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DESIGN & IMPLEMENTATION OF MPPT SOLAR PHOTOVOLTAIC - ELECTRIC VEHICLES IN FAST VARYING PARTIAL SHADING CONDITIONS USING SERVAL OPTIMIZATION ALGORITHM

Hendry C. Saputra, SST.[1)], Dr. Isdawimah, MT.[2)], Dr. Belyamin, Msc. [3)]

1) Electrical Engineering Department, Polytechnic Negeri Jakarta, Jl. Prof. Dr. G.A. Siwabessy, Depok, Indonesia
2) Electrical Engineering Department, Polytechnic Negeri Jakarta, Jl. Prof. Dr. G.A. Siwabessy, Depok, Indonesia
3) Mechanical Engineering Department, Polytechnic Negeri Jakarta, Jl. Prof. Dr. G.A. Siwabessy, Depok, Indonesia

Corresponding email [1)] : hendry.christiansaputra.te19@mhsw.pnj.ac.id

Abstract. Solar panels are used to convert solar energy into electrical energy. In this study it was applied to electric vehicles which have a very large potential for being constrained by shadows. In fast varying partial shading conditions, the position of the maximum power point is divided into two, namely GMPP and LMPP. This condition makes the MPPT process stuck in LMPP. Therefore, this research proposes the application of Serval Optimization Algorithm (SOA) in MPPT. This method refers to the natural behavior of the serval in nature. The fundamental inspiration of SOA is the serval hunting strategy in two stages of exploration and exploitation. The SOA is implemented in MPPT to change (duty cycle) so that it gets the best value and produces maximum solar panel output power. This SOA method was chosen to complete the partial shading conditions so that MPPT can optimally reach GMPP without going through LMPP. The solar panels used in this system are 2 units with specifications of 25 Wp with a 24V battery load and a 120W BLDC Motor compact in Electric Vehicle - Two Wheeler Scooter. MPPT SOA was tested in a simulation using PSIM and actual Software in 6 variations of normal and partial shading conditions. In the Simulation Test of Partial Shading Conditions, an average accuracy of 99.958% and an average tracking time of 0.492 seconds were obtained. SOA has a higher accuracy than PSO and GWO, which is 99.95%. And it has a faster tracking time of 0.55 seconds. In the SOC Integration Test, the SOA Method obtained an error value of 6.48% better than the GWO Method. On the Road Test with 6 condition, it can slow down the value of the decrease in battery capacity by 16.24%. The application of Single Source on the PV-MPPT-Converter can be implemented with an efficiency value of 76.86%. In previous research where SOA is a new method in Optimizing Problem Solving which has quite good accuracy performance, and in this research it can be implemented in Solar PV Optimization to track MPPT electric vehicles with varied and fluctuating partial shading conditions.

Keywords : Serval Optimization Algorithm (SOA), Fast-varying Partial Shading, Maximum Power Point Tracking (MPPT), State of Charge (SOC), Electric Vehicle.

1. INTRODUCTION

The emergence of EV (electric vehicles) is inevitable. In Indonesia, EV has been introduced in various forms. In Indonesia, battery BEV (electric vehicles) have been introduced by several well-known manufacturers. However, their adoption is still limited to a handful of people, considering that vehicle prices are still very high and unaffordable for most car drivers. In addition, the availability of public infrastructure for battery charging stations is still minimal and limited. This ecosystem will include charging station infrastructure, nickel raw material providers, battery manufacturers, component makers, and EV assemblers/manufacturers. Several foreign investors have expressed their interest in becoming an important player in the electric vehicle business ecosystem in Indonesia [1].

There are several problems that affect BEV performance:

1. Behavior of BEV drivers regarding duration of use, charging and idle conditions;
2. Unbalancing Power Flow Control on the Grid;
3. Battery performance (Battery Aging, Unbalance condition, Battery Degradation, SOC SOH measurement accuracy);
4. The results of the aggregation of purchasing intentions from all sources are 0.77 to buy and 0.23 not to buy or buying is preferred to not buying with a ratio scale of 3.35. It should be noted that these results do not mean that 77% of target customers will buy a BEV and 23% will not. [1].

There are several problems that affect the performance of Solar PV (details can be seen in Table 1.):

1. Tracking Duration, Oscillation, and MPPT Control Efficiency of Solar PV;
2. The accuracy of the implementation of the MPPT Algorithm.

Table 1. The Comparison of MPPT Algorithm

Reff	Method	Category	Criteria Parameter		
			Time Tracking	Oscillation Level	Efficiency
1	P & O	Conventional	0,4 – 3 s	High	70,77 – 99,99 %
2	P & O	Conventional	0,11 – 0,153 s	High	84,71 – 99,98 %
3	P & O	Conventional	0,08 s	High	99,28 %
4	IC	Conventional	0,3 s	High	61,89 %
5	IC	Conventional	0,434 – 0,479 s	High	100 %
6	PSO	Metaheuristic	0,11 – 0,172 s	Low	99,84 – 99,98 %
7	PSO	Metaheuristic	0,8 s	Low	91,42 %
8	ANN	Metaheuristic	0,063 s	Low	99,97 %
9	ANN	Metaheuristic	0,065 – 0,083 s	Low	90,6 – 99,25 %
10	DE	Metaheuristic	0,309 s	Low	99,9 %
11	DE	Metaheuristic	0,075 – 0,014 s	Low	98,6 – 99,1 %

Based on literature studies related to the application of Conventional-Metaheuristic algorithms in MPPT Solar PV where each method has advantages and disadvantages [2]. This research will carry out development by considering changes in partial shading conditions which are quite fast due to mobile conditions. On the DC Converter side, to be able to balance Pick differences in Solar PV irradiance conditions, the combined Buck-Boost converter is considered more optimal than just Boost/Buck [3] [4], or those using High Freq Inverters [5].

