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The Implementation of MPPT Incremental Conductance Method with Boost Converter on PV System

Dorothy Patricia Monique[1, a)], Yehezkiel Krisma[1, b)], Petrus Setyo Prabowo[1, c)], and Bernadeta Wuri Harini[1, d)]

[1] *Sanata Dharma University, Paingan Maguwoharjo Sleman, Indonesia*

[a)] othyothy123@gmail.com
[b)] kielyehez552@gmail.com
[c)] petrus_set@usd.ac.id
[d)] Corresponding author: wuribernard@usd.ac.id

Abstract. The development of renewable energy has been rapidly growing since renewable resources have become a crucial necessity to fulfill electricity needs. Solar energy is constantly flowing away from the sun and will soon become one of the main energy resources that people depend on. Therefore, a highly efficient PV system is needed to get the maximum power of a panel could absorb. This paper presents an implementation of the Maximum Power Point Tracking (MPPT) Incremental Conductance method on PV systems using a DC-DC Boost Converter. This algorithm controls the system by changing the duty cycle using the ATmega328 microcontroller on Arduino UNO. INA219 sensor is used to read the output of the converter, which is used as input for the algorithm. A motor DC will be used to drive the panel vertically (Single-Axis), therefore the panel will get the best intensity from the sun. The results of the study prove that solar panel with the MPPT Incremental Conductance method and vertical tracking system produces 45.52W of power with 91.01% efficiencies.

INTRODUCTION

The current development has rapidly forced technological advances in many areas of life towards more effective and efficient technologies to facilitate human work, which caused electricity consumption in the whole world from time-to-time increases, both industrial and household electricity. The urge to improve the use of alternative energy is required due to the identified factors, such as the scarcity of fossil energy resources and the growing public understanding of the harmful effects of using natural gas on the environment [1]. The use of alternative energy is the only solution to continue using electricity, even when oil and gas run out. Sunlight energy may be used as an alternative electrical source of energy. Aside from the endless energy of sunshine, this electricity supply does not pollute the environment [2]. Solar panel uses a solar cell to transform solar radiation into electricity [3]. PV energy production has shown remarkable potential for satisfying energy demand.

A passive solar tracker is a solar panel system that is pointed vertically toward the sky. The vast majority of passive solar trackers are manually controlled [3]. An active solar tracker, on the other hand, is a solar tracker with a mechanism that allows solar panels to simply shift from one side to the other when the sun moves, it is a solar tracking device that operates automatically and is based on microcontrollers, computer-controlled data, and time [4,5]. The solar panel remains straight despite the sun moving from east to west [6]. A solar panel tracking system is a technique

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to increase the production of electricity while lowering the costs of energy production. A solar tracker is a method for improving the efficiency of photovoltaic panels [7].

There is no guarantee that PV energy will be provided consistently because it is entirely dependent on sun-oriented irradiance and the temperature of the PV modules, cell area, and load [8]. When the sun position is adjusted to the PV panel, power generation increases as well [9]. For the PV system to operate efficiently under climatic circumstances, a suitable technique to attain maximum output is necessary, which is what the Maximum Power Point Tracking method is utilized for. A photovoltaic module with a solar tracking system has the potential to raise the conversion system's efficiency from 20% to 50% [10]. Research of comparison various PV systems using the MPPT method has shown a result that the conventional algorithm used like P&O and IC is simple compared to the other algorithm since their circuit of implementation is not complex. However, they are also sluggish to react, less precise, and subject to oscillations about the MPP in a variety of atmospheric circumstances [8]. A solar tracking system used by itself on a solar panel still lacks in power efficiency and the MPPT method used is to add more power efficiency. In order to that, this research uses the MPPT method based on the Incremental Conductance Algorithm and a solar tracking system to maintain the greatest optimum output power the panel can provide and monitor how great the power efficiency is compared to the one without the MPPT system.

EXPERIMENTAL METHOD

Solar cells transform light energy into electrical energy by a process called photoelectric, which converts the sunlight when it hits the surface of the solar cell. The insolation or heat received by the panel affects the electric current that the solar cell can produce, while changes in the light on the panel will affect the voltage generated by the solar cell. Solar Panel used for this research has specifications that are shown in **TABLE 1**.

TABLE 1. Solar panel specification.

Specification	Where
Rated Maximum Power (Pm)	50W
Voltage at Pmax (Vmp)	18V
Current at Pmax (Imp)	2,78A
Open-Circuit Voltage (Voc)	22,4V
Short-Circuit Current (Isc)	3,24A

MPPT method optimizes the performance of a solar cell by observing the maximum output of the solar cell [11]. The incremental conductance algorithm looks for the maximum power point based on the comparison between the increase and the instantaneous conductance of PV. This method works by measuring changes in current and voltage on the panel through sensors to be able to predict the effect of changes in photovoltaic voltage (Vpv) as **FIGURE 1**.

