International Conference on Electrical Engineering, Informatics, and Its Education 2015

Maximum Power Point Tracking Using Perturb & Observe Method For Photovoltaic System Based On Microcontroller

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***Abstract*— Electrical energy consumption increase but the availability of fossil energy, as fuel the national plant, dwindle. Besides environmental concerns to reduce CO2 emissions as the cause of green house effect increasing as well. This led to the use of renewable energy instead of fossil fuels is increasing. Indonesia has the potential of solar energy is large enough around 4.8 kWh / m2 / day with a monthly variation of approximately 9%. Photovoltaic is used to convert solar energy into electrical energy. However, photovoltaic efficiency is only about 20% and depends on the intensity of sunlight. PV efficiency can be increased when operating at maximum power point. To be able to work at the maximum power point, it is required maximum power point tracking (MPPT), which track the maximum power point to changes in light intensity. The purpose of this research is to design methods perturb and Observe (P & O) as the maximum power point tracking in photovoltaic system that is embedded in the microcontroller. A photovoltaic system is used in charging the battery via the buck boost converter. P & O algorithm is embedded in the microcontroller that is used to adjust the duty cycle of the buck boost converter to achieve the maximum power point. Microcontroller also regulates battery charging based on battery condition. Based on test results, the method of P & O can determine the maximum power point to changes in light intensity with good performance.**

Keywords*— *MPPT; Photovoltaic; pertub&observe

I. Introduction

Until 2014, the electrification ratio in Indonesia amounted to 80.25% which shows there are still around 20% of Indonesia's people who have not had electricity. In Indonesia, power generation depends on the availability of fossil fuels that are increasingly limited. So that the development of renewable energy sources is necessary as energy diversification efforts. Based on the geographical location of Indonesia, solar energy has great potential to be developed because the sun shines all year round. To utilize of the solar energy, photovoltaic is needed to convert solar energy into electrical energy. . Photovoltaic utilization is increasing every year in proportion to the decrease in the price of photovoltaic. The advantages of using photovoltaic is an environmentally friendly, low maintenance costs and availability is not limited. However, the use of photovoltaics are very dependent on the intensity of sunlight and ambient temperature and has a low efficiency so that photovoltaic should work at the maximum power point to improve the efficiency. To be able to work at the maximum power point, it's required maximum power point tracking (MPPT), which will seek the maximum power point to changes in light intensity.

MPPT is an electronic system that operates the PV to generate maximum power [1] using a dc-dc converter. Dc-dc converters connect the PV system to load. The use of dc-dc converter is simpler than the mechanical tracking because it does not require the measurement of light intensity and temperature directly [2]. MPPT methods can be classified into three categories: methods of online, offline and hybrid. Online method consists of a method of P & O, incremental conductance and extremum seeking control method. Compared with other MPPT method, the method P & O has a high efficiency with fast convergent speed [3]. Compared to the incremental conductance method, P & O method requires a faster time to reach the maximum power point [4]. MPPT with dc-dc converter will determine the maximum power point by adjusting the duty cycle dc-dc converter. Some converter topologies that can be used is the buck converter, boost converter, buck-boost converter. Dc dc converter topology compared to the others, buck boost converter is suitable for applications in photovoltaic [5] and has a high efficiency for applications on MPPT of photovoltaic[6].

P & O method, constant voltage IC and easy to implement on embedded systems using a microcontroller. P & O method causes oscillation at MPP value whose magnitude depends on the size of the step duty, while the constant voltage method has fast tracking capability but on the changing weather conditions its performance is not so good. Compared both methods, the IC shows a more stable performance in different weather conditions and reduces oscillations in local MPP[7]. This paper will implement perturb and Observe methods as MPPT by adjusting the duty cycle buck boost converter using a microcontroller. MPPT algorithm embedded in the microcontroller connected to buck boost converter.

