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Efficiency Improvement of Photovolataic 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—Photovolaic (PV); Maximmum 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 alternatife , 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

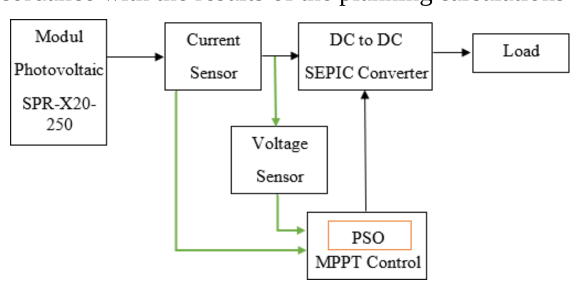

Figure 1. Block diagram of the MPPT System PSO using SEPIC Converter

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.

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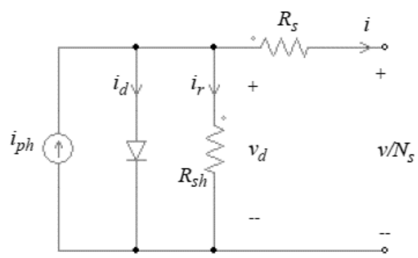

Figure 2. Equivalent circuit of a physical model of solar cell

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

$i = i_{ph} - i_d - i_r$ (1)

$i_{ph} = I_{sc0} \cdot \frac{S}{S0} + C_t \cdot (T - T_{ref})$ (2)

$i_d = I_0 \cdot (e^{\frac{qvd}{AkT}} - 1)$ (3)

$I_0 = I_{s0} \cdot (\frac{T}{Tref})^3 \cdot e^{\frac{qEg}{Ak}(\frac{1}{Tref} - \frac{1}{T})}$ (4)

$i_r = \frac{Vd}{Rsh}$ (5)

$v_d = \frac{V}{Ns} + i \cdot R_s$ (6)

$T = T_a + k_s \cdot S$ (7)

Where q is the electron charge (q = 1.6 x 10-19), k is the Boltzmann constant (k = 1.3806505 x 10-23), S is the input light intensity, Ta is the input temperature, v is the voltage across the solar modules, and i is the current out of the positive terminals of the module Surya.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 1. PV Module parameter type SunPower SPR-X20-250-BLK

***PV* SunPower SPR-X20-250-BLK**	
Pm	249,9 W
Voc	50,93 V
Isc	6,2 A
Vmp	42,8 V
Imp	5,84 A
Maximum System Voltage	1000VDC
Dimension	775 x 680 x 28 mm
Test Condition	AM 1.5, 1000 W/m² 25°C

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

a.

b.

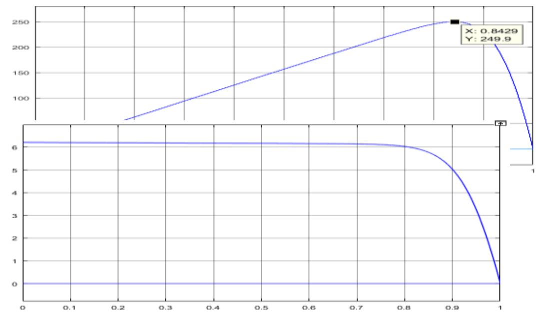

Figure 3 (a) Power and voltage Characteristics Curve (P-V), (b) the curve characteristics of the Current and voltage (I-V)

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.

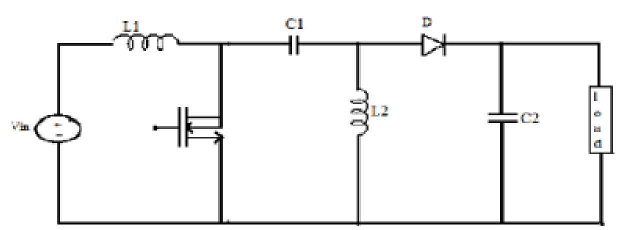

Figure 4 Circuit SEPIC Converter

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

$$Vout = \frac{Vin\ D}{(1-D)} \quad (8)$$

$$\Delta IL1 = \text{Iin } 10\% \quad (9)$$

$$L1 = L2 = [\frac{n\ D}{fs\ \Delta I1}] \quad (10)$$

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$$\Delta \mathrm{Vo} = 0{,}1\%\ Vo \quad (11)$$

$$R = \frac{V\ Out}{I\ Out} \quad (12)$$

$$C1 = C2 = \frac{Out\ D}{R\ \Delta \mathrm{Vo\ fs}} \quad (13)$$

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).

$$\overrightarrow{X_i}\ (t) => \overrightarrow{X_i} \quad \text{is vektor} \quad \mathrm{Xi} \quad (14)$$

Particle i in the equation (15).

