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Maximum Power Point Tracker Based on Perturb and Observe Algorithm in the Dual Axis Solar Panel Tracking

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Abstract:

Digitalization era is now growing very rapidly encouraging individuals from each human being to try hard to find a variety of equipment that can support human life so that almost some of the available equipment requires an electrical energy supply. The power sources utilized by existing power plants in Indonesia mostly come from fossils that are already threatened with availability and cause greenhouse effects. Such utilization can threaten the sustainability of human life and the environment. Then renewable energy is needed that is able to replace fossil energy. Renewable energy that can be used as a power plant include solar, wind, water and so on. Solar energy is the right form of energy source to be developed, because it is a high capacity energy source, continuous, not pollute and can be utilized for free. But solar panels can only convert energy from sun into electrical energy about 14% of the total energy obtained from the sun. Therefore, it is necessary for MPPTs to maximize the output power of the solar panels. Testing using MPPT generates a power of 13.48 W, while when without using MPPT only 8.44 W.

Keywords **—Solar Panel, Servo Motor, Solar Tracking, Dual Axis, MPPT.**

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I. INTRODUCTION

Energy utilization is almost a worldwide problem. Energy is the main factor for the growth of a country, from various sectors including the economy, food, and people's welfare. This is due to the increasingly complex and increasing energy needs. Energy needs currently reach 10 Terra Watt equivalent to 3 x 1020 Joule/year and is predicted to increase to reach 30 Terra Watt by 2030[1]. The growing need for energy is not comparable to a clean environment of pollution, therefore, it is expected that an alternative energy that creates a clean environment will pollute.

Alternative energy used by utilizing solar energy. Solar energy as the main energy source of life on earth. Solar energy is an unlimited source of energy and will never run out of availability and this energy can also be utilized as an alternative energy that will be transformed into electrical energy, using solar cells. Photovoltaic (PV) are a type of power plant that is environmentally friendly and does not cause air pollution. Solar cells can be used in various locations with the potential of sunlight. A solar cell in a bright state will produce a voltage of 0.5 V to 0.7 V with a current ranging from 20 mA. Energy can be received by solar cells optimally when the position of the solar cell is facing straight against the sun's rays[2].

The constantly changing position of the sun at all times results in solar panels not being able to always be perpendicular to the sun. So the energy produced cannot be optimal the Sun is constantly moving resulting in sunlight is not fully acceptable to solar panels. Solar panels are needed that can follow the sun's constantly changing movements so that optimal energy is obtained[3].

So based on the introduction that has been revealed above, in this study the author designed a Photovoltaic (PV) tracking system with two degrees of freedom and using the Maximum Power Point Tracker (MPPT) based on perturb and observe method on output DC-DC converter type buck converter. So that this system can follow the movement of the sun and can produce more energy value.

II. LITERATURE REVIEW

A. Solar Panel

Solar cells are a device that converts sunlight into electrical energy with a photovoltaic effect process when illuminated by a single commercial solar cell generally produces a DC voltage of 0.6V without load and 0.45V using load. The amount of voltage generated is not enough to be implemented on a device and is very small, so the solar cells are arranged in a form of solar module. Usually the solar module consists of 28 -36 solar cells and produces a DC output voltage of 12V. to produce voltage and larger output current panels can be combined in series and parallel [4].

B. Solar Tracker

Solar Tracker or sun tracker is a tool that can detect the direction of sun light and change the position of the solar panel so that it faces perpendicular to the direction of the sun's arrival so that with this tool optimizes the absorption of the sun by solar panels. Solar tracker is classified into two types, namely the type based on the time in which the trajectory of sun has been calculated in time so that the solar panel will move according to the time specified, and the second type is the type with solar panels that will react directly with the sun[5].

C. Buck Converter Concept

Buck Converter is the most commonly used converter type in power management applications. The application uses transient frequencies and responses at wide current ranges. Buck converter can convert high voltage to low voltage setting. Here is a picture of the buck converter circuit shown in the picture below[6].

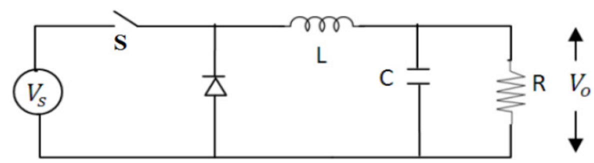

Fig. 1 Circuit Buck Converter

D. Maximum Power Point Tracking (MPPT)

The Maximum Point Tracker (MPPT) system is fully an electronic circuit that can change the operating point of a solar panel. One easy method that can be applied to MPPT system is to raise / lower the voltage until the discovery of the panel maximum power point. Given the change in sun power illumination level changes every time, it is expected that MPPT system can work dynamically in search of maximum power point[7]. MPPT system is implemented into an electronic device. Work by stabilizing the solar panels to work at their maximum point, so that the power given to the load is maximum power[8].

