Design and development of maximum power point tracking (MPPT) for 100 watt solar panel base on buck boost converter

by Berkah Fajar T.k

Design and Development of Maximum Power Point Tracking (MPPT) for 100 Watt Solar Panel Base on Buck Boost Converter

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INTRODUCTION

One of potential renewable energy source which offers a replacement to fossil energy is solar energy. Indonesia lies on equator therefore can get the benefit of availability of solar energy all days in year. The potency of solar energy in Indonesia is around 4.8 kWh/m^2/days with monthly variance of 9%. A preliminary survey on solar intensity resource assessment in Indonesia has been conducted based on sun spot number, latitude and rain fall analysis [1]. Photovoltaic is needed to harvest the solar energy, and it has some advantages such as environment friendly and low maintenance cost. The main disadvantages of PV are it needs a high installation cost and it has a low efficiency (less than 20%) [2]. To improve its efficiency, a PV must work at maximum power point which is always change depends on sun irradiation and temperature. A change of temperature and irradiation shifts the maximum power point and reduce the PVs efficiency [3].

Solar energy can drop dramatically, so that the output power is not used optimally. Therefore, we need a system that can stabilize the output power of the solar panel. Non-linear PV characteristics cause difficulty in operating in

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obtaining maximum PV power. To get the maximum PV output power a method called Maximum Power Point Tracking (MPPT) can be used. The maximum power point tracking (MPPT) usually is implemented by a power electronic circuit which provides an interface between PV and load [4]. Some researchers were conducted to optimize PV by using some methods, for instance: Constant voltage control, Perturb & Observe, Incremental Conductance, Fuzzy Logic and Neural Network [11]. Many MPPT methods have been researched and developed, such as Pertub & Observe (P & O), incremental conductance, and Fuzzy Logic Controller [5,6,7]. Other alternative of MPPT methods are Fuzzy Control and Neural Network [12,13,14]. Fuzzy control has been used to control Boost converter in an electric car which is powered by solar energy [14]. Fuzzy control and Neural Network deteriorate from the complexity of fuzzy rules design process and also depend on learning process [12,13,14].

Control of P & O Incremental Conductance combinations can be used as MPPT control. This control has two inputs, namely changes in power and voltage of PV (ΔP-PV and ΔV-PV). The desired output is PV can drain maximum power. The accuracy of controls is strongly influenced by the membership function and the rule base created. Usually these variables are obtained by trial and error method. In this study, the buck boost converter is used as an actuator from the MPPT control on a PV generator that works stand alone.

COMPLETE BLOCK PV SYSTEM

In general, the design of the solar panel system connected to the MPPT system to the battery, the system consists of three main elements, 100 Watt Solar Panel, MPPT, Buck Boost Converter and 12 V - 100 Ah Battery. The complete system consists of 3 blocks that can affect the results which include temperature changes, solar radiance and batteries and the buck boost converter used as an actuator from the MPPT control in the Solar Module generator as shown in Fig. 1.

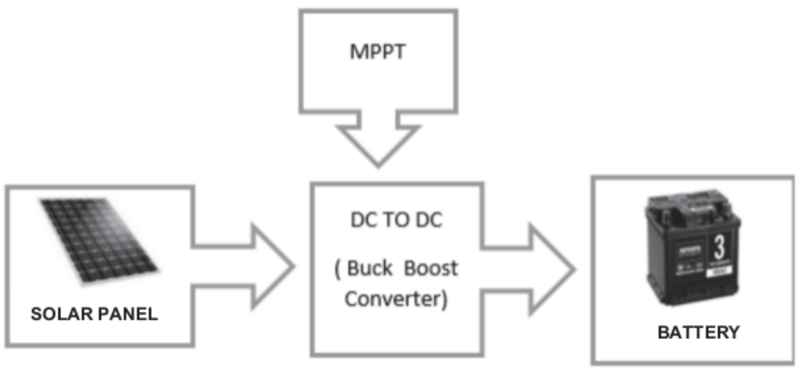

FIGURE 1. Complete block of PV systems.

When the solar module is exposed to sunlight, the solar cells will convert sunlight into direct electricity (DC. Then the voltage generated from the solar panel will be entered into the MPPT charger before entering directly into the battery.

In the main electronic controller hardware in the control charger section there is an Arduino Nano microcontroller and DC to DC Buck Boost Converter as the main particle. The voltage and current entering from the solar panel will enter the DC-DC converter before entering the battery. But voltage and current information also goes into the charger microcontroller to be calculated according to the MPPT algorithm.