The advantage of this research is optimizing the performance of Solar PV as a Mobile Source so that it supports more optimal battery lifetime performance. Application of MPPT Buck-Boost Converter Combination on Solar PV output [3]. So that it is expected to further stabilize the output voltage and current due to Partial Shading and Variations of Rapid Changes in irradiance conditions and Implementation of the Serval Optimization (SOA) Algorithm where the algorithm scheme is a hunting strategy to attack the selected prey and then hunt the prey. SOA implementation steps in two stages of exploration and exploitation. As well as the implementation of PV & Battery monitoring conditions that can be monitored.

2. METHODS

This research was conducted through the Process of Design, Testing and Data Analysis. Monitoring the characteristics of the voltage and current originating from Solar PV until a power optimization setting is obtained which is then gradually sent through the converter to the battery for storage and then transferred to the BLDC Motor as a load. In this research, MPPT Control and Buck-Boost Converter function as regulators to obtain the most optimal power level due to drop voltage and load disturbance. Caused by the Partial Shading Condition, the System Flow can be seen in the image below.

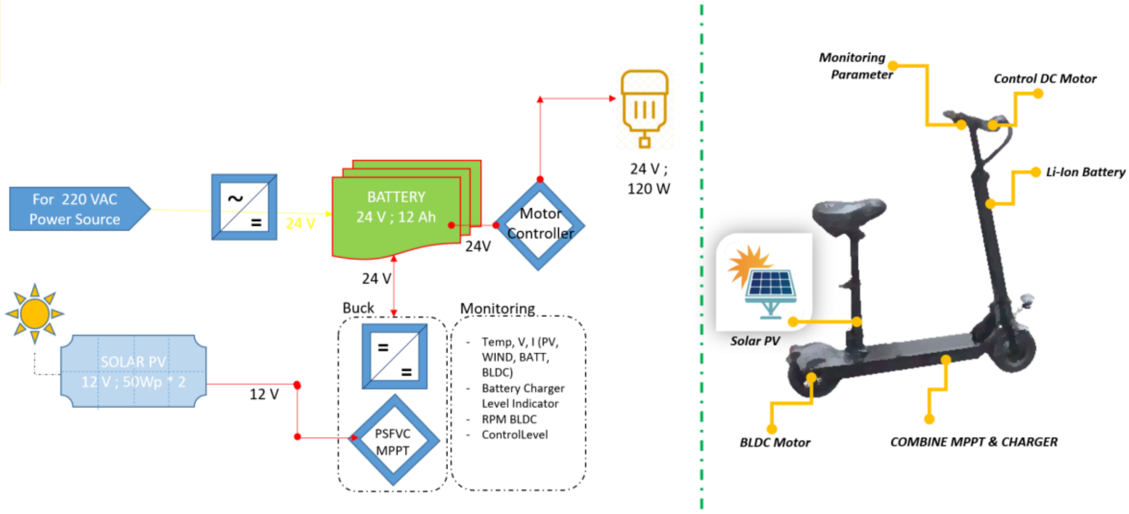


Figure 1. General Design System

2.1 System Design Simulation & Algoritma MPPT

First step of design for this research are by simulating system in PSIM software for knowing the working system properly. The circuit diagram as below :

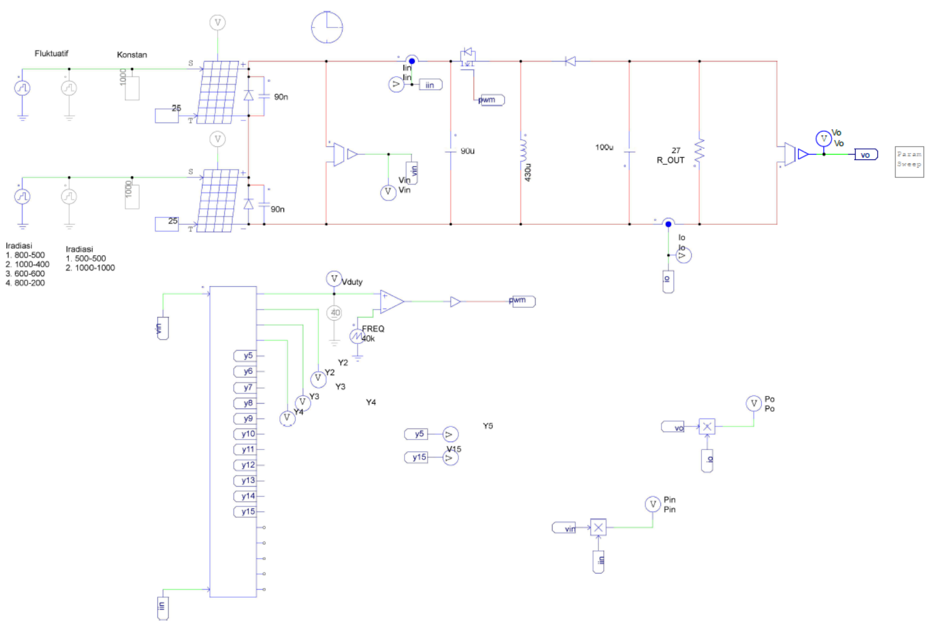


Figure 2. Electrical Design by PSIM Simulator

The next step is uploading the MPPT SOA Algorithm for measurement, compare & Analyze before hardware implementation. Flow chart algorithm as below :

