Variable Step Size P&O MPPT Algorithm on 250 W Interleaved Flyback Converter

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***Abstract*—Maximum power point tracking (MPPT) algorithm seek the MPP to maximize delivered the power of a photovoltaic panel. From several MPPT algorithms, the perturb and observe (P&O) algorithm is commonly used algorithm because of its easy implementation. However, it is not the most efficient algorithm due to the perturbation step is fixed. By using the high step size, the MPP tracking became fast but there would be a high steady state error and by using the low step size, there would be less steady state error but the MPP tracking became slow. Resulting in a waste of energy in steady-state conditions when the working point passes through the MPP and poorly dynamic performance indicated when the setpoint changes due to solar irradiation changes. In this paper, a modification variable step-size of the P&O algorithm has been proposed with setting the step-size automatically at each point of work. To validate the concept of modification variable step-size, simulation using PSIM has been carried out. Compared with the conventional P&O method with fixed step-size, the proposed modified P&O method can increase tracking speed and efficiency in the system.**

***Keywords*— MPPT, P&O, MPP, Step-size, photovoltaic.**

I. INTRODUCTION

Solar energy will be a very important of renewable energy source because of environmentally friendly, pollution-free and abundant energy sources. However, the power generated by photovoltaic (PV) is affected by environmental conditions such as solar irradiation and ambient temperature so that current and voltage characteristics changes. The low output voltage and high output current are the characteristics of the Photovoltaic energy source. Due to the unique characteristics, the PV array is not connected directly to the load but use a dc/dc converter to connect between the solar panel and the load [1], [2].

A maximum power point tracking (MPPT) is used to optimize the power that can be absorbed by a PV panel. In many applications, MPPT is a DC/DC converter that connects PV panel with load, and its control is achieved by a tracking algorithm. Research related to MPPT is usually grouped into two categories: first relating to the optimization of DC/DC converters, focusing on selecting suitable DC/DC converters to operate as MPPT, and second is to choose the maximum point power tracking algorithm, where the selected algorithm should increase the efficiency and speed of tracking, and can also avoid oscillations around MPP [3], [4].

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Several MPPT algorithms on photovoltaic systems have been developed. Where, there are different concepts, complexity, number of sensors used, cost and performance to achieve several goals: tracking accuracy, fast response and small oscillations in MPP [5]. Some popular algorithms are perturb and observe, incremental conductance, constant voltage, fractional open circuit current, current sweep and some modified techniques have also been developed. Of the several MPPT algorithms, the perturb and observe (P&O) algorithm is a commonly used algorithm because of its easy implementation and low cost. On the other hand, its main drawbacks are the waste of energy in steady state conditions, when the working point moves across the MPP and the poor dynamic performances exhibited when a set point change when solar irradiation changes over a wide range [6].

This paper presents a modification variable step size of the perturb and observe (P&O) algorithm designed to overcome the deficiencies of conventional P&O algorithms, applied to a 250 W photovoltaic system using an interleaved flyback converter. By varying the value of the step-size, oscillation around the MPP can be reduced and faster tracking response to reach MPP. When the maximum power point changes due to insolation, the step size will automatically set by control circuit based on the operating point. If the operating point far from MPP, the step-size can be increased in order to achieve fast-tracking.

II. METHODOLOGY

This research can be clasified into three main parts of the system, namely Photovoltaic, control circuits, and interleaved flyback converters, as shown in Fig. 1.

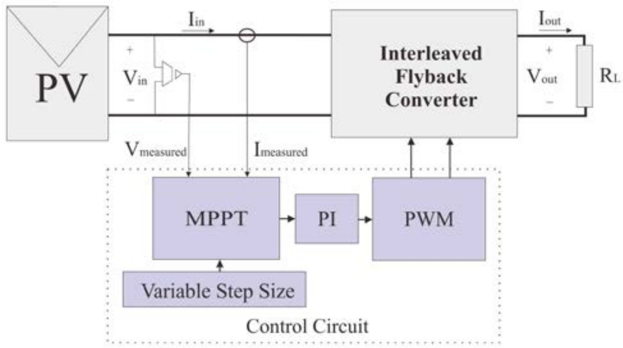


Fig. 1 Photovoltaic system proposed.

A. Photovoltaic (PV)

Photovoltaic are devices that deal directly with sunlight and convert it into electrical energy. The photovoltaic model used in this paper is taken from the specification of solar world products with type Sunmodule SW 250 mono/Version 2.0 and 2.5 frames as seen in Table I.