SOLAR PANEL

The power output of a PV array is based on solar radiation and temperature changes. Figure 2 shows the equivalent circuit of solar panels. The power output in this model is calculated as follows in the equation 1.

$$P_{pv=}\eta_{pvg}\ A_{pvg}\ G_t \qquad (1)$$

Where η_{pvg} is PV generation efficiency, A_{pvg} is a PV generating area (m^2), and G_t is solar irradiation in the sloping module plane (W/m^2).

The mathematical model of solar panels is the short circuit current (I*sc*) of solar panels which is influenced by the function of solar radiation (S) and open circuit voltage (V*oc*) with the equation (2).

$$I_o = n_p\, I_{ph} - n_p\, I_{rs} \left[\exp\left(\frac{qV_o}{kTA_{n_s}}\right)\right] \quad (2)$$

Io is the output current of the solar panel, n_p the number of cells connected in parallel, *ns* the number of connected cells in series, k Boltzmann constant, q speed of electron displacement, T panel surface temperature, and A constant deviation of p-n junction cell characteristics. I_{rs} is a cell saturation current that changes with temperature with the equation (3).

$$I_{rs} = I_n \left[\frac{T}{T_r}\right]^3 \exp\left(\frac{qE_G}{kA}\left[\frac{1}{T_r} - \frac{1}{T}\right]\right) \quad (3)$$

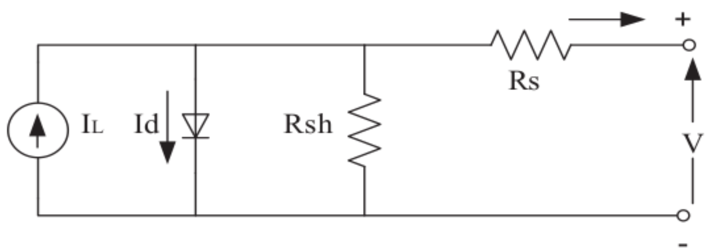

FIGURE 2. Equivalent circuit of solar panels

Photo current (I_{ph}) depends on the light / solar radiation and cell temperature shown in equation (4)

$$I_{ph} = [I_{scr} + k_i(T - T_r)]\ \frac{S}{100} \quad (4)$$

where :

I_{scr} = short circuit cell current

K_i = temperature coefficient short circuit current

S = light radiation (Watt /m^2)

In this study only one solar cell panel with maximum power parameters PMAX = 100 W, maximum voltage VMP = 17.6 V, maximum current IMP = 5,69 A, open circuit voltage VOC = 22,4 V, and short circuit current I_{scr} = 6,03 Amp. The solar panel data sheet is shown in Table 1.

TABLE 1. Specification of solar panels used

Solar cell for I = 1000W/cm² dan T = 25ºC	
Maximum Power	100 Watt
Open-circuit voltage	22,4 Volt
Short-circuit current	6,03 Ampere
Current at maximum power	5,69 Ampere
Voltage at maximum power	17,6 Volt
Number of cells	33

MAXIMUM POWER POINT TRACKING

The Maximum Power Point Tracking (MPPT) method is used to find the maximum power point (MPP). And the algorithm used is the Perturb and Observe Method algorithm or commonly known as the other Hill-Climbing algorithm.

Maximum power transfer is the goal of the whole system, namely the ability to generate maximum power. The change in voltage and MPPT detection is how the MPPT is produced. In order to have the ability to modify the voltage, MPPT increases or decreases the voltage by changing the duty cycle [8, 9]. To detect the maximum working point is done by tracking the resulting power obtained from the voltage and current sensors. In Fig. 3 shows Diagram of the MPPT block.