Based on the equation and graph in figure 1 it is shown that the incremental conductance is represented on the left, the instantaneous conductance is represented on the right, and the gradient value of the curve is equal to zero at the maximum point of the P-V curve [12]. So from the graph, we get:

$$\frac{dP}{dV} = 0 \tag{1}$$

$$\frac{d(V.I)}{dV} = 0 \tag{2}$$

$$\frac{(V.dI + dV.I)}{dV} 0 \tag{3}$$

$$V\frac{dI}{dV} + I = 0 \tag{4}$$

$$V\frac{dI}{dV} = -I \tag{5}$$

$$\frac{dI}{dV} = -\frac{I}{V} \tag{6}$$

Left side of the MPP, $$\frac{dI}{dV} > -\frac{I_{pv}}{V_{pv}} \quad (7)$$

Right side of the MPP, $$\frac{dI}{dV} < -\frac{I_{pv}}{V_{pv}} \quad (8)$$

The input for this algorithm is the value of voltage V(t) and current I(t) from sensor INA219. This algorithm monitors the voltage changes and current changes from samplings. dV = V(t) – V(t-1) and dI = I(t) – I(t-1). It can be seen in **FIGURE 2**.

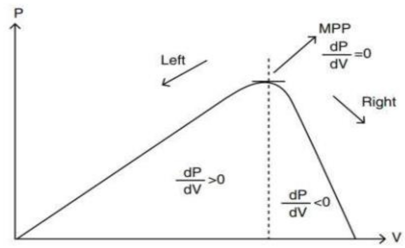

FIGURE 1. Power vs voltage curve for incremental conductance [11].

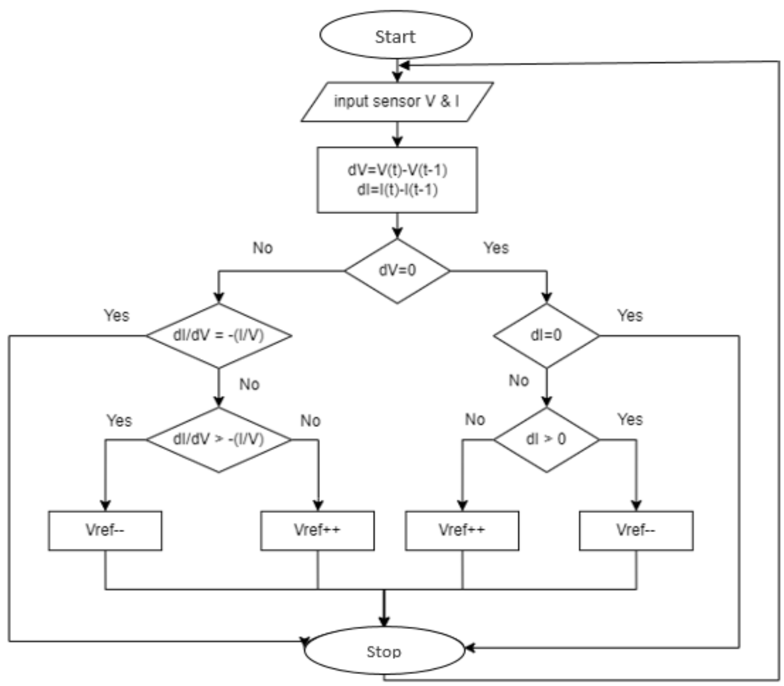

FIGURE 2. Flowchart MPPT IC.

There are two parts of hardware design, the design of a Single-Axis PV system and the design of a Boost Converter. The framework for a single-axis PV system was designed for the panel to move vertically. The PV panel is moving in the direction of the incident sunlight together with the sensor route. It is put at a specified spot in the solar tracker mechanism to ensure proper movement of the tracker. The combination of the MPPT IC system and the Single-Axis PV system is used for the maximum power the panel could produce.

Because a boost converter may provide an output voltage larger than the input voltage, it is also known as a step-up DC-DC converter. The output voltage is set based on the duty cycle of the converter. This converter's input voltage, output voltage, and duty cycle are related as follows [13]:

$$V_o = \frac{1}{1-D} V_i \quad (9)$$

Where:

V_o = Output voltage
V_i = Input voltage
D = Duty cycle

Find the component critical value of the inductor and capacitor so the converter can maintain its work in the Continuous Conduction Mode (CCM). The specification of the Boost Converter is shown in **TABLE 2** and the design of the Boost Converter is shown in **FIGURE 3**. The critical value of the inductor and capacitor in the boost converter can be determined using the following equation [14]:

$$L_C = \frac{D(1-D)^2 R}{2f} \quad (10)$$

$$C_C = \frac{D}{R(\frac{\Delta Vo}{Vo})f} \quad (11)$$

Where:

L_C = Crisis Inductor
C_C = Crisis Capacitor
f = Sampling frequency
R = Load
ΔVo = Voltage ripple

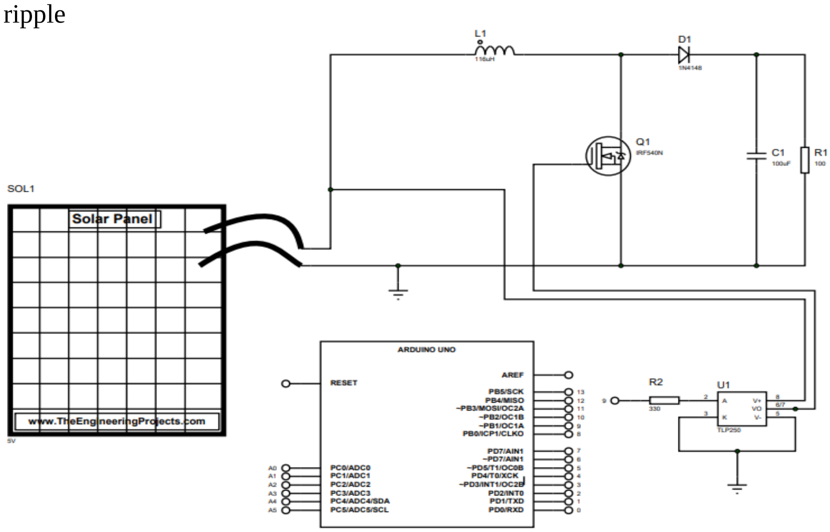

FIGURE 3. Design of Boost Converter Circuit with gate driver, microcontroller, and solar panel.

By the specification in **TABLE 2** the converter was simulated first and has shown an accurate range in the result, therefore boost converter design is implemented. The boost converter consists of an inductor, capacitor, MOSFET, driver MOSFET, diode, and resistor. Several experiments were done on the boost converter to see if it works with normal and stable inputs such as power supply and adaptor.

TABLE 2. Specification of boost converter.

Parameter	Value
Output Voltage	24V
Inductor	116uH
Capacitor	100uF/160V
Load	100Ω
Sampling Frequency	31,25kHz

EXPERIMENTAL RESULTS AND ANALYSIS

This experiment is to prove that the system made in this research is applicable to work based on the MPPT IC theory. The experiment was done with three different loads using an adaptor 10V to see the effect on the outputs based on the loads used in the system. The three loads used are 82 Ω, 110 Ω, and 220Ω. The power difference will be seen as the effect of the different loads. Based on **FIGURE 4**, it is shown that the greater the load, the lesser the output power. On the other hand, the smaller the load, the bigger the output power. Based on the graph as well, it is shown that the smaller load has stable output because of the bare oscillation, the greater load produces bigger oscillation which means the output is less stable. Besides the difference in output power caused by the various loads, this experiment proves that the MPPT IC system works on the boost converter designed because it could maintain the output power in a stable range.

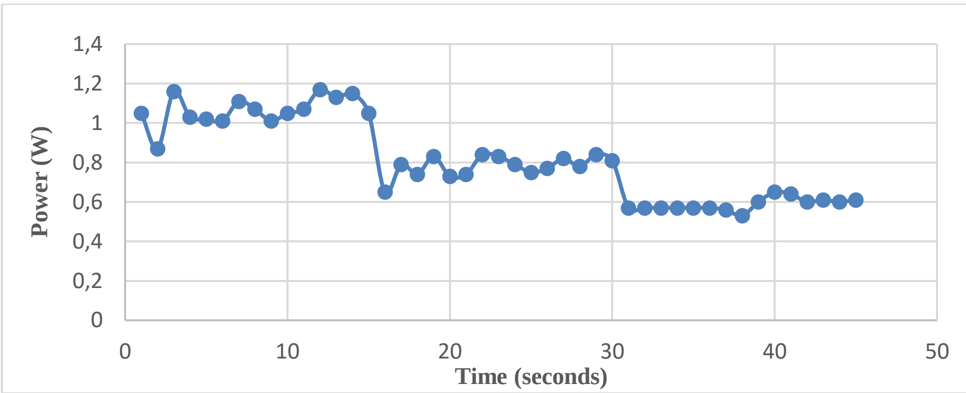

FIGURE 4. Output power experiment MPPT IC system using boost converter in three different loads.

