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An Improving Efficiency MPPT in PV Systems with a Modified Voltage Regulator

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Abstract— The hybrid renewable energy system is a breakthrough that can manage energy for consumer needs. In this system, the energy source of PV is apriority. On the other hand, PV is strongly influenced by environmental factors to produce maximum electrical energy. MPPT is a tracking technique that forces solar cells to work at their maximum working point. In this study, the algorithm applied to the SEPIC-type DC-DC system was P&O. The MPPT technique is able to increase the power that goes into the converter, but a problem is the efficiency of the input power and the output power of the PV that goes to the converter which in several previous studies has not been maximized. Therefore a voltage regulator system is given which functions to control the output voltage of the MPPT system so that it is able to be constant, this is also a solution to maximize the efficiency of PV. Based on the experiment, the voltage regulator's system work is to cut the output voltage from the DC Converter side with a duty ratio of about 20% to increase the MPPT system's efficiency with a value ranging from 80 - 95% at different irradiation variations.

Keywords—MPPT, Perturb and Observe, SEPIC, Voltage Regulation

I. INTRODUCTION

According to Indonesian Electricity General Plan 2019-2035, that mention Indonesia's per capita electricity consumption is predicted to increase rapidly from 1,295 kWh to 3,302 kWh in 2038. Indonesia's electricity production sector is currently dominated by coal by 62%, gas by 24%, fuel by 1%, and renewable energy by 12%. In comparison, the target in the 2038 renewable energy sector can produce 28% of total energy needs [1].

With the government plan presented in the previous paragraph, a system capable of improve the efficiency and balance of energy supply is needed, the hybrid energy source systems is capable to managing both conventional energy source and renewable energy for consumer needs [2]. HESS systems always involve solar cells that can convert free, clean energy. PV have a relatively long service life compared to other renewable energy, but environmental factors strongly influence solar cells to produce maximum electrical energy. Some things that affect solar cells' ability to generate electrical power include the degradation of solar panels, varied solar radiation, panel temperature, fill factors, parasite resistance, and shading effect [3].

The problem presented in the previous paragraph causes the power generated in a solar panel system to fluctuate. Maximum power point tracking is a power curve tracking technique used to solve power fluctuations in solar cells that

are not at their maximum working point. MPPT technique works based on the type of algorithm used, such as Perturb & Observe, Incremental Conductance, Ripple Factor Correlation, etc [4].

P&O algorithm is a common and popular algorithm used because of its simplicity and ease with the efficiency obtained is quite high [4]. Although many studies try to implement other algorithms for MPPT, most of them have high efficiency but also have a higher level of complexity as a consequences [5].

MPPT is generally applied to solar cell output power converters. Of some existing DC-DC converters, SEPIC (Single-Ended Primary Inductance Converter) has several advantages over other types of converters, such as the same input and output polarity, low input current ripples, and can operate as buck and boost [6]. MPPT on DC-DC converter works by manipulating voltage to reach a maximum power point, in other words, voltage controlling the current. Such voltage manipulation causes the output voltage value of the converter cannot to be linear because it uses MPPT when the input voltage varies [7].

The authors want to do is inspired by research that has been done before. Here are some studies that have been done before.[8] it coordinated the MPPT system and voltage regulation by using a SSC (Single Switch Converter) .Then [9] it discusses the buck-boost converter combined with the Marx converter to regulate the output voltage. [10] For coordinating MPPT with a voltage regulator connected to the grid, the coordinated control delivers constant DC voltage to the load then in the inverter. [11] in this paper the researchers coordinated the MPPT system with voltage regulator on a two-stage grid-tied PV system topology by using boost converter and buck converter.

In some of the research presented above, some things are not discussed in the application of MPPT. As a continuation of previous research, the author plans to implement the concept of MPPT into dc bus hybrid renewable energy system, which requires constant voltage to supply load or store energy. Based on this, of course, in the SEPIC circuit, it is necessary to add a voltage stabilizer so that the electrical power that MPPT has maximized can be set to a constant output voltage at a specific value. The addition of a voltage regulator using the concept of switching mode power supply, this is a modification of the SEPIC type power converter system so that the two circuits work side by side with SEPIC handling MPPT and the voltage regulator handling constant output voltages.

II. SYSTEM DESCRIPTION

A. Maximum Power Point Tracking (MPPT)

The characteristics of the P-V curve are influenced by several factors such as those presented in the introduction, particularly the irradiation factors and temperature factors that make the characteristic curves not linear. The characteristic curve of solar cells influenced by irradiation factors and temperature factors is shown in Figure 1.