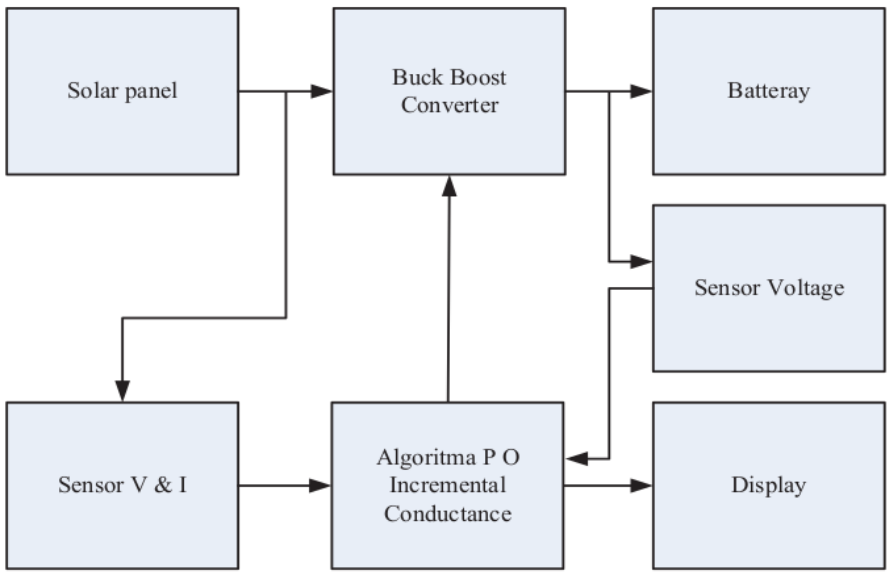

FIGURE 3. Diagram of the MPPT block

From the flow diagram Fig. 4 shows that the flow chart of the P & O technique can be seen, when there is no change in power in the solar panel, the duty-cycle ratio does not change. If there is an increase in power and voltage on the solar panel, the duty-cycle ratio will be reduced. If there is a power increase but the voltage is fixed or down, the duty-cycle ratio will be added. And if the solar panel's power and voltage drops, the duty-cycle ratio will be reduced. If the power decreases but the voltage rises, the duty-cycle ratio will be added. The change in duty-cycle in the MPPT system with the P & O technique is 0.32% [15,16].

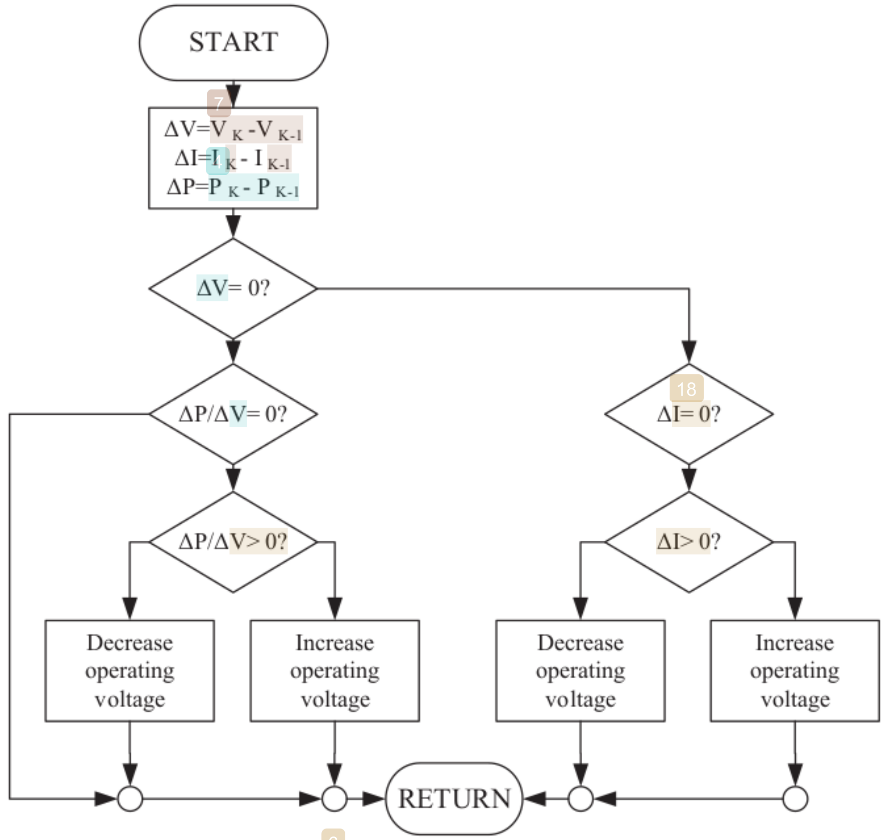

FIGURE 4. P & O Incremental conductance algorithm

BUCK BOOST CONVERTER

Buck boost type power converter or often called a step-down regulator, the average output voltage, Vout, is smaller than the input voltage, Vin.[10] The basic buck boost converter circuit and its circuit diagram are shown in Fig.5 (a) and (b), respectively. Whereas, Buck boost converter compiler components are listed in Table 2.

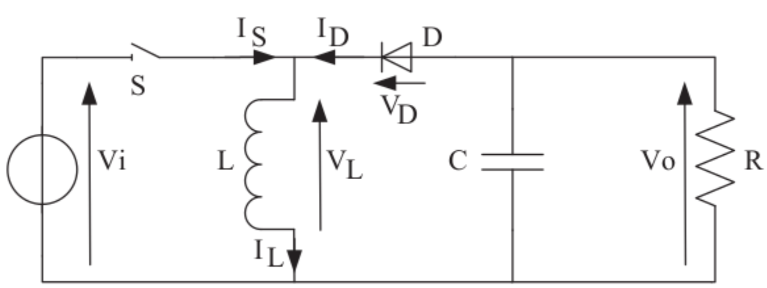

FIGURE 5. (a) Buck boost converter circuit.