II. Buck Boost Converter Operation

DC-DC converter is a circuit that converts a DC input voltage into a different DC output voltage with a lower or higher magnitude. Some of the basic topology dc-dc converter circuits are buck converter, boost converter and buck boost converter. Buck-boost mode as one of the switching regulator generates output voltage that is smaller or larger than the input voltage. Figure 1 shows a buck-boost circuits in general.

The working principle of this circuit is divided into two modes. During the first mode, the condition of the switch is ON and the diode Dm gets a reverse bias so that the input current to flow through the inductor L and switches, as shown in Figure 2. This causes the charging current in the inductor so that the inductor current (IL) rise. During the second mode, the condition of switch is OFF so diode Dm gets forward biased, as shown in Figure 3. This causes a current to flow through the L, C, Dm and load. The energy stored in the inductor experienced discharging. Current flows from the inductor L, forwarded to C, Dm and to the load. The energy stored in the inductor L is transferred to the load. In this mode, the inductor current will be reduced until the condition of the switch ON in the next cycle.

Buck-boost converter generates an inverted output voltage without requiring a transformer. The regulator also has high efficiency. If the duty cycle of the PWM buck boost converter, as the trigger switch, more than 50%, the output voltage will be higher than the input voltage. And if the PWM duty cycle is less than 50%, the output voltage will be lower than the input voltage.

The relationship between the output voltage (Vo), the input voltage (Vin) and the duty cycle (D) can be expressed by the equation

$$Vo = \frac{D}{(1-D)} Vin \tag{1}$$

where

$$D = \frac{t_{on}}{T} \text{ , } 0 < D < 1. \tag{2}$$

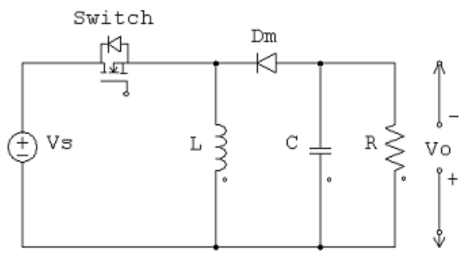

Fig. 1. Circuit of Buck-Boost Converter

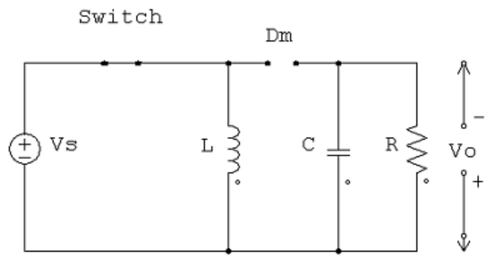

Fig. 2. Buck-Boost Converter With Switch Off

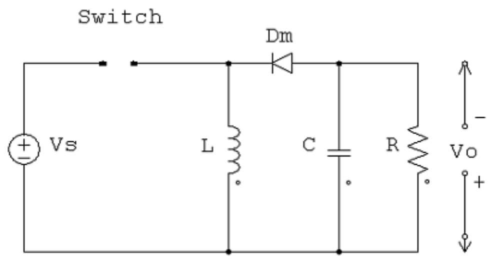

Fig. 3. Buck-Boost Converter With Switch On

In this study, buck boost converter will be operated in the continuous current mode (CCM) so that the value of inductance (L) and capacitance (C) the minimum that can be used can be calculated using the equation

$$L_{min} = \frac{(1-D)^2 R}{2f} \tag{3}$$

$$C_{min} = \frac{D}{\frac{\Delta v_0}{v_0} Rf} \tag{4}$$

Where R is resistance, f is switching frequency, and v0 is output voltage.

III. Perturb & Observe Method

P & O method is widely used because it is easily implemented but if the PV power increase will occur disturbances and if it has reached the peak power, the power will go down and the next will be even greater disturbance [8]. Chin et al [9] applied the method P & O in the buck-boost converter to increase or decrease the PWM duty cycle. If power is now greater than ever before, the duty cycle is increased until the MPP is found. This method make control through voltage adjustment with a small array on the measurement of power, if power increases, the adjustment voltage proportional to the increase in power. Perturb and Observe method in the MPPT algorithm uses the power curve to the voltage to be able to search the maximum power point of photovoltaic. Figure 4 shows the curve of the determination of maximum power with P & O method.