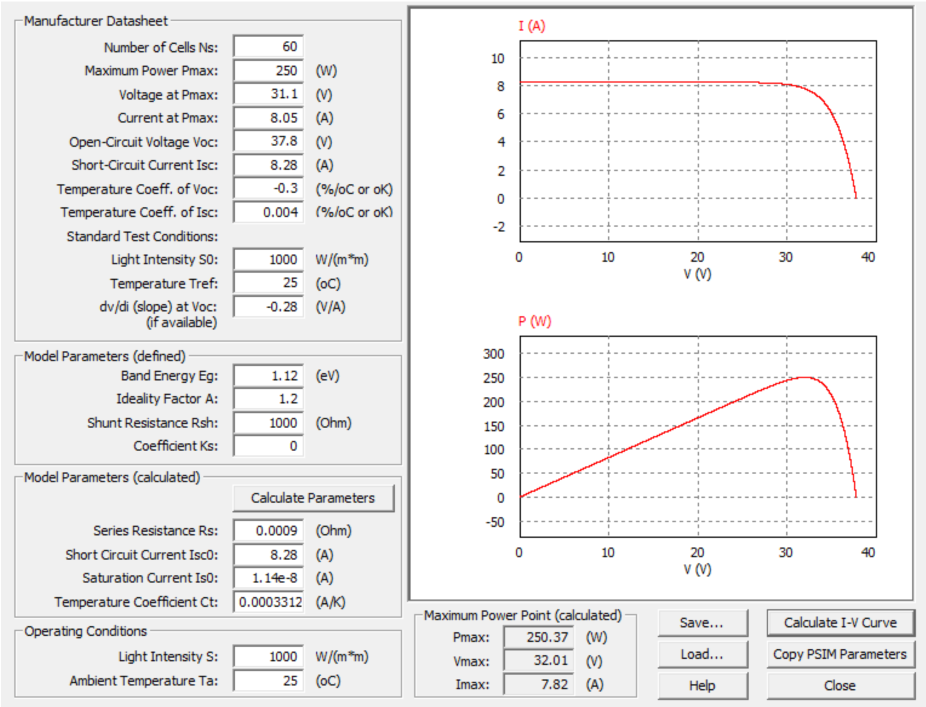


Fig. 2 The PV model of Sunmodule 250 W on PSIM.

TABLE I
THE CHARACTERISTIC OF SUNMODULE SW 250 MONO

Specification @ S = 1,000W/m^2 dan T = 25^{o}C	
Maximum Power, P_{max}	250 Wp
Open Circuit Voltage, V_{OC}	31.1 V
Maximum Power Point Voltage, V_{MPP}	8.05 A
Short circuit Current, I_{SC}	37.8 V
Maximum Power Point Current, I_{MPP}	8.28 A
Thermal Characteristic I_{SC}	0.004%/K
Thermal Characteristic V_{oc}	-0.30%/K
Thermal Characteristic P_{mpp}	-0.45%/K

TABLE II
RESULT OF MEASUREMENT OF SUNMODULE 250 W IN VARYING INSOLATION

Insolation (W/m^2)	**I_{MPP} (A)**	**V_{MPP} (V)**	**P_{MPP} (W)**
100	0.827	26.59	21.99
200	1.655	27.75	45.93
300	2.483	28.42	70.57
400	3.312	28.87	95.62
500	4.139	29.23	120.98
600	4.967	29.51	146.57
700	5.792	29.75	172.33
800	6.606	30.01	198.23
900	7.306	30.69	224.25
1,000	7.820	32.01	250.37

Based on the characteristics of Sunmodule SW 250 mono in Table I, a model of PV on PSIM is made to get current, voltage and power in the system to be used. The result obtained are current = 7.82 A, voltage = 32.01 V and power = 250.37 W, as seen in Fig. 2.

After doing the modeling, PV panel testing was done to the solar irradiation change from 100-1,000 W/m^2 to obtain the current-voltage curve (I-V) as seen in Fig. 3 and the power-voltage (P-V) curve as seen in Fig. 4. So obtained the data current, voltage and maximum power as shown in Table II.

B. *Interleaved Flyback Converter*

Fig. 5 shows the main circuit of an interleaved flyback converter consisting of two converted flyback converters, each switch is shifted 180° to achieve a double-frequency switching equation which can decrease the current ripple. Capacitor C_1 is a bulk capacitor and C_2 is the energy storage before it is transferred to the Load resistance (R_L). Primary switches, S_1 and S_2, are the main switches running PWM and D_1 and D_2 are secondary diodes used to avoid reverse diode losses [7].