E. Algoritma Perturb and Observe (P&O)

Perturb and Observe is one of the maximum power point tracking algorithms that are widely used to find the optimal value of PV, because it uses only a few parameters guided and a simple algorithm structure. For practical conditions, this algorithm is quite reliable to use and has a response that always oscillates near its optimal value (MPP). This P& method works based on perturbation technique in the system by increasing or reducing reference voltage (Vref) according to the response changed through dutycycle parameters.

III. SYSTEM MODELLING

A. Componenet Design

Solar Tracker or sun tracker is a tool that can detect the direction of sun light and change the position of the solar panel so that it faces perpendicular to the direction of the sun's arrival so that with this tool optimizes the absorption of the sun by solar panels. With the LDR sensor as a reader of the direction of the sun's arrival and to move the paenl is used two servo motors controlled using Arduino uno R3.

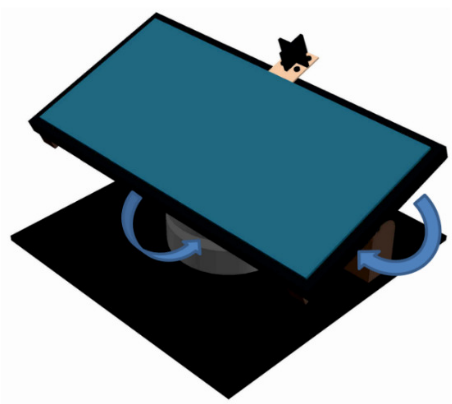

Fig. 2 Solar Panel Design With Dual Axis Tracking

With two servos and 4 LDR sensors are expected to be able to move the solar panel to always face the direction of the sun's arrival so that later expected to eject from the solar panel can be connected with dc-dc converter to be in control using MPPT with algorithm perturb and observe so that it gets maximum power to support the load of DC lamps 18 W.

B. System Design

In the picture above is a diagram of the work of the research system. With solar panels branded ST Solar 30 WP polycrystalline cell. Solar panel with a maximum output voltage of 21.8 V. Solar panels above are moved using a servo motor as much as two pieces, namely vertical and horizontal servo motors. The motor moves towards the direction of the sun as read by the LDR. The output of the solar panels is received by a buck converter designed to stabilize the output voltage of the photovoltaic. This Buck converter uses Arduino Uno as a microcontroller and P&O method with a voltage output of 12 V. Output from buck converter is used to supply DC 18 W lamps.

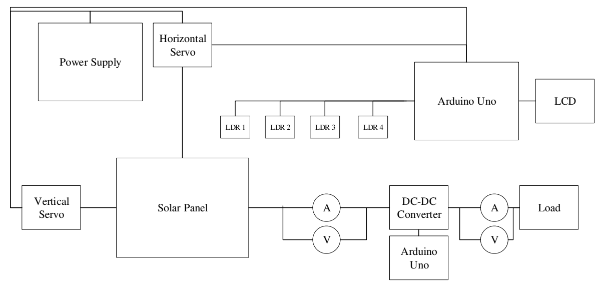

Fig. 3 Block Diagram of the work of the whole system

C. Designing the Arduino P& O Control Program

This algorithm starts with the measurement of the voltage and current values of the generator so that the power value is obtained. The current measurement power value compared to the previous power measurement.

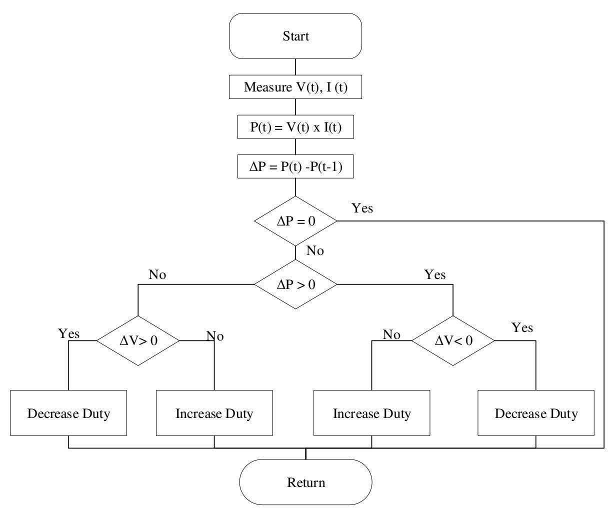

Fig. 4Flowchart Perturb and Observe Algorithm (P&O)

This algorithm starts with measuring the voltage and current values of the solar panels so that the power value is obtained. The current measurement power value compared to the previous power measurement. When the difference between the two measurements is equal to zero, the PWM value is used as the latest or equalized value. But if the difference is not equal to zero, it will be given an increase or reduction of PWM in accordance with the specified reference voltage. From this voltage perturb obtained the latest power value. The voltage with duty cycle in this study is directly proportional, meaning that increasing duty cycle causes the voltage to increase. The process of adding or subtraction of duty cycle sees the condition of power delta and voltage delta.