Position $: \overrightarrow{X_i}\ (t) \in \mathrm{x}$ (15)

Velocity $: \overrightarrow{V_i}\ (t)$

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

$$\overrightarrow{P_i}(t) - \overrightarrow{X_i}\ (t) \quad (16)$$

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

$$\vec{g}(t) - \overrightarrow{X_i}\ (t) \quad (17)$$

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

$$\overrightarrow{X_i}\ (t+1) = \mathrm{Xi}\ (t) + \mathrm{Vi}\ (t) \quad (18)$$

the latest particle speed in the equation (19).

$$\overrightarrow{V_i}\ (t+1) = \mathrm{GO\ Vi}\ (t) + \mathrm{C1\ r1}\ (\mathrm{Pi}\ (t) - \mathrm{Xi}\ (t) + \mathrm{C2\ r2}\ (\mathrm{g}(t) - \mathrm{Xi}(t) \quad (19)$$

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.

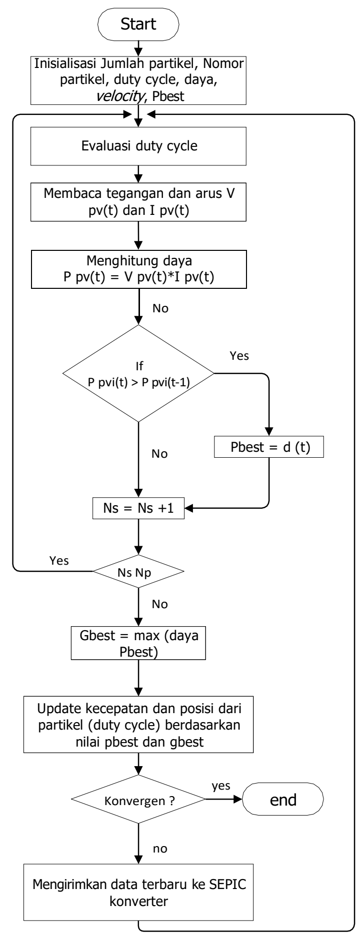

Figure 5 Flowchart PSO

MPPT algorithm design is simulated using MATLAB PSO 2016b. The goal of this simulation is to know the response of search results and the performance of the SEPIC converter.Simulation on MATLAB 2016a shown in Figure 6.

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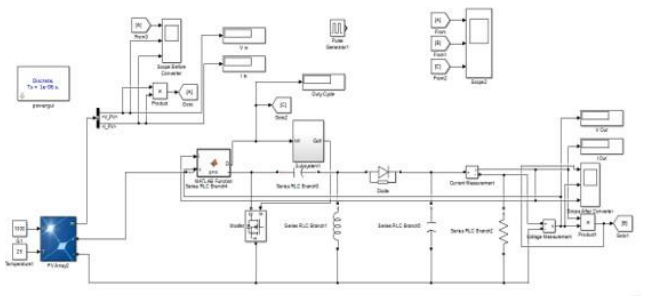

Figure 6 PSO and SEPIC Converter Design in MATLAB 2016a

III. RESULT AND DISCUSSION

In this experiment, go to the test in advance against the performance of the SEPIC converter without 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.

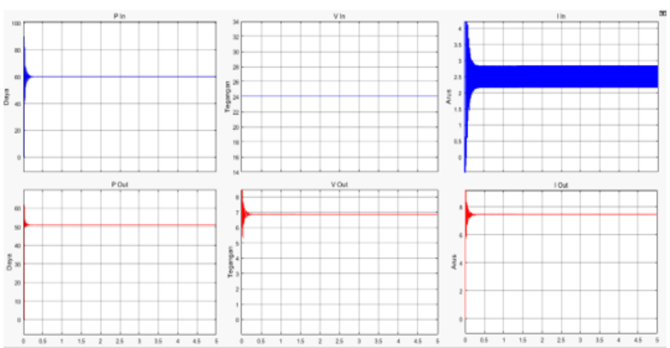

Figure 7 Input Output Voltage, current, and Power in the SEPIC Converter with constant voltage source.