TABLE III
PARAMETERS OF INTERLEAVED FLYBACK CONVERTER

Elements	**Value**
Capasitor Input, C_{in}	500 µF
Capasitor Output, C_{out}	5 µF
Resistans Output, *Rout*	640 Ω
Frekuensi @ Switching S_1,S_2	100 kHz
Duty cycle maximum, D_{max}	0.5
Winding Ratio, N	2:25
MOSFET, M_1,M_2	Infineon IPB036N12N3
Dioda, D_1,D_2	ROHM RFN5TF8S

With the lowest input voltage generated by a photovoltaic panel of 32 Vdc, to produce the output voltage of 400 Vdc required to produce 220 Vac outputs, a transformer with winding ratio of 2:25 is required. Parameter interleaved flyback converter used is shown in Table III.

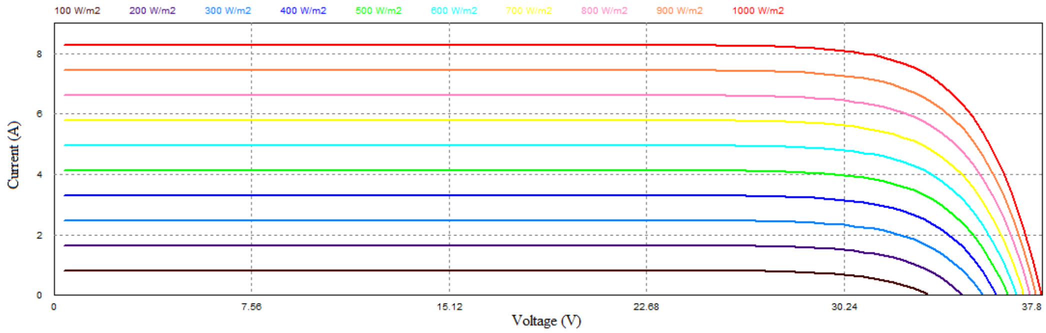


Fig. 3 I-V curve in varying insolation.

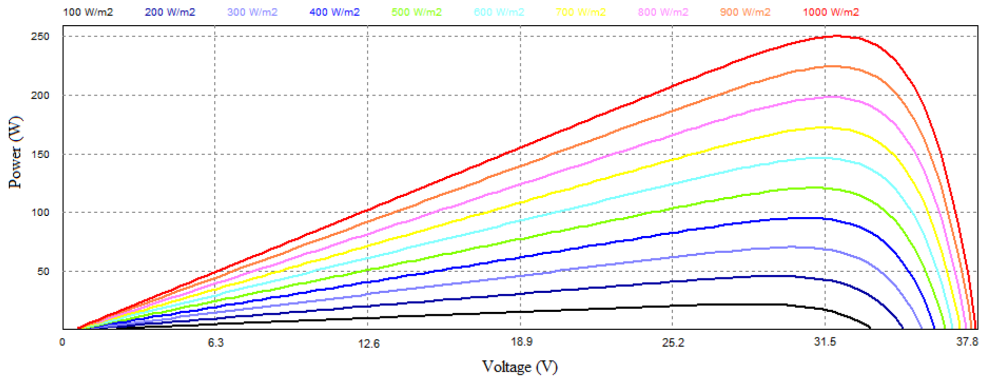


Fig. 4 P-V curve in varying insolation.

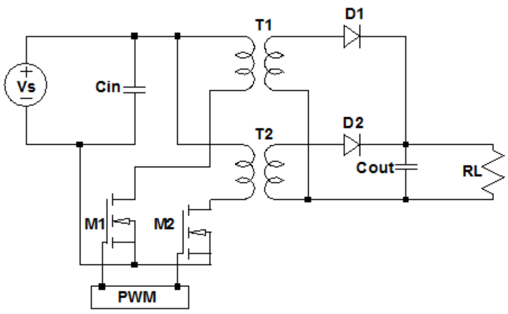


Fig. 5 Interleaved flyback circuit.

Based on Table III, the interleaved flyback simulation is connected to the solar panel, validating the current, voltages value input and output, while the system interleaved flyback 250 W is shown in the Fig. 6.

Based on the interleaved flyback circuit above, so obtained the voltage and current curves on the flyback interleaved as shown in Fig. 7. It are measured to obtain the current value, I_{in} = 7.82 A, I_{out} = 0.65 A and voltage value, V_{in} = 32 V, V_{out} = 400 V.