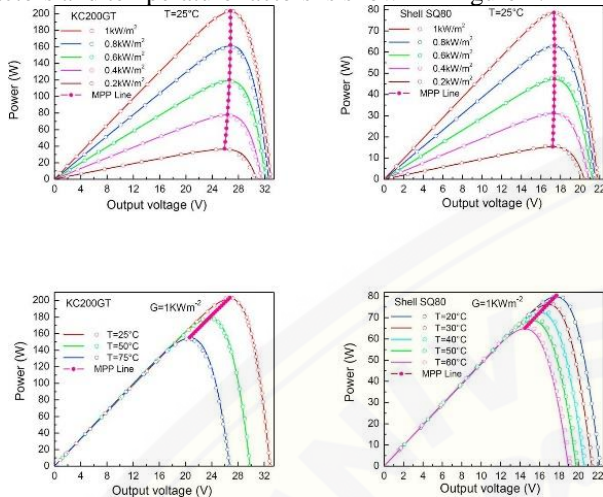


Figure 1. P-V Characteristic Curve of Solar Cells Influenced by Irradiation and Temperature Factors [12]

As shown in Figure 1, problems can be solved with Maximum Power Point Tracking (MPPT). MPPT is a technique that can force solar panels to generate as much power as possible so that the energy produced can be harvested to the maximum. The parameters required for MPPT techniques depend on the algorithm or control system used. In general, the voltage and photovoltaic current are two parameters that are often used, but some algorithms use different parameters, e.g., irradiation, temperature, and even variations of all parameters [13].

In this study, the system was designed using MPPT with description from the system, starting from polycrystalline 100 WP solar cells with a maximum output voltage point of 17.8V with a maximum current of 5.62A, a converter used for MPPT sepic type. To make the voltage can be of constant value, used voltage regulator. The voltage control system works by controlling the mosfet using a duty ratio. The system diagram block is shown in Figure 2.

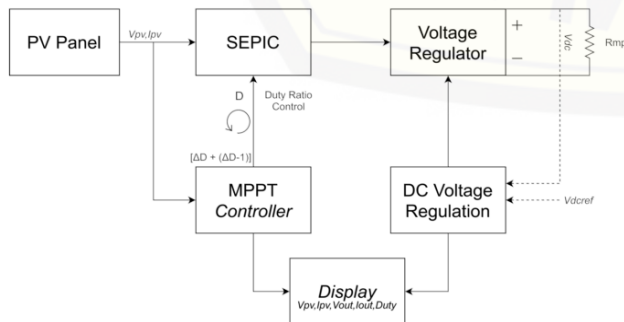


Figure 2. Systems Block Diagram

B. Single-Ended Primary Inductance Converter (SEPIC)

SEPIC (Single-Ended Primary Inductance Converter) is one of several types of DC – DC converter topology that can generate a voltage at the output with greater, less than, or the same input. SEPIC is based on developing other previous DC-DC converter topologies such as buck, boost, buck-boost, and CUK, so sepic topology has the converter's characteristics, sepic topology shown in Figure 5 [14].

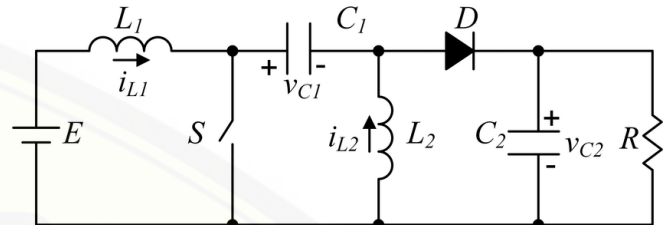


Figure 3. SEPIC Topology [15]

To determine the specification of the components used on SEPIC depends on the system you want to create. Here are the SEPIC specifications used for PV:

Table 1. SEPIC Specifications

Specifications	Value
Input Voltage	12 - 17.8 V
Output Voltage	24 V
Output Current	4.1 A
Switching Frequency	62500 Hz

Here is the equation used to calculate the duty ratio on SEPIC:

1. Duty ratio minimum

$$D_{MIN} = \frac{V_{OUT} + V_{fwd}}{V_{in(max)} + V_{OUT} + V_{fwd}} \quad (1)$$

$D = 0,58$

2. Duty ratio maximum

$$D_{MAX} = \frac{V_{OUT} + V_{fwd}}{V_{in(min)} + V_{OUT} + V_{fwd}} \quad (2)$$

$D = 0,67$

3. Calculation of load value

$$R_{Lout} = \frac{V_{out}}{I_{out}} \quad (3)$$

R_{Lout}	D_{min}	D_{max}
Min	4.96 Ω	7.3 Ω
Max	203.6 Ω	299.4 Ω

The calculation of the value of other components is based on the journal texas instrument.

The solar panel module used in this study was the SUNASIA SP100-18P. The PV characteristic curve used is shown in Figure 4.