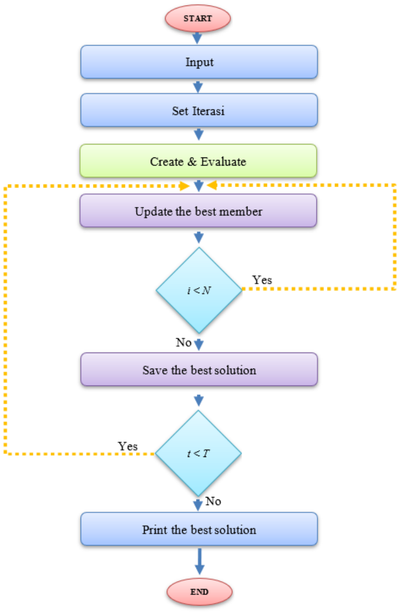


Figure 3. Flow Chart SOA Algorithm

2.2 Iteration Calculation SOA Algorithm

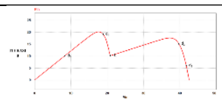
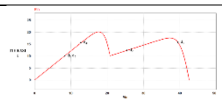
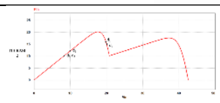
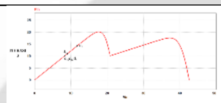
Calculations are performed as baseline parameters. The conditions implemented are partial shading with a reference value of irradiation of:

a. Solar PV I = 1000 W/m2
b. Solar PV II = 400 W/m2
c. With T 1 up to 5 using equation

$$d[T] = d[T] + r1 * (d_{best} - r3 * d[T]) \quad (1)$$

The number of sampling iterations calculated is 3 iterations in the following table:

Table 2. Iteration Calculation

Iteration 0	Iteration 1	Iteration 2	Iteration 3
$d_1^0 = 22$	$d_1^0 = 34.54$	$d_1^0 = 50.96$	$d_1^0 = 64.8$
$d_2^0 = 33$	$d_2^0 = 41.6$	$d_2^0 = 50.28$	$d_2^0 = 65$
$d_3^0 = 44$	$d_3^0 = 65$	$d_3^0 = 65$	$d_3^0 = 65$
$d_4^0 = 55$	$d_4^0 = 61.6$	$d_4^0 = 65$	$d_4^0 = 65$
$d_5^0 = 65$	$d_5^0 = 65$	$d_5^0 = 63.6$	$d_5^0 = 62.2$
d_{best}= 55	d_{best}= 55	d_{best}= 55	d_{best}= 55
			

2.3 Hardware Design

For Making circuit Hardware connection must starting by PCB Design and continuing make a port of hardware semiconductor, microprocessor, sensor, etc.

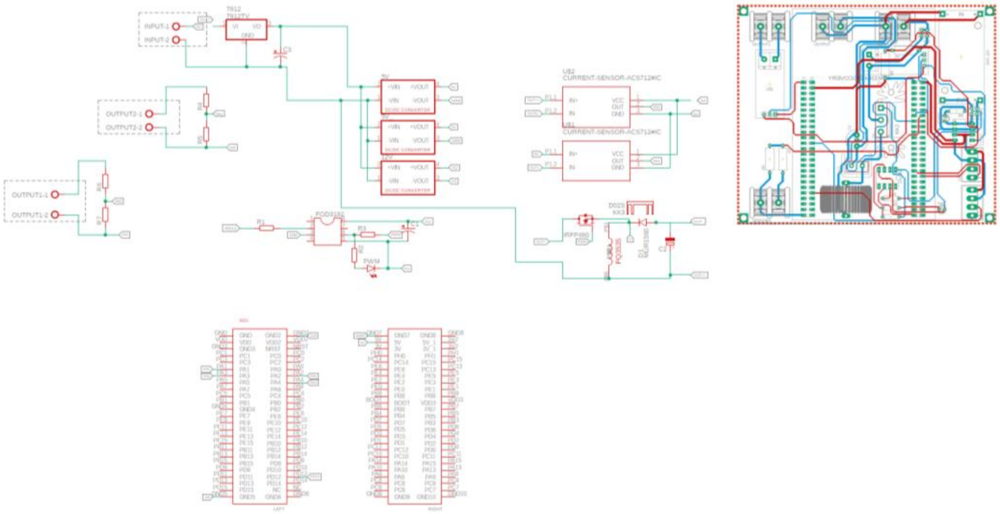


Figure 4. MPPT Diagram Block – Buck Boos Converter & PCB Design

2.4 Hardware Integration

Hardware Integration are connecting between Microcontroller, Solar PV, Battery & BLDC Motor with the mechanical wheeling system. The Design of Hardware starting when the simulation by software simulator (Eagle & PSIM) already firm & works by SOA MPPT method.