IV. RESULT AND DISCUSSION

A. Buck Converter Without Load

Buck testing without load is done with variations of changes in duty cycle with values ranging from 10% to 90%.

TABLE 1
BUCK CONVERTER TEST RESULTS WITHOUT LOAD

No	*Duty cycle*(%)	Vin (V)	Vout (V)	Vout Teory(V)	*Error* Percent(%)
1	10%	20,6	1,56	2,06	24,27
2	20%	20,59	3,62	4,118	12,09
3	30%	20,58	5,8	6,174	6,06
4	40%	20,56	7,92	8,224	3,70
5	50%	20,53	9,81	10,265	4,43
6	60%	20,5	11,74	12,3	4,55
7	70%	20,47	13,91	14,329	2,92
8	80%	20,43	15,85	16,344	3,02
9	90%	20,39	18,01	18,351	1,86
Average					**6,99**

Output voltage based on theory can be written as follows.

Vout=D x Vin

At the time of duty cycle 30% and input voltage of 20.6 V then the output voltage of

Vout=30% x 20.58= 6,174 Volts

From the data, it is known that the average error percent of the theory output and output voltage of the converter is 6.99%.

B. Buck Converter With Load

Testing buck converter with input power and power output. From the data generated power efficiency of the buck converter.

TABLE 2
BUCK CONVERTER TEST RESULTS WITH A LOAD OF 39OHM

No	Duty cycle (%)	Vin (V)	Vout (V)	Iin (A)	Iout (A)	Pin (W)	Pout (W)	η (%)
1	10%	20,6	1,88	0,009	0,055	0,19	0,10	56%
2	20%	20,59	3,67	0,031	0,119	0,64	0,44	68%
3	30%	20,58	5,63	0,07	0,188	1,44	1,06	73%
4	40%	20,56	7,68	0,113	0,255	2,32	1,96	84%
5	50%	20,53	9,59	0,19	0,325	3,90	3,12	80%
6	60%	20,5	11,58	0,274	0,396	5,62	4,59	82%
7	70%	20,47	13,52	0,37	0,463	7,57	6,26	83%
8	80%	20,43	15,47	0,488	0,536	9,97	8,29	83%
9	90%	20,39	17,27	0,614	0,603	12,52	10,41	83%
Average						4,91	1,02	77%

Based on the data of buck converter test results with load can be concluded that the efficiency of the converter is obtained from the equation as follows.

$$\eta = \frac{Pout}{Pin}\ x\ 100\%$$

So the efficiency obtained from the equation as follows is.

$$\eta = \frac{4{,}02}{4{,}91}\ x\ 100\% = 82{,}01\%$$

The amount of duty cycle that goes into the converter makes a big increase in the power coming out of the converter. This makes the size of the duty cycle directly proportional to the power that goes into the load.

C. Solar Panel Testing With Tracking

In this test conducted to find out the difference in power obtained when using tracking and without tracking.

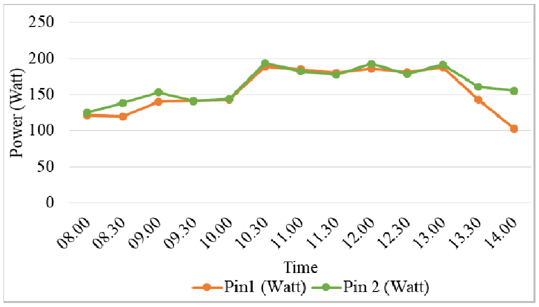

Fig. 5Input Power Comparison Graphic

From the comparison chart without tracking is written with 1 and 2 for testing with tracking. it is known that the input power value in tracking usage is greater, but at some time the data retrieval of input power value in the test without tracking shows a greater value. This is due to the difference in the value of irradiation obtained. The input power value was different at the time of testing with tracking of 193.52 W, and tracking without tracking tested obtained the largest power of 188.39 W.