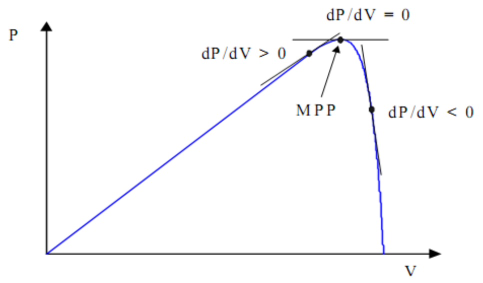

Fig. 4. Curve of Maximum Point Tracking

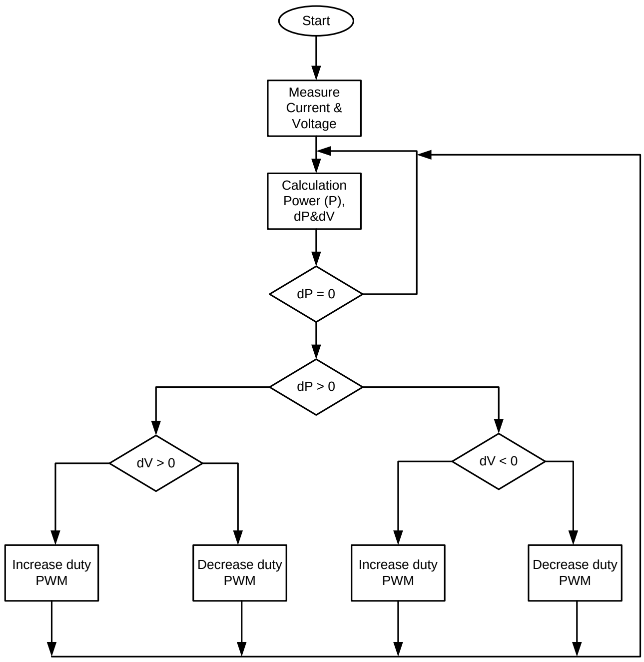

Fig. 5. Flowchart of Perturb and Obseve Method

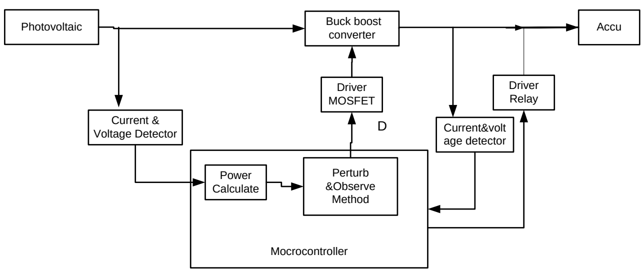

Fig. 6. Diagram Block of MPPT For Photovoltaic

P & O algorithm works by comparing the current power and the previous power . to determined the power used, it is necessary detector of current and voltage. Duty cycle of Converter will be changed based on the comparison power value to get the MPPT point. Flowchart of Perturb and observe algorithm is shown in Figure 5.

Based on P & O algorithm, the value of maximum power point is reached if dP / dV = 0. If dP / dV is negative then MPPT on the right MPP then the voltage of buck boost converter must be reduced. In this condition, the converter will work on buck mode. While if dP / dV is positive then the MPPT is located on the left MPP so that the voltage should be raised and converter is worked on boost mode [8]. dP and dV values can be determined by the equation

$$dP = P(n) - P(n-1) \quad (5)$$

$$dV = V(n) - V(n-1) \quad (6)$$

where P (n) is the current power, P (n-1) is the previous power, V (n) is the current voltage and V (n-1) is the previous voltage.