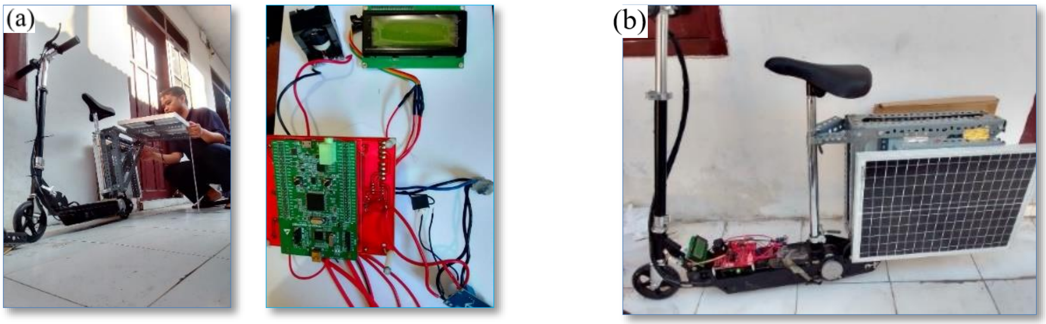


Figure 5. Hardware Integration: (a) Solar PV & MPPT Installation & (b) Microcontroller, LCD, Converter, Battery & BLDC Installation

2.5 Data collection, observation, measurement & analysis techniques

Data collection, observation, measurement & analysis techniques consist of:

(a) MPPT SOA Characteristic Test:
  i. Characteristic Test Solar PV
  ii. SOA Simulation Test (Uniform & Partial Shading Condition)
  iii. SOA Simulation Test (Fluctuation Shading Condition)

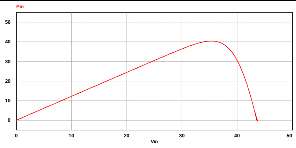
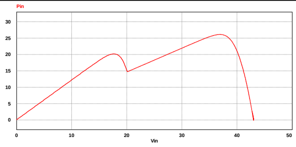
(b) MPPT SOA System Test
  i. Sub System Real Condition Test
    - Sub System Buck Boost Converter Test
    - MPPT System Test with Variable Condition (Non Shading and Partial Shading)
  ii. Integration Test Real Condition & Comparation MPPT Method
    - SOA Algorithm Comparation with other Method
    - MPPT System Integration Test

3. RESULTS AND DISCUSSION

3.1 MPPT SOA Characteristic Test

a. Characteristic Test Solar PV

Table 3. PV Characteristic Test

Condition	No.	Irradiation (W/m^2) PV 1	Irradiation (W/m^2) PV 2	GMPP	LMPP	Best Graphics
Uniform Condition	**1**	**1000**	**1000**	**40.4**	**-**	
	2	800	800	32.24	-	
	3	500	500	19.90	-	
	4	400	400	15.74	-	
PSC	**5**	**1000**	**600**	**26.41**	**20.19**	
	6	1000	400	20.19	17.6	
	7	800	600	25.63	16.11	
	8	800	200	16.11	8.71	

The result of characteristic test of solar PV above are in Uniform Condition just get one pick of GMPP, beside in partial shading condition when there are have a different irradiance condition on each PV Panel. So that the output will be potentially decrease because of the LMPP result.

b. SOA Simulation Test (Uniform & Partial Shading Condition)

Table 4. SOA Simulation Test Uniform & PSC

No.	P_Ideal (W)	P_SOA (W)	Duty Cycle (%)	Converter mode	Accuracy (%)	Tracking time (second)
1	**40.4**	**40.38**	**48.26**	**Buck**	**99.95**	**0.31**
2	32.24	32.24	45.53	Buck	100.00	0.43
3	19.90	19.79	40.10	Buck	99.45	0.4
4	15.74	15.42	38.57	Buck	97.97	0.6
5	**26.41**	**26.13**	**41.79**	**Buck**	**98.94**	**0.55**
6	20.19	20.18	56.89	Boost	99.95	0.55
7	25.63	25.60	42.12	Buck	99.88	0.53
8	16.11	16.1	54.02	Boost	99.94	0.55

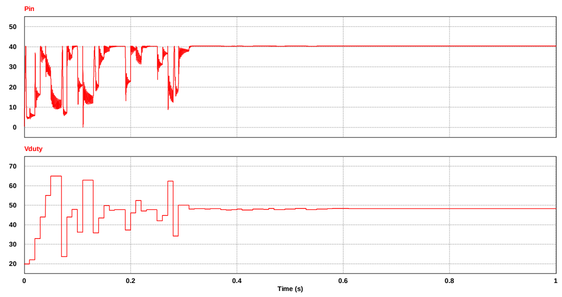


Figure 6. Graphics Simulation PV I 1000–PV II 1000

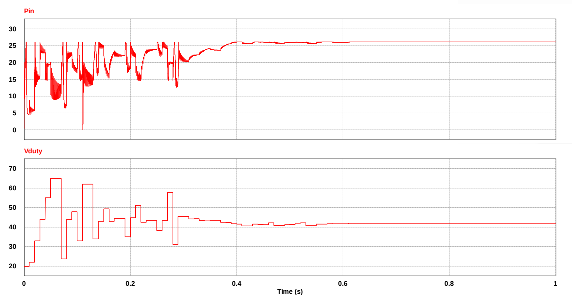


Figure 7. Graphics Simulation PV I 1000–PV II 600

After Characteristic PV Test and knowing the GMPP and LMPP, next is simulation SOA algorithm test for knowing how accurate and how fast the tracking time. With result as below :

Ideal Condition = Theory = based on Irradiance Condition by location
Accuracy = (P_SOA)/(P_ideal)×100%
The Simulation Test of SOA MPPT Algorithm in ideal condition , with accurate above 97% dan tracking time between 0,3s - 0,6s.

c. SOA Simulation Test (Fluctuation Shading Condition)

Table 5. Simulation SOA Fluctuation

Detik	Iradiasi		P_Ideal (W)	P_SOA (W)	Duty Cycle (%)	Accuracy (%)	Tracking time (detik)
	PV1	PV2					
1	500	500	19.90	19.88	40.12	99.90	0.52
2	1000	1000	40.4	40.38	48.09	99.95	0.37