Experiment with running the solar panel using a single-axis system using a DC motor, LDR, and Arduino Uno Atmega328 microcontroller. A total of 4 LDRs which are divided into 2 pairs are used in this study as a reference so the panel will move to the brightest direction. The microcontroller reads the difference in resistance on the LDR with the maximum difference value being 20. When all LDR values are in the same range, the panel will not move. The DC motor used voltage from the accumulator and is supported by the L298n motor driver in driving the DC motor. Panels that can move accurately towards the direction of the sun make the panel absorb more current because the heat will be absorbed greater if the panel directly faces the sun. This experiment was taken in 25 minutes and as seen in **FIGURE 5** there are differences in the output power captured because of the climatic condition such as moving clouds which affect the solar irradiance. The output power of this system is in a range between 9W to 44W.

Based on **FIGURE 6**, it is shown that the static panel system provides the lowest output power, with the average power produced being 9.27W. Single-axis PV system provides bigger output power than the static panel, with the average power produced being 31.98W. The MPPT IC with a single-axis PV system produced the biggest power from this research, which is 45.52W. Based on the data above, efficiency power could be found in **TABLE 3**. The efficiency value is achieved by comparing the optimum value of the panel with the average output power PV systems. The power efficiency value of each system is different based on the average power of each system being tested. The power efficiency of the static panel is 18.54% which is the lowest efficiency compared to the other PV system in this research. Single-axis tracking PV system provides 63.96% power efficiency, less than the MPPT IC with single-axis tracking able to produce, which is 91.01%. The average output power of the three tested systems shows that the MPPT Incremental conductance and single-axis tracking solar panel system efficiency is the system with the greatest efficiency.

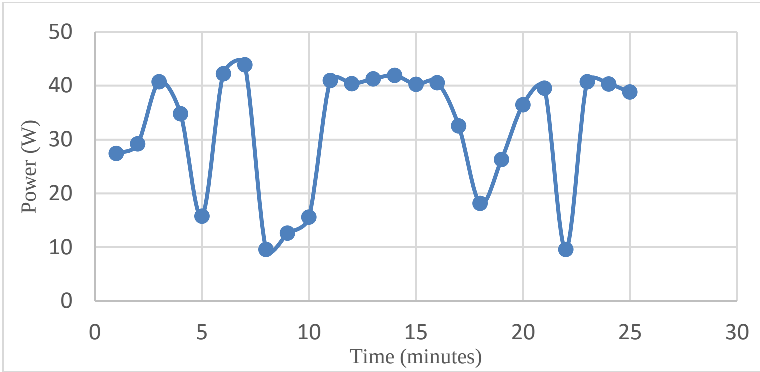

FIGURE 5. Output power experiment single-axis pv system.

TABLE 3. Efficiency PV systems.

PV system	Average Power (W)	Efficiency (%)
Static	9.27	18.54
Single-Axis tracking	31.98	63.96
MPPT IC with Single-Axis tracking	45.52	91.01

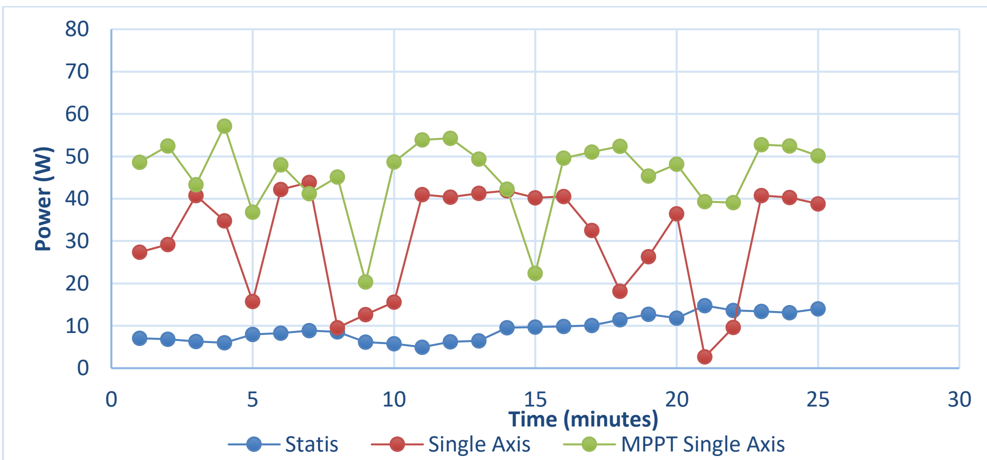

FIGURE 6. The output power of three different PV systems.

CONCLUSION

Based on the Results of this research, the Boost converter design is applicable for using the MPPT method on a PV system. Static panel with 50W optimum power produced an average power of 9.27W with a power efficiency of 18.54%. Solar panels using a single-axis tracking system produced 31.98 average power with 63.96 efficiencies. The MPPT IC with a single-axis tracking PV system produced the greatest efficiency as big as 91.01% by 45.52W of average power.

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