C. Maximum Power Point Tracking (MPPT)

MPPT is a technique used to reach the maximum power point (MPP) that can be obtained from PV. In the perturb and observe algorithm method performs sampling of voltage and current data from PV panel and uses a resistance to obtain maximum power output for each environmental condition. If the power increases with increasing voltage then the duty ratio will be changed in the same direction, otherwise, the duty ratio will be changed in the opposite direction [8]. Perturb and observe conventional algorithm can be seen in Fig. 8.

To make a modification variables of step size that can work based on changes in current received from PV panels, the problem is how to create a small step size value that can reduce the oscillation of power around the MPP and the large step size that can speed up the response tracking, where the value of step size may change automatically when solar irradiation changes occur. The algorithm for modification variable step size is shown in Fig. 9.

The first step is to set the reference current value (I_{ref}) as in (1).

$$set(I_{ref})\begin{cases} a = 2.5 \\ b = 5 \\ c = 7.5 \end{cases} \tag{1}$$

Then setting the step size *(SS)* for each change of current to be obtained, as in (2).

$$set(SS)\begin{cases} step\_1 = 0.01 \\ Step\_2 = 0.1 \\ Step\_3 = 1 \end{cases} \tag{2}$$

The working principle of the proposed modification variables step size system is first to sample the current data *I(n)* and *I(n-1)*, then calculate the value of current change *(dI)* as in (3).

$$dI = I(n) - I(n-1) \tag{3}$$

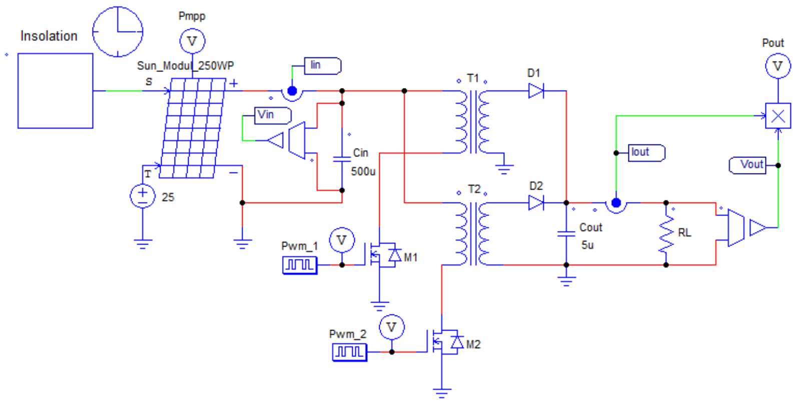


Fig. 6 Interleaved flyback 250 W system.

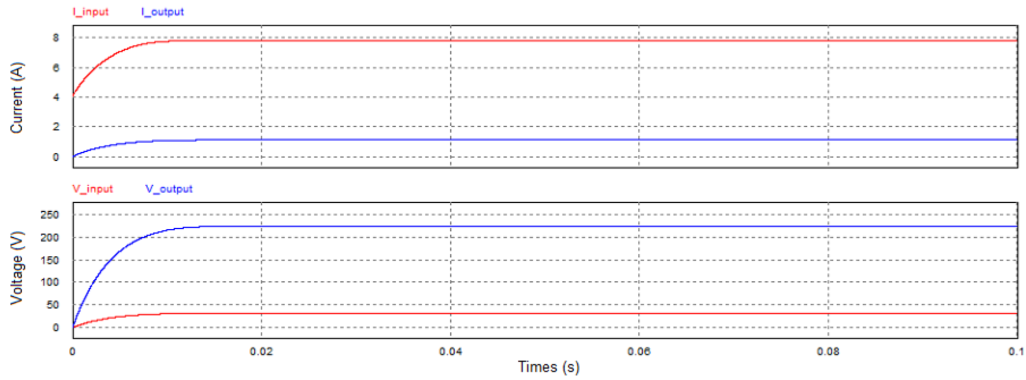


Fig. 7 Current and voltage curve on interleaved flyback.