Detik	Iradiasi		P_Ideal (W)	P_SOA (W)	Duty Cycle (%)	Accuracy (%)	Tracking time (detik)
	PV1	PV2					
1	800	800	32.24	32.23	45.4	99.97	0.55
2	1000	400	20.19	20.18	56.83	99.95	0.41
3	800	200	16.11	16.11	54.01	100.00	0.5
4	1000	1000	40.4	40.39	48.07	99.98	0.6

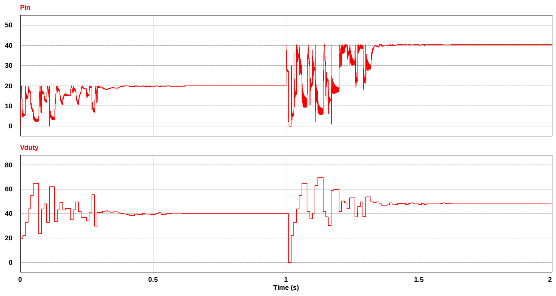


Figure 8. Graphics Simulation 2 s

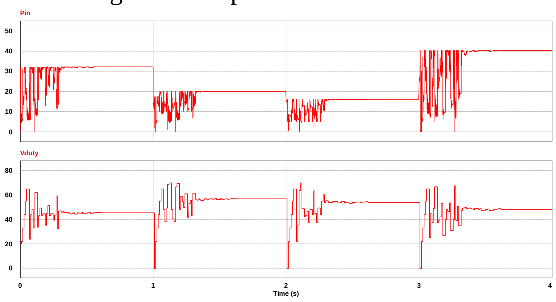


Figure 9. Graphics Simulation 4 s

The purposes of This testing is want to simulate a various partial shading condition it could be happened when the electric vehicle on movement situation with many shading condition by tree, other vehicle, etc. The result of MPPT SOA Algorithm in fluctuation condition when 2 second uniform and 4 second PSC with accurate result above 99% dan tracking time between 0,4s – 0,6s.

3.2 MPPT SOA System Test

a. Sub System Real Condition Test

i. Sub System Buck Boost Converter Test

Table 6. Sub System Buck Boost Converter Test

D	Vin	In	Vout	Iout	Pin	Pout	Eff
30	15	0,18	5,76	0,2	2,7	1,152	42,67

	20	0,193	7,89	0,26	3,86	2,0514	53,15
	25	0,22	10,04	0,34	5,5	3,4136	62,07
	30	0,251	12,2	0,4	7,53	4,88	64,81
	35	0,279	14,36	0,46	9,765	6,6056	67,65
	40	0,313	16,52	0,53	12,52	8,7556	69,93
40	15	0,314	9,07	0,32	4,71	2,9024	61,62
	20	0,385	12,35	0,42	7,7	5,187	67,36
	25	0,46	15,64	0,52	11,5	8,1328	70,72
	30	0,54	18,94	0,62	16,2	11,7428	72,49
	35	0,622	22,25	0,72	21,77	16,02	73,59
	40	0,704	25,55	0,81	28,16	20,6955	73,49
50	15	0,726	14,9	0,5	10,89	7,45	68,41
	20	0,93	20,12	0,68	18,6	13,6816	73,56
	25	1,15	25,33	0,82	28,75	20,7706	72,25
	30	1,37	30,61	0,98	41,1	29,9978	72,99
	35	1,592	35,87	1,12	55,72	40,1744	72,10
	40	1,82	41,04	1,26	72,8	51,7104	71,03
60	15	1,25	19,79	0,66	18,75	13,0614	69,66
	20	1,63	26,56	0,87	32,6	23,1072	70,88
	25	2,034	33,47	1,12	50,85	37,4864	73,72
	30	2,42	40,04	1,3	72,6	52,052	71,70
	35	2,8	46,18	1,47	98	67,8846	69,27
65	15	1,8	23,45	0,82	27	19,229	71,22
	20	2,39	31,79	1,08	47,8	34,3332	71,83

Optimal

D	Vin	In	Vout	Iout	Pin	Pout	Eff
43	35,6	0,784	25,54	0,84	27,9104	21,4536	76,86597

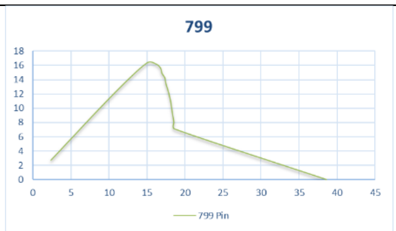
ii. MPPT System Test with Variable Condition (Non Shading and Partial Shading)

Test with real irradiance condition:

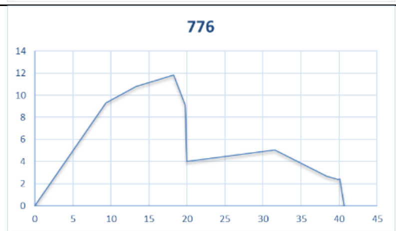
PV Case 1 - Non PSC
PV Case 2 – PSC PV I (variable load)
PV Case 3 – PSC PV I (variable duty cycle)
PV Case 4 – PSC PV II (variable load)
PV Case 5 – PSC PV II (variable duty cycle)

Case 1

Case 2



Case 3



Case 4

Case 5

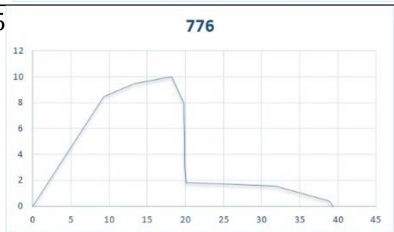


Figure10. MPPT sub system Test

b. Integration Test Real Condition & Comparation MPPT Method
   i. SOA Algorithm Comparation with other Method