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

The next testing phase on the MPPT is given the input form paramerter irradiasi and temperature conditions of STC, i.e. with irradiasi 1000 W/m2 and a temperature of 25oC.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.

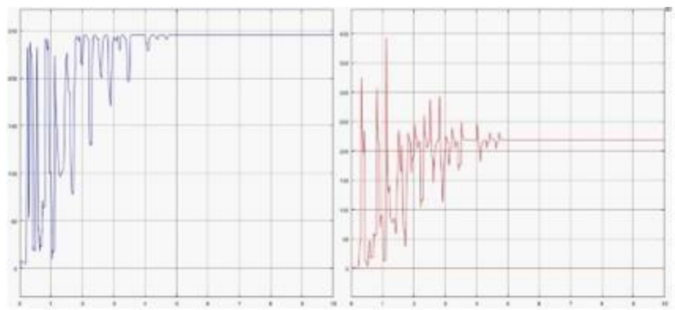

Figure 8 Power Input (blue) and Output (red) in the SEPIC Converter with MPPT PSO.

While the next testing phase is to provide the parameter values of irradiance down each step, the impact on the resulting power decline gradually as seen in Figure 9, whereas the voltage and current output can be seen in Figure 10.From Figure 9 can be known that when undergoing a gradual change in irradiance, PSO is able to keep track of any changes that occur.Average speed on every search is approximately 4.86 seconds. This proves that the PSO that is designed to have excellent performance.In the SEPIC converter also has a pretty good efficiency to reach 88%.

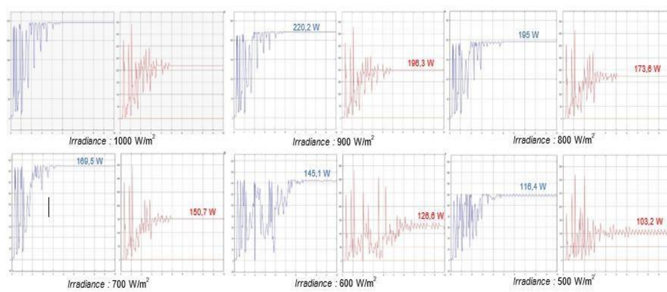

Figure 9 Power Input (blue) and Output (red) SEPIC Converter with MPPT PSO in the event of a decrease in irradiance gradually.

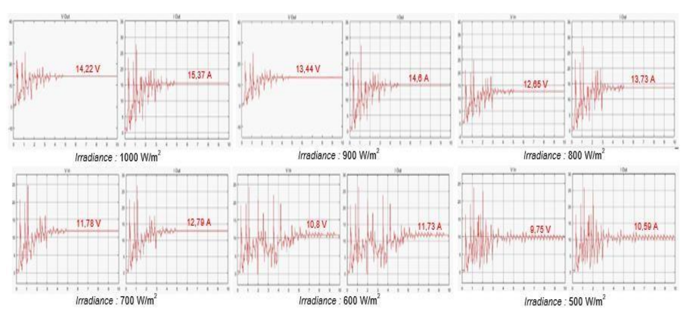

Figure 10 voltage and current Output SEPIC Converter with MPPT PSO

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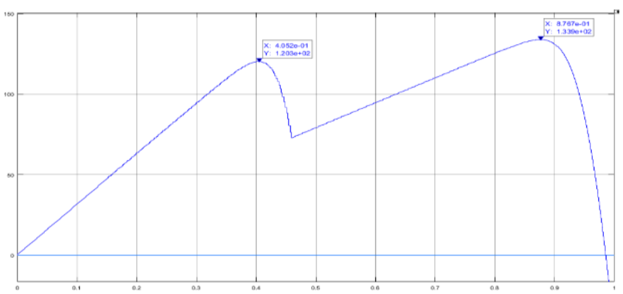
b. The results of the Simulation on the PSO MPPT Partial Shading

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.

a.



b.

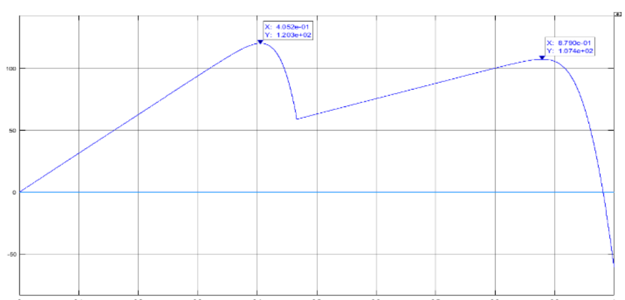


Figure 11. (a) the graph of P-V Characteristic Curve with maximum power point is to the right, (b) Graphs of characteristic Curve P-V with maximum power point is on the left.