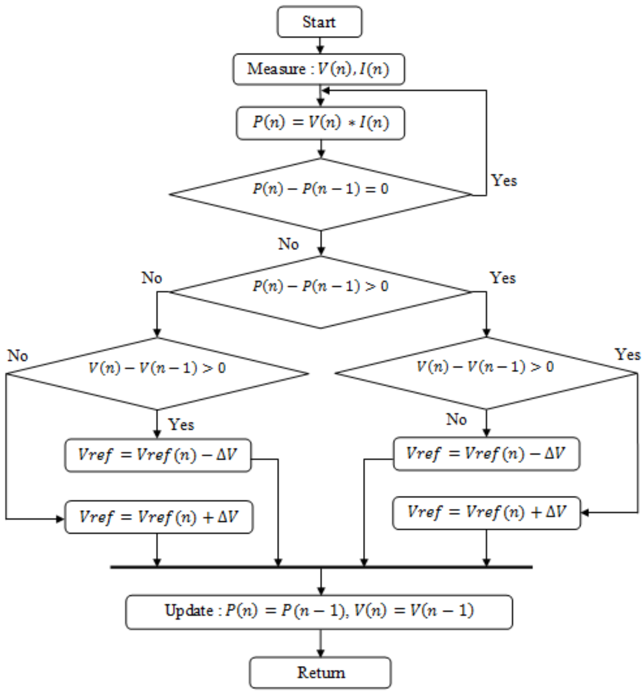


Fig. 8 Perturb and observe conventional algorithm.

When the *dI* value has been obtained, the value of the *dI* is calculated with the reference current *(I_{ref})* that is set in (1). Then do the action to determine the step size as set in (2). Equation (4), (5), and (6) are used to determine which step to use is for every change of solar irradiation. Then ΔV is updated.

$$if, dI < a, \text{going to step 1} \quad (4)$$

$$if, dI < b, \text{going to step 2} \quad (5)$$

$$if, dI < c, \text{going to step 3} \quad (6)$$

III. Result dan Discussion

To validate the concept of modification variable step size MPPT from perturb and observe algorithm made on photovoltaic system 250 W at interleaved flyback converter system on PSIM as seen in Fig. 10.

To experiment with changes in solar irradiation, the changes in solar irradiation were modeled, as seen in Fig. 11. The modeling is performed to obtain the desired distance of insolation.

The system has been made then tested on the set of control modifications variable step size. In order to make the system work automatically, we add the control circuit of the operation area selector by calculating the current change *(dI)* from the previously modeled solar irradiation changes. As for current-change *(dI)* curve of any change in solar irradiation can be seen in Fig. 12.