Table 7. Uniform Condition

ALGORITMA	P_IDEAL	P_MPP	ACC	TRACKING TIME
SOA	20,19 1000 1000	20,18	**99,95**	**0,55**
PSO		20,11	99,60	0,57
GWO		20,1	99,55	0,6
ALGORITMA	P_IDEAL	P_MPP	ACC	TRACKING TIME
SOA	32,24 800 800	32,236	**99,99**	**0,43**
PSO		32,04	99,38	0,6
GWO		32,23	99,97	0,6

Table 8. Fluctiation Condition

Detik	**Iradiasi**		**P_Ideal (W)**	**P_SOA (W)**	**Duty Cycle (%)**	**Accuracy (%)**	**Tracking time (detik)**
	PV1	PV2					
1	500	500	19,9	19,88	40,12	99,90	0,52
2	1000	1000	40,4	40,38	48,09	99,95	0,37
					Average	99,92	0,45
Detik	**Iradiasi**		**P_Ideal (W)**	**P_ PSO (W)**	**Duty Cycle (%)**	**Accuracy (%)**	**Tracking time (detik)**
	PV1	PV2					
1	500	500	19,9	19,22	39,9	96,58	0,55
2	1000	1000	40,4	40,02	48,25	99,06	0,5
					Average	97,82	0,53

Detik	Iradiasi		P_Ideal (W)	P_GWO (W)	Duty Cycle (%)	Accuracy (%)	Tracking time (detik)
	PV1	PV2					
1	500	500	19,9	19,85	39,55	99,75	0,6
2	1000	1000	40,4	40,3	48,48	99,75	0,6
					Average	99,75	0,60

Table 9. Fast Varying Partial Shading

Detik	Iradiasi		P_Ideal (W)	P_SOA (W)	Duty Cycle (%)	Accuracy (%)	Tracking time (detik)
	PV1	PV2					
1	800	800	32,24	32,23	45,4	99,97	0,55
2	1000	400	20,19	20,18	56,83	99,95	0,41
3	800	200	16,11	16,11	54,01	100,00	0,5
4	1000	1000	40,4	40,39	48,07	99,98	0,6
					Average	99,97	0,52

Detik	Iradiasi		P_Ideal (W)	P_PSO (W)	Duty Cycle (%)	Accuracy (%)	Tracking time (detik)
	PV1	PV2					
1	800	800	32,24	32,04	45,47	99,38	0,6
2	1000	400	20,19	20,18	56,76	99,95	0,58
3	800	200	16,11	16,1	54,15	99,94	0,6
4	1000	1000	40,4	39,4	48,16	97,52	0,58
					Average	99,20	0,59

Detik	Iradiasi		P_Ideal (W)	P_GWO (W)	Duty Cycle (%)	Accuracy (%)	Tracking time (detik)
	PV1	PV2					
1	800	800	32,24	32,22	45,49	99,94	0,6
2	1000	400	20,19	20,12	56,77	99,65	0,6
3	800	200	16,11	16,1	53,93	99,94	0,6
4	1000	1000	40,4	-	-	0,00	-
					Average	74,88	0,6

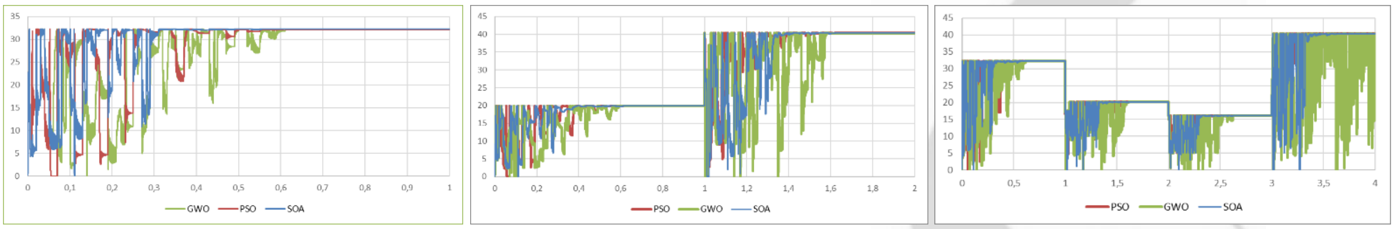


Figure 11. Graphics of Uniform 800 – 800, Fluctuation, Fast Varying Partial Shading Condition

ii. MPPT System Integration Test (13 Test Condition)