IV. MATERIAL AND METHOD

MPPT system with buck boost converters using perturb & observe method uses a microcontroller as the central controller with the overall system diagram block as shown in Figure 6. Panel PV as a source of electrical energy will charge the battery as the load of the system through the buck boost converter. Current and voltage detector is used to detect current and voltage output of PV panels and buck boost converter output that enters to the load. Microcontroller contain the algorithm of perturb and Observe method and control electronic system overall. Current and output voltage PV detected will be input to the microcontroller and will be calculated power output of PV panels.

Based on power calculations will be processed by the P & O algorithm to produces changes in duty cycle (D) for the buck boost converter. The microcontroller will generate PWM pulses with a duty cycle that corresponds to the output MPPT. Mosfet driver serves to connect the output voltage microcontroller with voltage MOSFET. This microcontroller also set the battery charging through current and voltage of battery input that detected by the detector. If the battery is fully charged, the microcontroller will activate a relay driver to break the link between the battery and the converter so the battery is not overload and use the battery a longer lifespan. The power supply of the microcontroller comes from battery which has been regulated by the voltage regulator circuit to generate a voltage of 5V in accordance with the needs of the microcontroller.

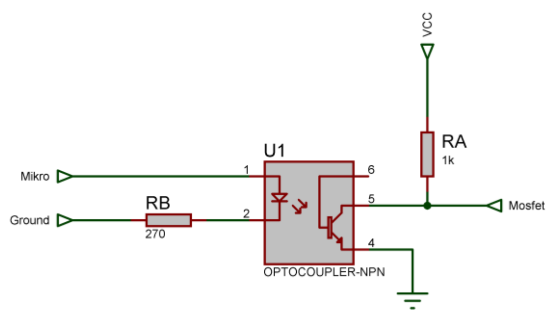

Fig. 7. MOSFET Driver Circuit

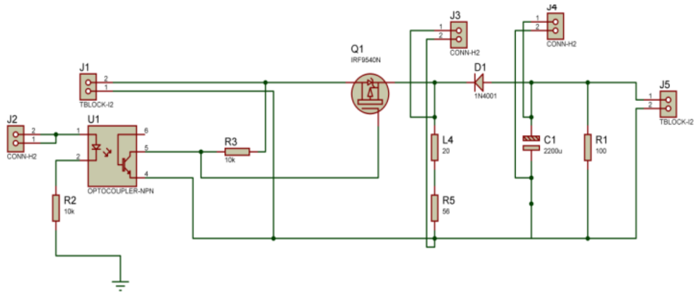

Fig. 8. Circuit of Converter Buck Boost

Figure 7 shows the MOSFET driver circuit which functions to as an interface between the microcontroller and MOSFET buck boost converter. MOSFET driver circuit using optocoupler where the input is connected to the microcontroller and output circuit is connected to the converter buck boost.

The use of the optocoupler as a driver gives the advantage the separation between power and control, in case of short circuit will not damage the microcontroller. To activate the P channel MOSFET should be given a low pulse of the output driver circuit. To be able to generate a low pulse, the microcontroller must be able to generate a logic high for the optocoupler. Figure 8 shows the buck boost converter circuits.

Inductor and capacitor value in buck boost converter can be determined with equation:

$$L = \left(\frac{1}{f}\right)(V_{out} + V_F)\left(\frac{V_{in\_min}}{V_{out}+V_F+V_{in\_min}}\right)\frac{1}{\Delta I_L} \quad (5)$$

Where f is the frequency switching of 20KHz, Vout is output voltage of converter, Vf is forward voltage of diode, Vin_min is the minimum input voltage of converter. Components that used in buck boost converter are Mosfet P-Channel IRF9540, inductor 2 mH, Capacitor 220 µF, diode MUR1560.