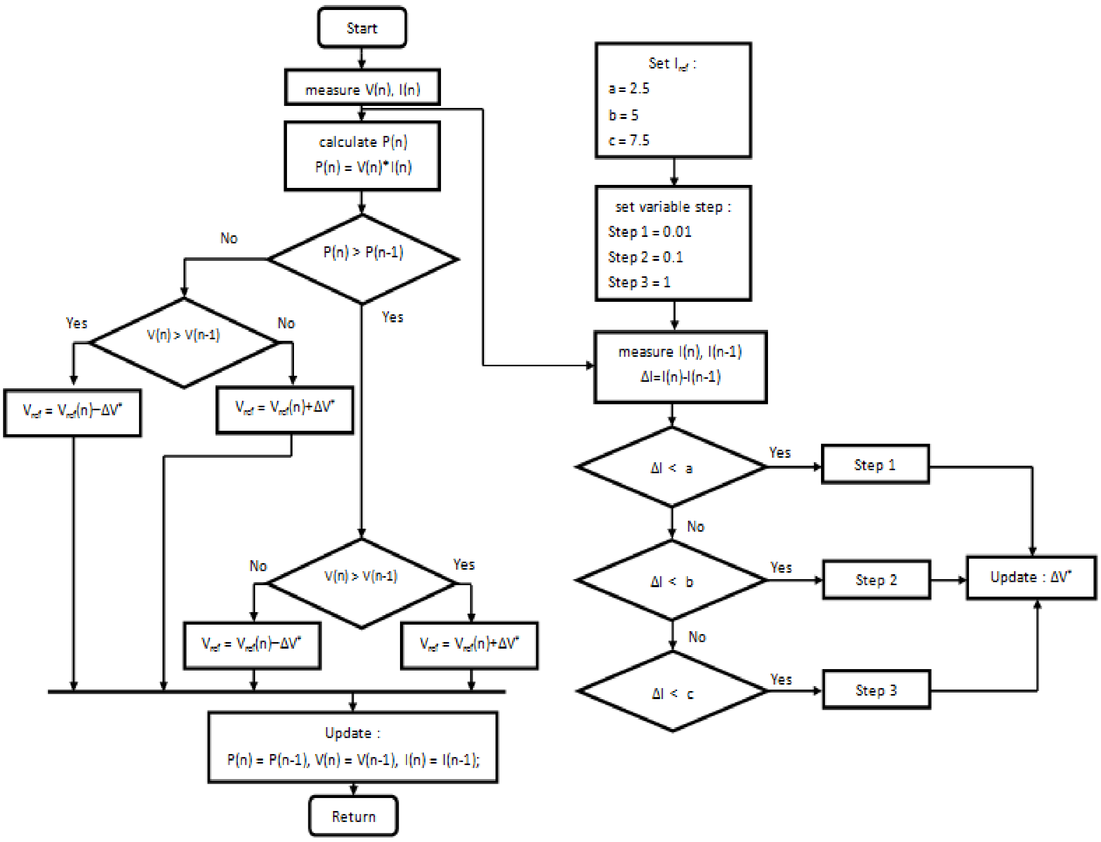


Fig. 9 Modification variable step size P&O algorithm proposed.

On the curve of the current changes *(dI)* of the previously modeled insolation to obtain the distance of the wide irradiationof the sun. I_{in} is the current *I(n)* and I_{ZOH} is the delay current representing the current *I(n-1)* to obtain the difference between the two currents *dI*. After getting the value of *dI* then done determination which step will be used.

TABLE IV
STEP CONDITION BASED ON CURRENT CHANGE

Range of solar insolation (W/m^2)	Wide of insolation (W/m^2)	Current Changes *(dI)* (A)	Step Condition		
			Step 1	Step 2	Step 3
100 – 1,000	900	6.993	Off	Off	On
1,000 – 200	800	6.165	Off	Off	On
200 – 900	700	5.337	Off	Off	On
900 – 300	600	4.508	Off	On	Off
300 – 800	500	3.681	Off	On	Off
800 – 400	400	2.853	Off	On	Off
400 – 700	300	2.028	On	Off	Off
700 – 600	200	1.214	On	Off	Off
600 – 500	100	0.514	On	Off	Off

From the curve step condition in Fig. 13, the control system can work automatically when $dI < a$, where *dI* less than 2.5 A at wide of insolation from 100-300 W/m^2, step 1 in On condition and when $dI < b$, where *dI* less than 5 A at wide of insolation from 400-600 W/m^2, step 2 in On condition and when $dI < c$, where *dI* less than 7.5 A at wide of insolation 700-900 W m^2, step 3 in On condition, as seen in Table IV.

TABLE V
RESPONSE TIME ON FIXED STEP AND VARIABLE STEP

Range of solar irradiation (W/m^2)	Response Time (ms)	
	Fixed Step	Variable Step
100 – 1,000	85 ms	64 ms
1,000 – 200	132 ms	115 ms
200 – 900	182 ms	166 ms
900 – 300	231 ms	218 ms
300 – 800	283 ms	276 ms
800 – 400	324 ms	319 ms
400 – 700	376 ms	368 ms
700 – 600	420 ms	415 ms
600 – 500	462 ms	459 ms

In testing, the tracking speed response is performed to compare which response is faster between the fixed step system and the step size variable system in the output power condition. The solar irradiation modeling is the same as in Fig. 11. The results of the tracking speed curve on the fixed step can be seen in Fig. 14(a) and the step size variables can be seen in Fig. 14(b).

From the results of tracking speed in Fig. 14, then obtained the value of time response on the fixed step and variable step from the vary of insolation that has been modeled. The results of the measurement of the tracking response can be seen in Table V. From these results show the tracking response on the step-variable is better than the fixed step.