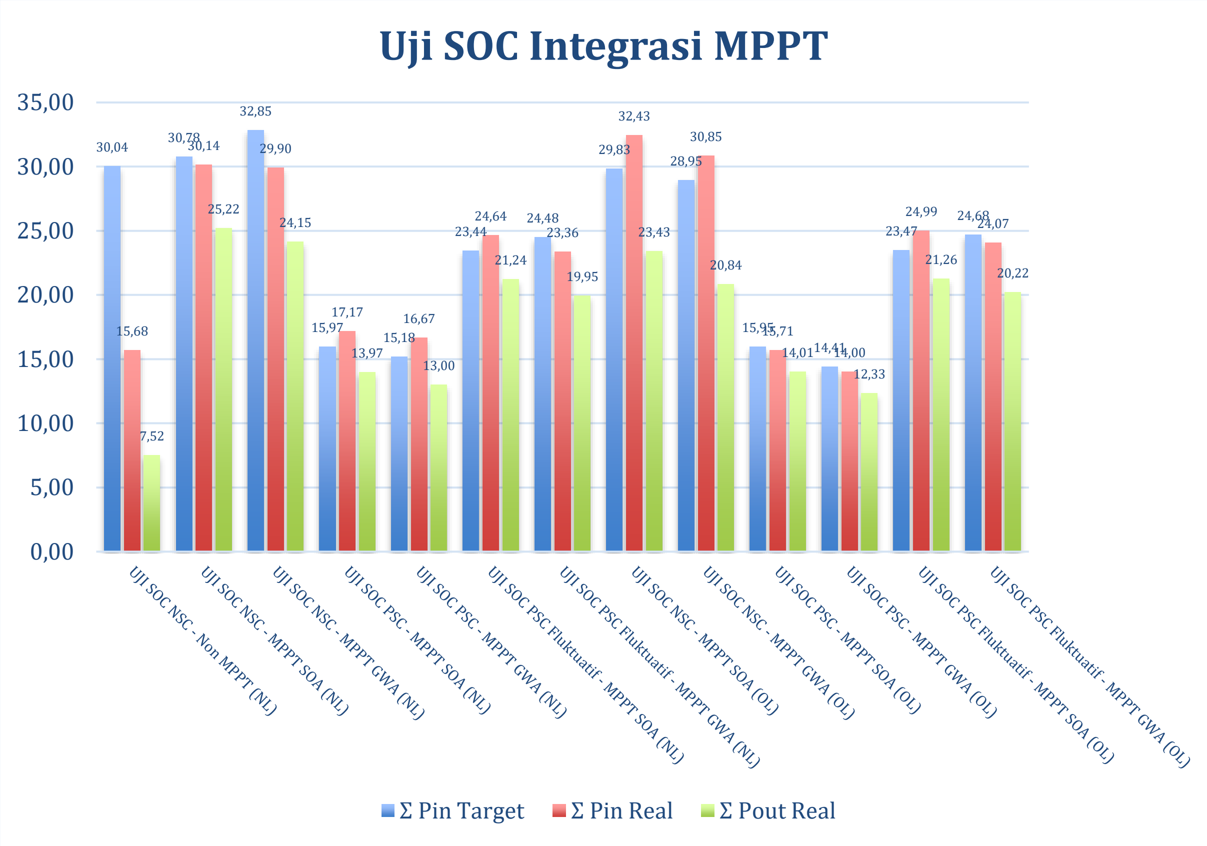


Figure 12. MPPT System Integration Test

The Result of comparison of MPPT System integration test as below :

- In No Load Testing with Fluctuation PSC, the best result is SOA (output 21,24 by 23,44) ; GWA (output 19,95 by 24,48)
- In On Load Testing with Fluctuation PSC, the best result is SOA (output 21,26 by 23,47) ; GWA (output 20,22 by 24,68)

3.3 Citation and References

a. Electric Vehicle

An electric bicycle that will be driven with the help of a battery and thus provide the necessary voltage to the motor. This bicycle can be driven with the help of electricity or also with the help of solar energy. An electric bicycle is a bicycle that is powered by a battery coupled to an electric motor [6] [17].

b. Battery System

The Thevenin topology for a lithium-ion battery is shown in Figure 13, where Vocv is the electric motor power of the battery, R1 and R2 are defined as the internal resistor and ohmic polarization resistor, and C is the polarization capacitor, which is connected in parallel with the polarization resistance R2 [7] [13] [14] [15] [16].

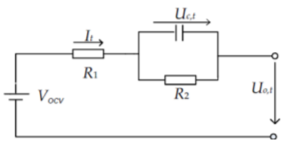


Figure 13. Battery Thevenin Topology

c. Solar Photovoltaic

Solar panels are semiconductor components that function to convert solar energy into electrical energy. The energy conversion is carried out by releasing electrons when receiving stimulation from sunlight. The semiconductor material used in solar panels to convert this energy is silicon. This material consists of two layers, namely a negatively charged layer (N) and a positively charged layer (P), as shown in the following figure [8].

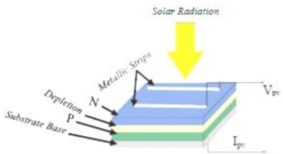


Figure 14. Solar Photovoltaic

Solar panels have an ideal equivalent circuit which functions to obtain an I-V characteristic curve. The circuit consists of 1 diode and 1 current source so it can be seen in the following picture.

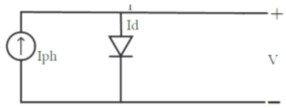


Figure 14. Solar PV Equivalent Circuit

d. Partial Shading Solar PV

Partial shading is a condition where some parts of the solar panel surface are covered from exposure to sunlight. This condition is caused by the presence of an object that blocks the solar cell. This can make the power generated by solar cells decrease. This decrease is also affected by the solar radiation received by the solar panels, thereby reducing the value of the resulting output current, as shown in the figure below [8] [9] [10]. Below is the equation for solar panel efficiency on the effects of partial shading.

$$I = I_{ph} - I_d \left(e^{\frac{qV}{k_B T}} - 1 \right)$$

$$V = \frac{k_B T}{q} \ln \left(1 + \frac{I_{ph}}{I_d} \right)$$

$$P_{IN} = Radiance \cdot A$$

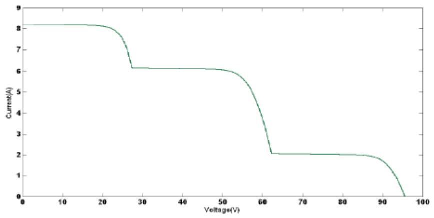


Figure 15. Equation and Partial Shading Curve

e. MPPT System

MPPT or Maximum Power Point Tracking is a technique for finding the maximum or highest power point. MPPT requires a DC-DC converter to work, because the way MPPT works is by changing the duty cycle to achieve MPP. There are many DC-DC converters that can be used, such as buck converters, boost converters, buck-boost converters, flyback converters, and others, depending on the needs of the users. The switch component on the DC-DC converter is set for the ON-OFF switching process using MPPT algorithms. MPPT requires a current sensor and a voltage sensor on the input side which are used as data for algorithm processing to obtain the duty cycle value [11].