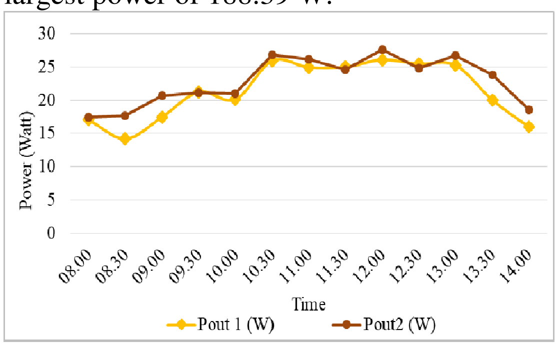

Fig. 6Output Power Comparison Graphic

In figure 8 the output power comparison graph obtained two tests with tracking and without tracking. tracking test produces 27,567 Watts and no tracking of 26,083 Watts.

D. MPPT Testing With P&O Algorithm

MPPT power optimization testing using P&O algorithm is done by retrieving data at the time of control with the P&O algorithm enabled. The change in duty cycle will be recorded using the serial monitor on the laptop in order to see the average power change (ΔP) of the P&O algorithm within every 1 second called the maximum power point or called the maximum power point. Can be seen in figure 9 Graph of changes in duty cycle to power and voltage.

From the first data when the duty cycle given by 78 produces known data Vout of 12.01 V and Iout 0.75 A then known MPP of 9.58 Watt.

Duty = 78 %

Vout = 12,01 V

Iout = 0,85A

MPP1 = 9,58W

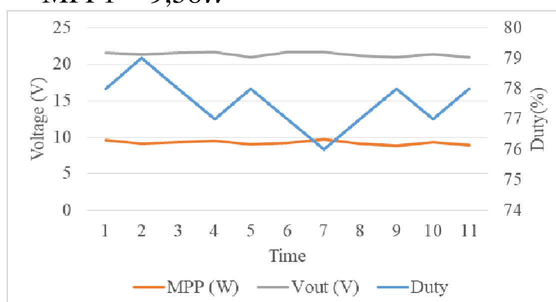

Fig. 7 Graph of changes in duty cycle to power and voltage

The second data is known to be the size of MPP obtained by 9.15 W which means that it has decreased from the previous power, the duty cycle value is increased to 79% with Vout of 12.2 V and Iout 0.76 A.

MPP1 = 9,58W

MPP2 = 9,15W

ΔMPP = 9,58 - 9,15 = 0,43 W

ΔPWM = $(D_2 - D_1)/100$ x255

= (79- 78)/100 x255

=2.55

The ΔMPP of 0.43 W and the value of ΔPWM of 2.55 of the data is known to change the value of ΔMPP directly proportional to the value of ΔPWM. The algorithm can find the maximum power point capable of being channeled to the load.

E. Analysis Of Overall System

System testing as a whole is carried out two kinds of testing with MPPT and without MPPT for testing without MPPT is carried out with a period of one hour. The data taken in the form of voltage, current and power from the output converter. Fig 8 is test graphicof system without MPPT.

Based on the data of system test results without MPPT efficiency average obtained by 85.86% in the range of duty cycle value in the test of 80% using DC lamp load 18 W.

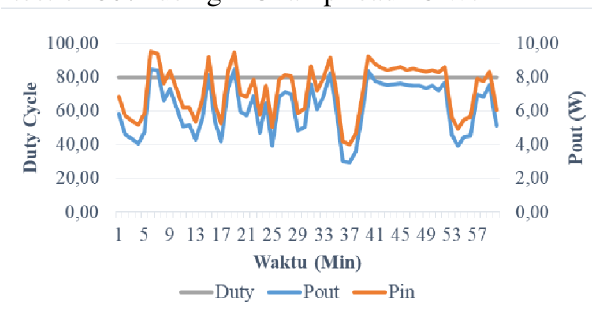

Fig. 8Graphics Testing System without MPPT

At the time of system testing with MPPT is done within an hour. Data taken in the form of voltage, current and power. Here are the results of system data with MPPT. This test obtained Pmax value from irradiation value multiplied by 1000 W/m2 then multiplied by maximum value of solar panel work can be written as follows.

$$Max = \frac{Irradiation}{1000}\ x\ 30$$

$$P\ Max = \frac{679}{1000} x\ 30 = 20{,}38\ W$$

To obtain efficiency obtained by dividing the entry power of the converter or the output power of the panel with the power received by the panel is written as follows is.

$$efficiency \frac{14{,}86}{23{,}76} x100 = 73\ \%$$

In the test using MPPT the average power received by solar panels was 17.70 W with an average Irradiation value of 640 W/m2 and the average power received by the convergence was 11.51 W so that the efficiency obtained was 60%. The largest efficiency value of 68% is at the time of irradiation of 78 W/m2 and panel power of 21.84W and the power received from converter output is 14.86 W. And the smallest efficiency value is at 43% at the time of irradiation of 472 W/m2 and panel power of 14.15 W and received power of 6.06 W.