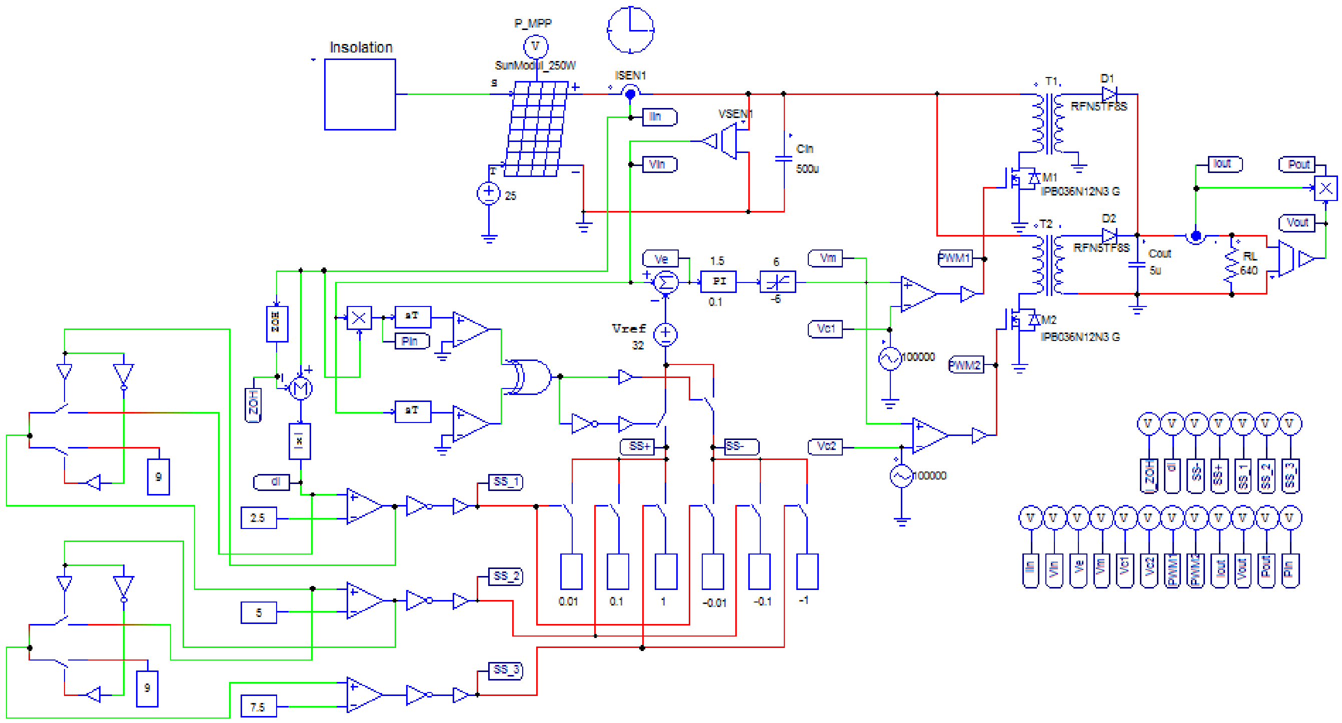


Fig. 10 PV system with modification variable step size of P&O at interleaved flyback converter 250 W.

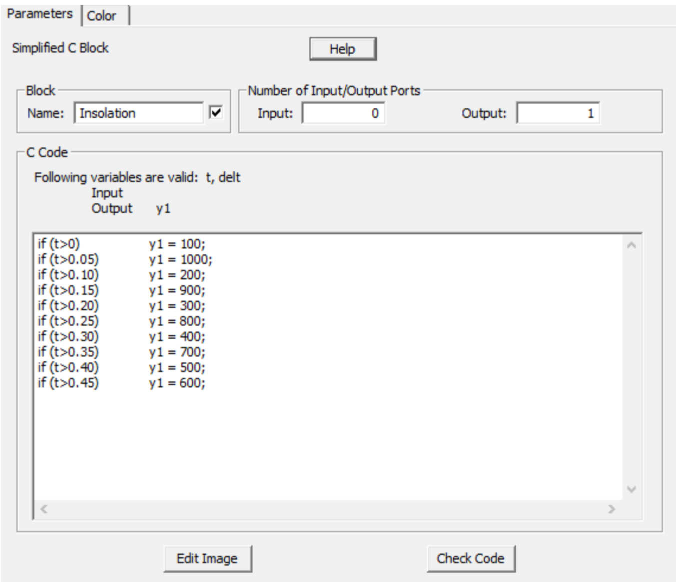


Fig. 11 Insolation model in PSIM.

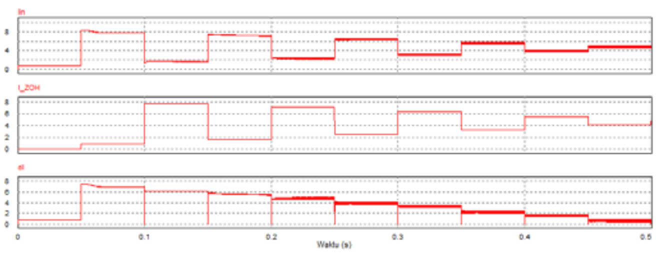


Fig. 12 Current changes *(dI)* curve in varying insolation.