V. Result and Discussion

Microcontroller have been produced PWM pulse with duty cycle change based on P&O method. Mikrokontroler telah dapat menghasilkan pulsa PWM dengan perubahan duty cycle berdasarkan algoritma P&O. Figure 9 shows result of PWM output voltage from microcontroller in frequency 40KHz and Duty cycle 10% and 60%.

To control the battery charging process, it is needed the buck-boost converter to keep the voltage to be able to fill the battery. At the time of the PV output voltage is less than the required voltage of battery, then use the boost mode. But when the PV output voltage is greater than the required voltage of battery, then use a buck mode. The test results buck boost converter is shown in Table 1.

TABLE I. Measurement Result For Buck Boost Converter

No	Vin	Duty cycle (%)	Vout	Mode
1	12	5	0.61	Buck
2	12	10	1.32	Buck
3	12	15	2.1	Buck
4	12	20	2.89	Buck
5	12	25	3.96	Buck
6	12	30	5.12	Buck
8	12	35	6.42	Buck
9	12	40	7.95	Buck
10	12	45	9.75	Buck
12	12	50	12.10	Boost
13	12	55	14.58	Boost
14	12	60	17.89	Boost
15	12	65	22.13	Boost
16	12	70	27.79	Boost

a. Duty cycle of 10%

b. Duty cycle of 60%

Fig. 9. PWM Output Voltage From Microcontroller

Based on test results buck boost converter, an input voltage of 12V from digital power supply with resistive load (R) 5W 1KΩ. At the moment the range of 5% duty cycle (buck mode) produced voltage of 0.61V. At the time of the trial with a duty cycle of 50% (boost mode) produced voltage of 12.10V.

Figure 10 shows the relationship between the output voltage of the photovoltaic to output voltage of buck boost converter. Changes in light intensity will cause a change in the photovoltaic voltage. However, the use of P & O method can maintain the buck boost converter output voltage by adjusting the duty cycle converter. Testing implementation P & O methods carried out by charging the battery and compared with no use of P&O method. Tests without using P & O carried out by directly connecting between photovoltaic and battery. Table 2 shows a comparison between charging batteries with P & O and without P & O.

The battery charging use perturb & Observe method that utilizing the output voltage of the photovoltaic. Duty cycle setting is done in order to maximize battery charge. After testing the battery charging using perturb & Observe method is obtained that the input voltage of the photovoltaic with varying light intensity and initial voltage of 9V battery, after charging the battery voltage becomes 12V and need time 1.45 hours. Based on data from the battery charging, the charging time using the P & O faster.

VI. Conclusion

Implementation of perturb and observe method for maximum power point tracking in photovoltaic system have presented. Use P&O method may track the maximum power point to changes in light intensity. Photovoltaic utilization for charging the batteries using the P&O method, compared without P&O method, can accelerate the charging time.

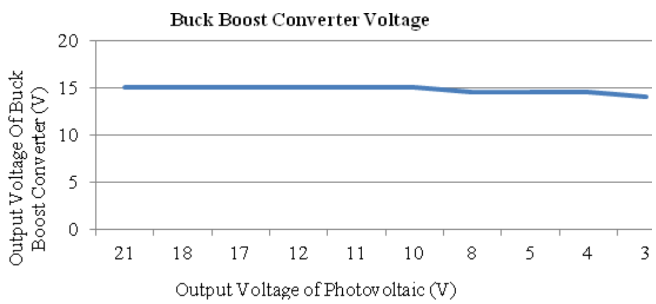

Fig. 10. Buck Boost Converter Voltage To Photovoltaic Output Voltage

TABLE II. MEASUREMENT RESULT OF BATTERY CHARGING

No	Condition	Initial Voltage of Baterry (V)	Final Voltage of Battery (V)	Charging Time (Hours)
1	Without P&O	9	12	2
2	With P&O	9	12	1.45

Acknowledgment

The authors would like to thank you to the Ministry of Research, Technology and Higher Education and State Polytechnic of Malang which sponsored this research by using National Research Competition 2015 funding scheme.

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