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 seblah P-V curves right.

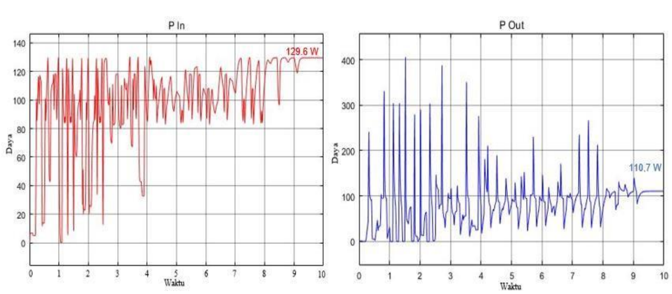


Figure 12 Power Input and Output SEPIC Converter with MPPT maximum power Point when the PSO Were Graph PV Curves on the right.

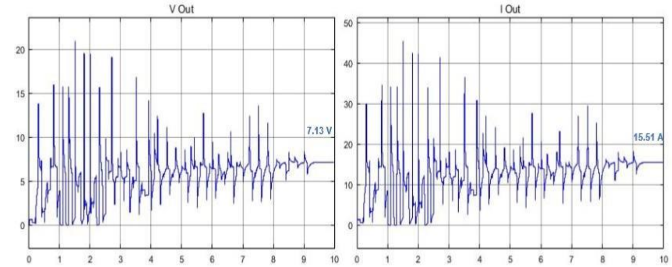


Figure 13 the voltage and current Output SEPIC Converter When maximum power Point is located on the right of the P-V Curve.

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%.

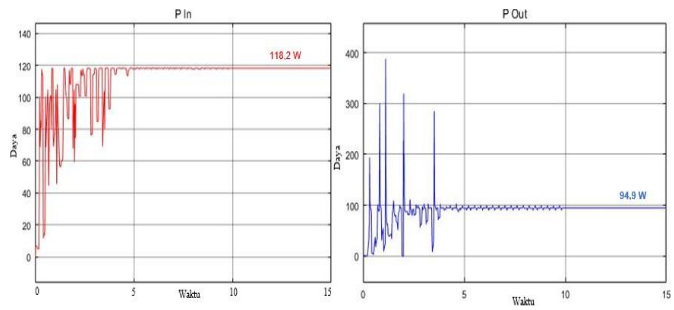


Figure 14 Power Input and Output Converter with Zeta MPPT maximum power Point when the PSO is located on the left of the curve of PV.

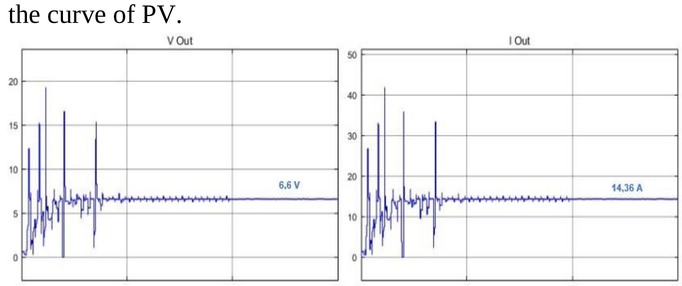


Figure 15 the voltage and current Output SEPIC Converter when the MPP Is the point on the left the P-V Curve.

Based on Figure 14 and Figure 15, then it can be was known when maximum power point is on the left of the curve P-V then it can be noted that the PSO are designed to have good performance in the maximum power point of the search.Time tracking is required in about 10 seconds. Whereas efficiency at SEPIC converter capable of achieving 80.28%.

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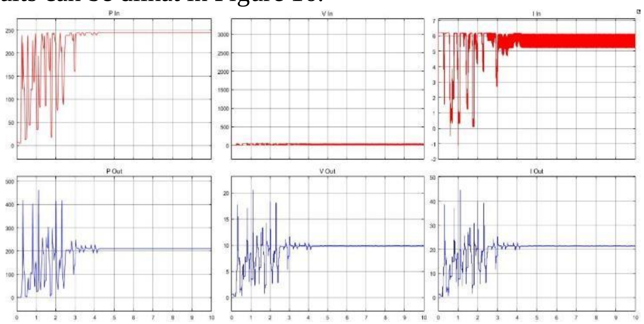
c. Comparison of Simulation Results MPPT Particle Swarm Optimization (PSO) and Peturb and Observe (P&O)

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 dlihat in Figure 16.

a.



b.

