience of each of the particles themselves, and other particles. In the first step start the iteration algorithm PSO got initial particles randomly. Every Member in this population is evaluated and the value that you set. After that, the particles the particles will move in the search spaces search spaces towards the global optimum based on personal best (best) and the global best (g best). Pbest is the best at each position of the particle, and is the best particle gbest on position in space solutions. Can we deduce PSO method as follows [12]. PSO can be realized mathematically in equation 6 below (14).

Particle i is the position of the solution is assumed to be in the equation (14).

\[ \overrightarrow{x_i}(t) = \overrightarrow{x_i} \text{ is vektor } \overrightarrow{X_i} \]  \hspace{1cm} (14)

Particle i in the equation (15).

Position  : \( \overrightarrow{x_i}(t) \in \mathbb{R} \)  \hspace{1cm} (15)

Velocity  : \( \overrightarrow{v_i}(t) \)

Elections to the position vector (P best) → P of x can be seen the equation (16).

\[ \overrightarrow{P_i}(t) - \overrightarrow{X_i}(t) \]  \hspace{1cm} (16)

Elections to the position vector (G best) from x → g views in the equation (17).

\[ \overrightarrow{g}(t) - \overrightarrow{x_i}(t) \]  \hspace{1cm} (17)

After the particles move against (P best) and (G best) then found the latest particle positions on the formulation of equation (18).

\[ \overrightarrow{x_i}(t+1) = \overrightarrow{x_i}(t) + \overrightarrow{v_i}(t) \]  \hspace{1cm} (18)

the latest particle speed in the equation (19).

\[ \overrightarrow{v_i}(t+1) = \mathcal{G} \overrightarrow{v_i}(t) + C_1 \overrightarrow{P_i}(t) - \overrightarrow{x_i}(t) + C_2 \overrightarrow{g}(t) - \overrightarrow{x_i}(t) \]  \hspace{1cm} (19)

PSO has advantages in terms of speed and efficiency of the search. In the search there are 4 parameters that very effect on search results i.e. W, C1, C2 and the number of particles used. Flowchart PSO designed can be seen in Figure 5. in the number of particulate matter flowchart is used as many as three particles, each particle has a number of different particles. in the process of tracking the three particles will renew their respective positions to get the value of the Pbest of each particle, the particle will be the third of the obtained values of nearby particles Gbest of goal achievement.

![Figure 5 Flowchart PSO](image-url)
III. RESULT AND DISCUSSION

In this experiment, go to the test in advance against the performance of the SEPIC converter without the use of PV with constant voltage source. From the results of pngujian on a simulated look at Figure 7 that the SEPIC converter has been designed as expected yauitu can reduce ripple currents and voltages at the output. This is proven by the ripple currents and tegnagan a very small output.

Figure 7 Input Output Voltage, current, and Power in the SEPIC Converter with constant voltage source.

a. Simulated results on Standard condition of PSO MPPT Test Condition (STC)

The next testing phase on the MPPT is given the input form parameter irradiasi and temperature conditions of STC, i.e. with irradiasi 1000 W/m² and a temperature of 25°C. From the results of the simulation is shown in Figure 8, it can be known that MPPT PSO has a performance in accordance with the design objectives. Power output search results use MPPT PSO has a good level of accuracy and searches that pretty quickly which is about 4.7 seconds to reach a State of Convergence. This is proven by the power generated by the PV modules that reach the point of maximum PV power i.e. 245.95 W. While in the SEPIC converter, power generated also has an excellent efficiency i.e. reaching 88.87% with power generated i.e. 218.6 W. The results show that the SEPIC converter has been designed in accordance with the purpose of design, that is, to maximize the power generated by the PV.
b. The results of the Simulation on the PSO MPPT Partial Shading

In the process of testing this used two PV SPR-X20-250 BLK arranged in parallel, so that the maximum power produced be 249.9 WP. The output of the PV produce graphs of characteristic curve as shown in Figure 11. From Figure 11 be aware that power generated by the PV has more than one point of MPP in pictures (a) the point of MPP is at the right of the P-V curve, while in figure (b) point MPP berrada left on the P-V curve.

From the above characteristics, then the curve will be used for testing with the PSO algorithm when there are conditions of partial shading. PSO at the time the test results of this condition can be seen in Figure 12, that is when the point of the MPP are in seblahan P-V curves right.