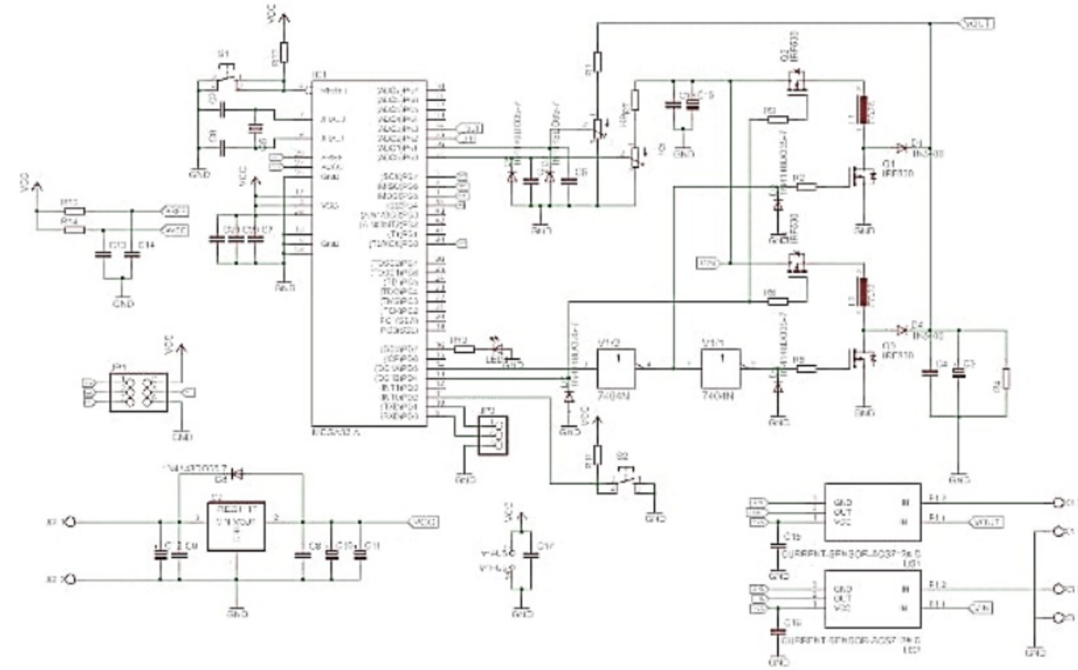

FIGURE 5. (b) Buck boost converter circuit diagram.

TABLE 2. Buck boost converter compiler components.

No	Component Buck Boost Converter	Total
1	*Atmega 32*	1
2	*Mosfet IRF 9540*	2
3	*Mosfet PN35*	2
4	*IC Lm 1117*	2
5	*Inductor 680-820 μ H*	2
6	*Capasitor 100 μ F*	8
7	*etc*	

BATTERY

The batteries used in this implementation, utilize generic batteries for the most popular types of batteries, Lithium-Ion batteries with nominal voltage of 12 V and Capacity of 100 Ah.

RESULTS AND DISCUSSION OF EXPERIMENTS

This study consists of three main processes, namely measuring the voltage and current of the solar cell, optimizing the output of solar panels using the Perturb and Observe method in MPPT to modify the voltage, increase or decrease the voltage by changing the duty cycle and charging for further testing on sunlight change with the temperature of the solar panel 42 Celcius. The MPPT test circuit battery charging solar panel is shown Fig. 6.

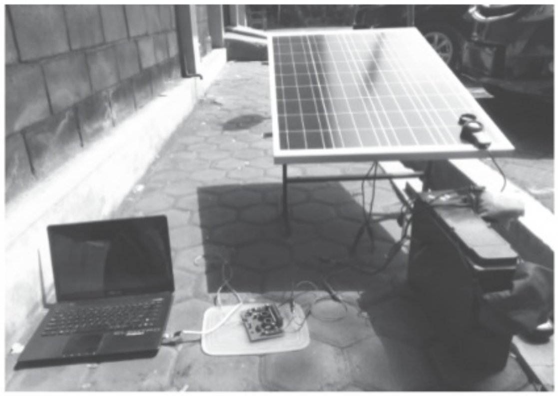

FIGURE 6. MPPT test circuit battery charging solar panel.