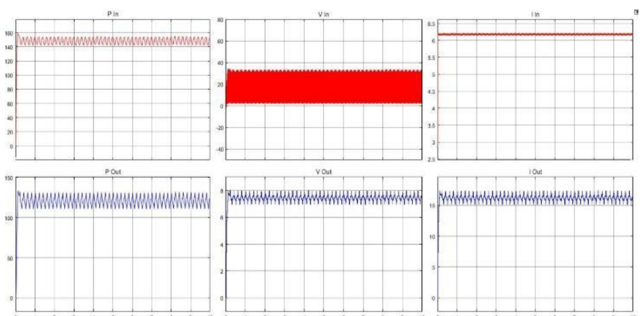


Figure 16 a. power, voltage, current, Input and Output SPEIC Converter with MPPT PSO, b. power, voltage, current, Input and Output P&O SEPIC Converter with MPPT.

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.

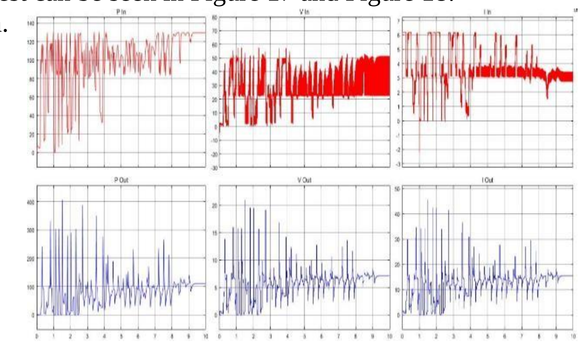
Table 2 comparison of power, voltage and current inputs and outputs SEPIC converter using PSO and P&O on the conditions of STC

Parameter Condition	MPPT	Pin (W)	Pout (W)	Vin (V)	Vout (V)	Iin (A)	Iout (A)	Trackin g (s)
Irradiance 1000 W/m² and temp 25ºC	PSO	244,5	210,4	42,85	9,83	5,72	21,39	4,2
	P&O	154	125,3	25,02	7,59	6,16	16,5	0,1

From table 2 it can be known that the PSO has a better employment performance dibandingakan 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.

a.



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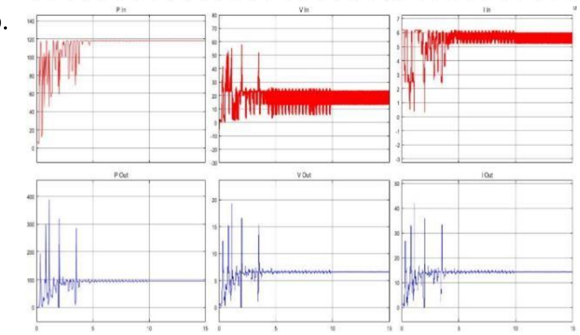
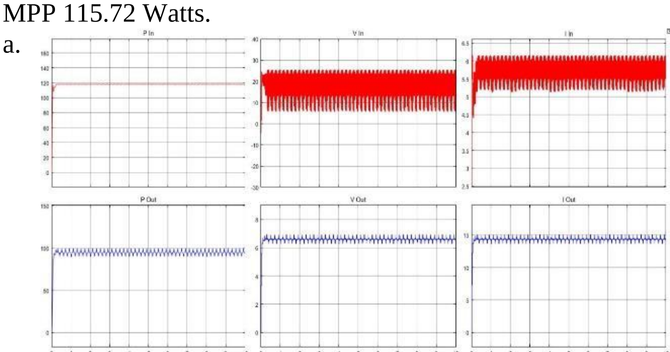


Figure 17 a. power, voltage, current, Input and Output SEPIC Converter with PSO when MPP 129.6 Watts, b. power, voltage, current, Input and Output SEPIC Converter with PSO when MPP 115.72 Watts.

a.



b.