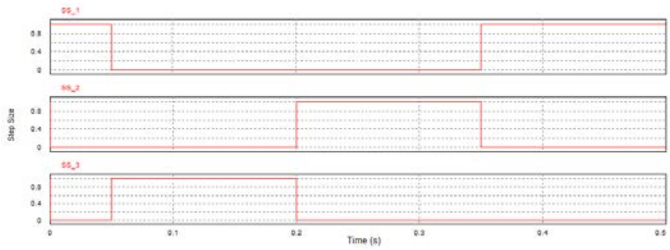
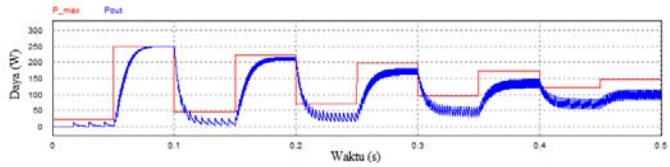
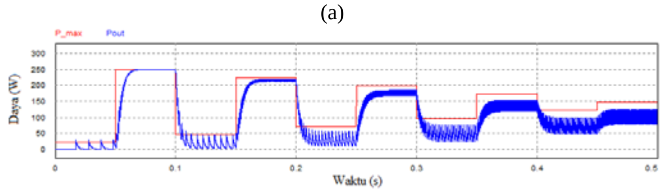


Fig. 13 Step condition on control variable step size.



(a)

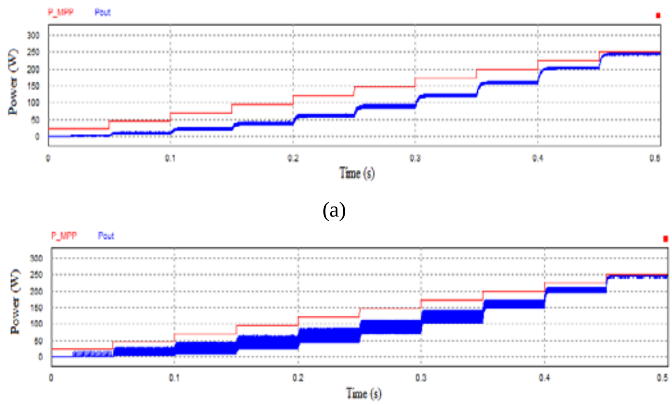


(b)

Fig. 14 Response time at varying insolation changes for: (a) Fixed step, (b) Variable step.

To test the efficiency of output power at fixed step size and step-variable the following equation is used.

$$\eta_{MPPT} = \frac{\int_0^T P_{out}(t)dt}{\int_0^T P_{MPP}(t)dt} \times 100\% \qquad (7)$$



(a)

(b)

Fig. 15 Result output power in the system: (a) Fixed step size, (b) Variable step size.

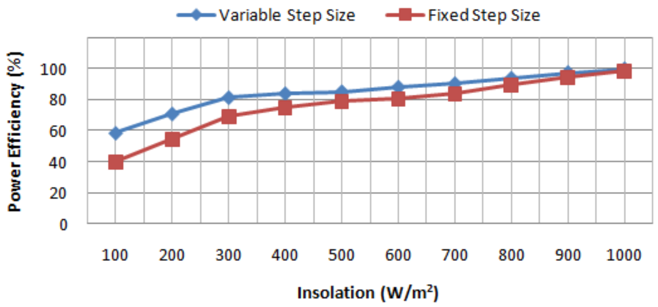


Fig. 16 Power efficiency on varying insolation.

In every change of insolation from 100-1,000 W/m^2 obtained power output curve with power at MPP condition from each system. The output power curve in fixed step size can be seen in Fig. 15(a) and variable step size can be seen in Fig. 15(b).

From the result of output power in fixed step and variable step system, power efficiency from each system can be obtained using (7). Power efficiency curve to the change of insolation obtained is shown in Fig. 16. From the results, the power efficiency obtained by the system with the step size variable shows a good efficiency when compared to the fixed step system, especially in solar irradiation below 500 W/m^2, the power efficiency can rise up to 20%.

IV. Conclusion

In this research, a system of modification variable step size MPPT of perturb and observe algorithm on photovoltaic 250 W has been made using interleaved flyback converter. By modifying variable step size MPPT of the P&O algorithm, the system is able to work automatically on changes in solar irradiance, with a calculation of the change in current *(dI)* with the reference current *(I_{ref})* so that it can determine the step size used automatically. Based on the modification variable step size MPPT of the P&O algorithm, the system can improved power efficiency compared to the P&O algorithm with fixed step size and can increase the tracking speed in every change of solar irradiation until it reaches steady state.

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