TABLE 3. Test results using MPPT

No	Light intensity (Lumen)	Vpanel (Volt)	V (volt)	I (amper)	P (watt)
1	62400	19,85	13,61	4,15	56,561
2	50900	19,68	13,5	3,75	50,705
3	46200	19,53	13,45	3,62	48,689
4	42500	19,53	13,44	3,37	45,292
5	37800	19,11	13,34	3,23	41,487
	Average Total	19,54	13,468	3,624	48,5468

In Table 3, 4. show the effect of changes in solar radiation on the energy system on I-V on solar panels, the greater the emission, the power produced by large solar panels, if the beam decreases, the solar power decreases and the voltage tends to remain.

TABLE 4 Testing results without using MPPT

No	Light intensity (Lumen)	Vpanel (volt)	V (volt)	I (amper)	P (watt)
1	62400	19,85	12,48	3,22	40,185
2	50900	19,68	12,4	2,89	35,836
3	46200	19,66	12,37	2,65	32,78
4	42500	19,53	12,38	2,47	30.579
5	37800	19,11	12,32	1,93	23,778
	Average Total	19,566	12,39	2,632	32,632

In **TABLE 3, 4.** also show the effect of changes in solar radiation on the energy system on I-V on PV panel, on the use of MPPT power produced by the Solar Panel is greater compared without use and there is an increase of 47,5 % in the use of MPPT.

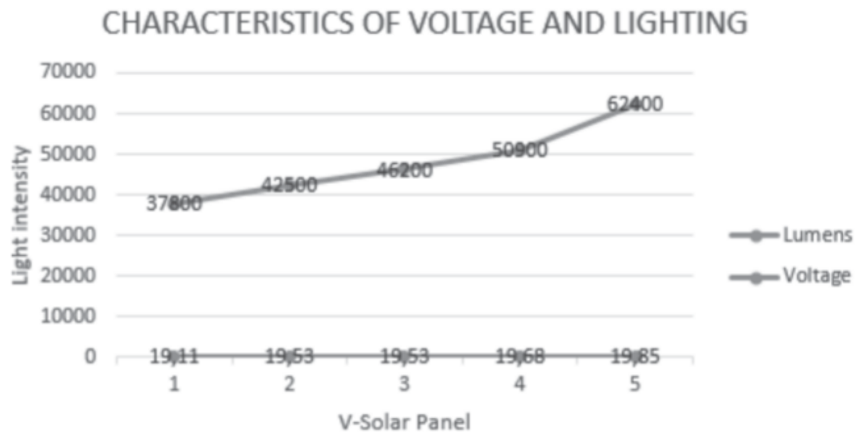

FIGURE 7. V- Lighting characteristics for solar panel

Figure 7 shows the effect of changes in solar radiation on the energy system at Lighting -V on Solar Panel.

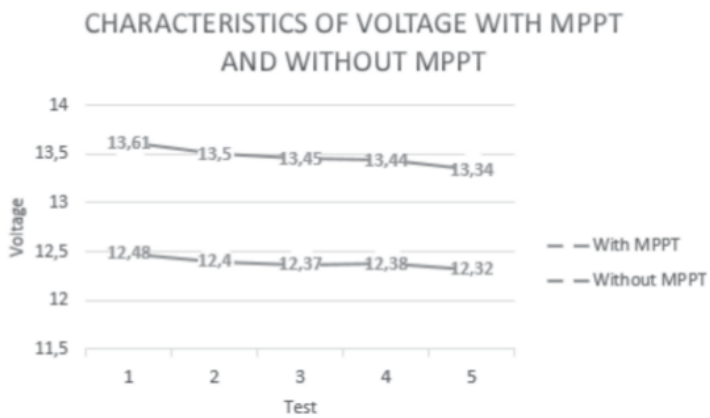

FIGURE 8. Characteristic V with MPPT and without MPPT

Figure 8 shows the effect of changes in solar radiation on the energy system at V on Solar Panel using MPPT and without using MPPT.

CONCLUSION

This research was targeted to analyze MPPT implementation on buck-boost converter by using Incremental Conductance method. The performance was compared to P&O algorithm for PV system, MPPT and Buck-Boost converter the results of testing that has been done, it can be concluded that the solar cell system uses 100 Watt solar panels and Pertub & Observe based MPPT technology can increase the maximum power produced by the PV panel. amounting to 56.56 Watts at 62400 Lumen solar intensity and PV does not use P & O-based MPPT technology resulting in low electrical power of 40.18 watts. With this method can increase average the maximum power by 47,5 % on the use of MPPT.

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