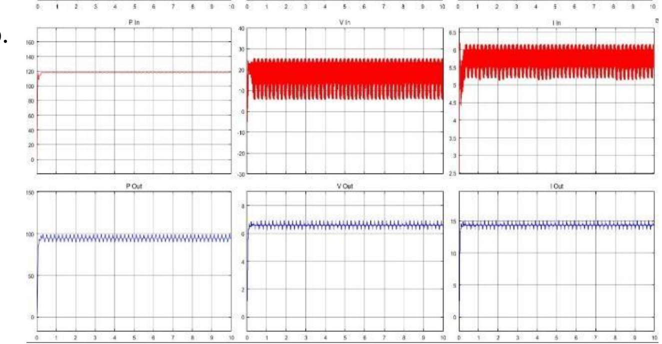


Figure 18 a. power, voltage, current, Input and Output SEPIC Converter with P&O when MPP 117.8 Watts, b. power, voltage, current, Input and Output SEPIC Converter with P&O when MPP 117.8 Watts.

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.

Parameter Kondisi	MPPT	Pin (W)	Pout (W)	Vin (V)	Vout (V)	Iin (A)	Iout (A)	Kecepatan *Tracking* (s)
Titik MPP di Sebelah Kanan dan Kiri	PSO	129,6	110,7	43,62	7,13	2,99	15,51	9,2
		115,72	99,72	22,96	9,58	5,04	10,41	10
	P&O	117,8	93,97	20,13	6,57	5,86	14,29	0,2
		117,8	93,96	20,1	6,57	5,86	14,29	0,2

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 efiseiensi $\geqslant$ 80% with the ripple current and output voltage is very small indeed.

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V References

[1] S. Rajendran and H. Srinivasan, "Simplified accelerated particle swarm optimisation algorithm for efficient maximum power point tracking in partially shaded photovoltaic systems," *IET Renew. Power Gener.*, vol. 10, no. 9, pp. 1340–1347, 2016.

[2] R. B. SATRIOADI, "Jurusan teknik elektro fakultas teknik universitas muhammadiyah surakarta 2014," no. 201210130311117, pp. 0–5, 2014.

[3] M. Sucipta, F. Ahmad, and K. Astawa, "Analisis Performa Modul Solar Cell Dengan Penambahan Reflector Cermin Datar," no. Snttm Xiv, pp. 7–8, 2015.

[4] P. Efisiensi, "Meningkatkan Efisiensi Konverter Dc-Dc Penaik Tegangan Dengan Teknik Zero Voltage Switching (Zvs)," vol. 7, no. 2, pp. 3–13, 2014.

[5] B. Prima and Aulia Siti, "Rancang Bangun Maximum Power Point Tracking pada Panel Photovoltaic Berbasis Logika Fuzzy di Buoy Weather Station," *J. Tek. Pomits*, vol. 2, no. 2, pp. 299–304, 2013.

[6] S. Khader and A. Abu-Aisheh, "The application of PSIM & Matlab/Simulink in teaching of power electronics courses," *Int. J. Online Eng.*, vol. 7, no. 3, pp. 15–18, 2011.

[7] K. Ishaque, Z. Salam, M. Amjad, and S. Mekhilef, "An improved particle swarm optimization (PSO)-based MPPT for PV with reduced steady-state oscillation," *IEEE Trans. Power Electron.*, vol. 27, no. 8, pp. 3627–3638, 2012.

[8] K. L. Lian, J. H. Jhang, and I. S. Tian, "A Maximum Power Point Tracking Method Based on Perturb-and-Observe Combined With Particle Swarm Optimization," vol. 4, no. 2, pp. 626–633, 2014.

[9] Y. H. Liu, S. C. Huang, J. W. Huang, and W. C. Liang, "A particle swarm optimization-based maximum power point tracking algorithm for PV systems operating under partially shaded conditions," *IEEE Trans. Energy Convers.*, vol. 27, no. 4, pp. 1027–1035, 2012.

[10] R. Vairamani, K.R; Vijayalakshmi , S; Sorna Vadivoo, "High frequency applications," *Des. ZVS Reson. SEPIC Convert. High Freq. Appl.*, vol. vol.13, no. International Conference on Circuit, pp. 873–880, 2014.

[11] M. Cabaj, "DC House Model Design and Construction A Senior Project The Faculty of the ELECTRICAL ENGINEERING DEPARTMENT California Polytechnic State University , San Luis Obispo By," 2012.

[12] S. Eilaghi, A. Ahmadian, and M. Aliakbar Golkar, "Optimal Voltage Unbalance Compensation in a Microgrid Using PSO Algortim," *Optim. Volt. Unbalance Compens. a microgrid Using PSO Algorithm*, vol. 52, no. 2, pp. 1395–1396, 2016.