Based on Figure 12, it was known that the MPPT can be designed has had good performance, that is able to track the maximum power generated by the PV and not get stuck on LMP. The time it takes to do tracking is about 9.2 seconds with efficiency tracking of 85.41%.

Based on Figure 12 and Figure 13, then it was known that the MPPT can be designed has had good performance, that is able to track the maximum power generated by the PV and not get stuck on LMP. The time it takes to do tracking is about 9.2 seconds with efficiency tracking of 85.41%.
c. Comparison of Simulation Results MPPT Particle Swarm Optimization (PSO) and Perturb and Observe (P&O)

At this stage do the comparison against the MPPT PSO with P&O which aims to find out the comparison of the performance of each algorithm. The process of testing is done by giving the condition of PV in a State of STC and partial shading. The test results can be dilihat in Figure 16.

From Figure 16, then obtained a great comparison of the value of the power, voltage and current is generated when using the PSO and P&O as shown in table 2.

Table 2 comparison of power, voltage and current inputs and outputs SEPIC converter using PSO and P&O on the conditions of STC

<table>
<thead>
<tr>
<th>Parameter Condition</th>
<th>MPPT</th>
<th>P_i (W)</th>
<th>P_out (W)</th>
<th>V_in (V)</th>
<th>V_out (V)</th>
<th>I_in (A)</th>
<th>I_out (A)</th>
<th>T_Time (s)</th>
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<td>STC 1000 W/m²</td>
<td>PSO</td>
<td>244.5</td>
<td>210.4</td>
<td>43.85</td>
<td>6.63</td>
<td>5.72</td>
<td>21.38</td>
<td>4.2</td>
</tr>
<tr>
<td>and temp 25°C</td>
<td>P&amp;O</td>
<td>104</td>
<td>125.3</td>
<td>25.02</td>
<td>7.59</td>
<td>6.15</td>
<td>16.0</td>
<td>0.1</td>
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From table 2 it can be known that the PSO has a better employment performance dibandingkan P&O. The time required to achieve PSO MPP that is 4.2 seconds, while P&O takes 0.1 seconds. The power generated by the PSO was also higher than the power generated by the P&O.

The next testing phase that is comparing the performance of the PSO and P&O when there are conditions of partial shading, which at this point there are two testing MPP the result of the test can be seen in Figure 17 and Figure 18.

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From Figure 17 and Figure 18, then obtained a large value of voltage and current, the power generated by each algorithm is as shown in table 3.

Table 3 comparison of power, voltage and current inputs and outputs SEPIC converter using PSO and P&O on the conditions of partial shading.

<table>
<thead>
<tr>
<th>Parameter Kondisi</th>
<th>MPP</th>
<th>Pin (W)</th>
<th>Pout (W)</th>
<th>Vin (V)</th>
<th>Vout (V)</th>
<th>lin (A)</th>
<th>Iout (A)</th>
<th>Kecepatan Tracking (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titik MP di Sebelah Kanan dan Kiri</td>
<td>PSO</td>
<td>129.8</td>
<td>110.7</td>
<td>43.62</td>
<td>7.13</td>
<td>2.99</td>
<td>15.51</td>
<td>9.2</td>
</tr>
<tr>
<td></td>
<td>P&amp;O</td>
<td>115.72</td>
<td>99.72</td>
<td>22.96</td>
<td>9.58</td>
<td>5.04</td>
<td>10.41</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>117.8</td>
<td>93.97</td>
<td>20.13</td>
<td>6.57</td>
<td>5.86</td>
<td>14.29</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Based on the data in table 3 indicates that the PSO is capable of working well despite the conditions of partial shading, that could reach the point of MPP and not get stuck on LMP with time tracking approximately 9.2 seconds, while P&O was only able to reach the LMP and stuck on the LMP so could not reach the MPP.

IV. CONCLUSION

Based on the results of the simulation have been performed, shows that the PSO and SEPIC converter has been designed to have accuracy and good performance. PSO has a good search results do not get stuck on LMP, either when in a State of constant temperature and irradiance parameter, or when the parameters of temperature and irradiance change change and when it occurs in conditions of partial shading. The time it takes to do tracking is about 9.2 seconds. While the SEPIC converter capable of achieving efisiensi ≥ 80% with the ripple current and output voltage is very small indeed.

ACKNOWLEDGMENT

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V REFERENCES