Graph of Irradiation Relationship, Pmax and Pin above, shows the change of duty cycle is influenced by the change in power from Pout which causes the output voltage of Buck Converter (Vout) to fluctuate as in the chart to get maximum power. From the graph above there is irradiation obtained from the intensity of light can be converted into irradiation. However there has been no direct conversion between lux and W/m2.

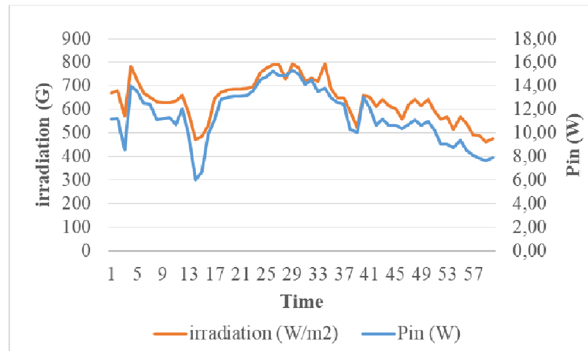

Fig. 9 of Irradiation, Pmax and Pin Relationships

Conversion size based on wavelength or colour produced by light source. But some scientific research assumes lux and W/m2 conversions. According on the study titled Prototyping of Environmental Kit for Georeferenced Transient Outdoor Comfort Assessment 1 lux = 0.00079 W/m2[9]. The power received by the converter and load can be seen in the chart below.

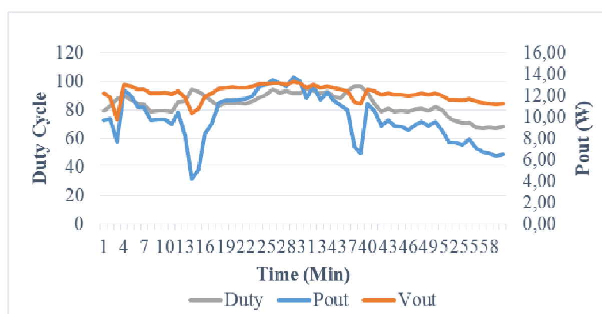

Fig.10 Graph of the Relationship between Pout, Vout, and Duty Cycle

Based on the results of the overall system test with a period of 1 hour, it is written as follows.

E = Power average (W) × t(s)

E = 19.20 × 3600 = 69,120 Joules

In units of Wh (Watt hour) then as follows. E(Wh)=E/3600=69120/3600=19.20 Wh

Based on the overall system test results with a time span of 60 minutes, it is written as follows. Based on the overall system test result data, it can be calculated the energy received by the converter with the following equation.

E = Power average (W) × t(s)

E = 11.51 × 3600 = 41,400 Joules

In units of Wh (Watt hour) then as follows.

E(Wh)= E/3600=41,400/3600=11.51 Wh

The total energy generated by solar panels is 69,120 Joules or 19.20 Wh while the total entering the converter is 41,400 Joules or 11.51 Wh. The power generated by solar panels averages 19.20 Watts. To turn on the lamp with a load of 18 Watts. MPPT used in this study using dual controller namely solar tracker follow the direction of solar movement and MPPT P&O is used to maximize the output power received by the converter.

V. CONCLUSSION

Based on the research results of Maximum Power Point Tracking for solar panel output 30 Wp with tracking system using buck converter control, it can be concluded.

1. Buck converter design results have the highest average efficiency of 80.9%. The highest efficiency result at duty cycle is 90% and 95%. The efficiency value on the buck converter is affected by the large value of the duty cycle.
2. At the time of testing solar panels with tracking produced an average power of 22.85 W obtained from the Voc average of 20.41V and isc average of 1.5 A and Voc of the average for panels without tracking of 20.27V and 1.41 A for isc on average so, power generated from solar panels without tracking with an average of 21,443 W, the difference in power generated by solar panels using tracking is greater than 1,407 W of solar panels without tracking.
3. Maximum power result by using MPPT is greater compared to the result without MPPT. At the time of non-MPPT testing where the start duty cycle of 80% produces a maximum power of 8.44 W with an average efficiency of 85.86% while when the MPPT system is included the maximum power generated is 13.48 W at the time of duty cycle 94% and average efficiency of 85.95 %.

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