f. Implementation of MPPT Serval Optimization Algorithm

This research introduces a new metaheuristic algorithm called Serval Optimization Algorithm (SOA), which mimics the natural behavior of servals in nature. The fundamental inspiration of SOA is the serval's hunting strategy, namely attacking selected prey and then hunting the prey by chasing. SOA implementation steps in two stages of exploration and exploitation. The proposed SOA approach is compared with the performance of twelve well-known metaheuristic algorithms to further evaluate it. The optimization results show that the SOA implementation of the CEC 2011 test suite and four engineering design challenges demonstrate the high efficiency of the proposed approach in handling real-world optimization applications. The proposed SOA approach is a population-based optimizer that is capable of providing suitable solutions to optimization problems by using the search power of its search agents. Servant prowling in nature has a similar approach to the agent-seeking mechanism of identifying optimal solutions. For this reason, from a mathematical point of view. Formation of the SOA population trying to reach the optimal solution [12].

$$X = \begin{bmatrix} X_1 \\ \vdots \\ X_i \\ \vdots \\ X_N \end{bmatrix}_{N \times d} = \begin{bmatrix} x_{1,1} & \cdots & x_{1,j} & \cdots & x_{1,d} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ x_{i,1} & \cdots & x_{i,j} & \cdots & x_{i,d} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ x_{N,1} & \cdots & x_{N,j} & \cdots & x_{N,d} \end{bmatrix}_{N \times d}, \quad (1)$$

$$x_{i,j} = lb_j + r_{i,j} \cdot (ub_j - lb_j),\ i = 1, 2, \ldots, N \text{ and } j = 1, 2, \ldots, d, \quad (2)$$

Step SOA Algorithm :

1. Input Information of Problem
2. Set a Population and amount of iteration
3. Calculation population matrix
4. Evaluation Object Function
5. Do Phase 1 (Exploration)

$$x_{i,j}^{P1} = x_{i,j} + r_{i,j} \cdot (P_j - I_{i,j} \cdot x_{i,j}),\ i = 1, 2,\ \ldots,\ N \text{ and } j = 1, 2,\ \ldots, d,$$

$$X_i = \begin{cases} X_i^{P1}, & F_i^{P1} < F_i \\ X_i, & else \end{cases}$$

6. Do Phase 2 (Exploitation)

$$x_{i,j}^{P2} = x_{i,j} + \frac{r_{i,j} \cdot (ub_j - lb_j)}{t},\ i = 1, 2,\ \ldots,\ N,\ j = 1, 2,\ \ldots, d, \text{ and } t = 1, 2,\ \ldots,\ T,$$

$$X_i = \begin{cases} X_i^{P2}, & F_i^{P2} < F_i, \\ X_i, & else, \end{cases}$$

7. Repeat as set iteration, until find the best output

g. DC-DC Converter

The DC–DC converter can be seen in the picture below. Where Uin is the output voltage. D1 is a reversed blocking diode, and also functions to withstand/anticipate reverse current. Consists of L1, D2, L2, C1, C2. The capacitor switch consists of D3, D4, D5, C3, C4 and C5. R is the load resistance and uo is the output voltage of the converter. Q is Power Switch. This converter is an inverting DC-to-DC converter i.e. the polarity of the output voltage is reversed compared to the input supply. So, it is a negative output buck-boost converter [3] [4].

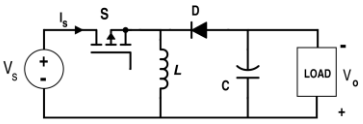


Figure 16. Buck Boost Converter Sequence

4. CONCLUSION

After carrying out testing and analysis in research on the design and implementation of MPPT solar panels - electric vehicles in fast varying partial shading conditions using the Serval Optimization algorithm, it can be concluded as follows:

1. Perform Quality of MPPT
   a. In the Non-Shading Condition Simulation Test, an average accuracy of 99,510% and an average tracking time of 0.490 seconds are obtained.
   b. In Partial Shading Condition Simulation Testing, Shading achieved an average accuracy of 99.958% and an average tracking time of 0.492 seconds.
   c. Comparison of the MPPT SOA method in the PSIM Comparison Test has a higher accuracy than the MPPT PSO and GWA methods, which is 99.95%. And has a faster tracking time of 0.55 seconds.
   d. In previous research, SOA is a new method for Optimizing Problem Solving which has quite good accuracy performance, which in this thesis research can be implemented in Solar PV Optimization to track MPPT.
2. Perform Quality of Converter & Battery
   a. In the State of Charge (SOC) Integration Test, with 12 test conditions, the Serval Optimization Algorithm (SOA) Method obtained an error value of 6.48% better than the GWO Method, so this method can be implemented in Battery and Solar PV based electric vehicles which has the potential for variations in partial shading to occur, due to mobile conditions.
   b. On Road Testing through 6 test conditions, using MPPT SOA can slow down the decrease in battery capacity by 16.24%.
   c. The application of Single Source on PV - MPPT - Converter can be implemented with an efficiency value of 76.86%, so it does not require 2 (two) sources.

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