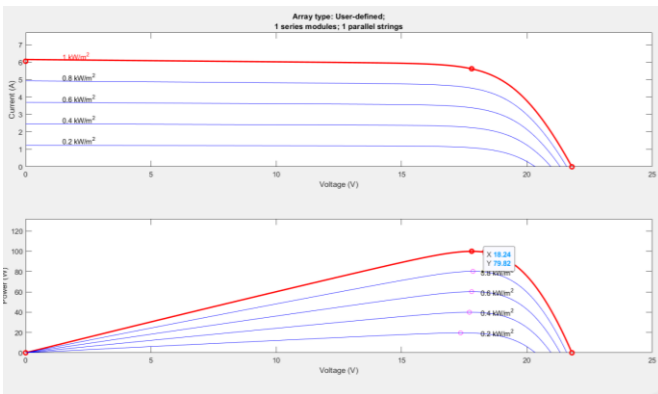


Figure 4. PV SP100-18P characteristic curve (a)V-I(b) P-V

C. DC Voltage Regulation

DC voltage regulator is an additional component that is functioned to keep the output voltage constant at a specific value. The concept of a voltage regulator works on the same principle as a DC converter in general, or in other words, the switching power supply mode, namely by switching the mosfet with a duty ratio to manipulate the voltage, in this case it is used to limit the measured voltage on the output side. The DC voltage regulator design is based on research [10]. Figure 5 shows the research system's configuration and the part of the voltage regulator that wants to be used in this study.

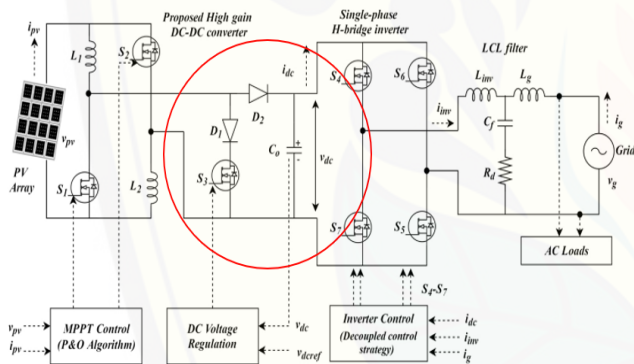


Figure 5. DC Voltage Regulator System Configuration [10].

Calculation of capacitor values used in voltage regulators, as follows:

$$C_o = \frac{P_{dc}}{V_{dc} \times \Delta V_{dc} \times f_s} \quad (4)$$

$$C_o = \frac{100}{24 \times 0,02 \times 62500} = 3333 \mu F$$

For diodes and mosfet used is likened to SEPIC.

III. MPPT METHOD

In this study, the method used is the MPPT P&O algorithm with the application of a voltage control system. Here is an explanation of the P&O method :

A. Perturb & Observe

Perturb And Observe (P&O) algorithm is a direct MPPT technique that works by giving interference (perturb) to the

reference voltage of the power converter, causing changes in the output power of the panel, which is then observed (observe) and compared back to the reference power. As long as the power trace value is not appropriate, it will again be disturbed to get close to the maximum power point. The P&O algorithm is formulated based on the P-V curve characteristics of solar cells. These characteristics curves may change depending on the irradiation value's magnitude and the temperature absorbed by solar cells. Basic flowchart of basic P&O algorithms in general as shown in the following Figure :

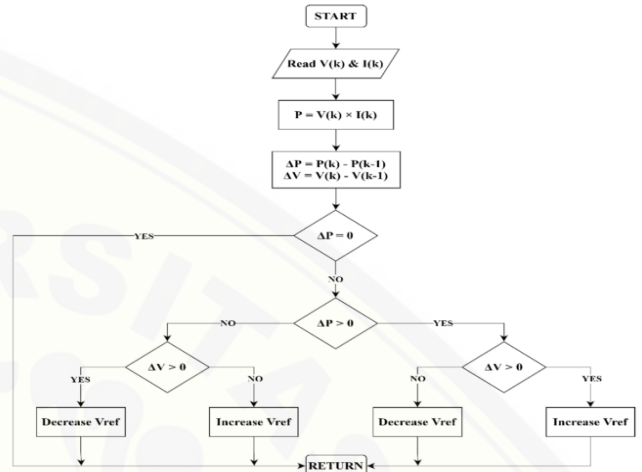


Figure 6. P&O Algorithm Flowchart

IV. DISCUSSION AND RESULT

After testing using MATLAB Simulink, several graphs were obtained that showed the system could work together between the concept of MPPT and voltage control. The series of experiments through Simulink is shown in Figure 7.

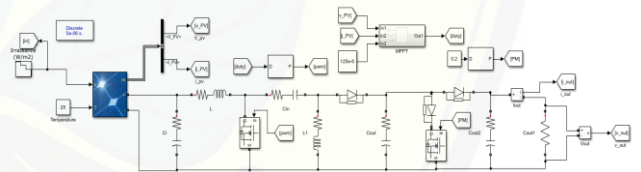


Figure 7. Simulink Coordination of the MPPT System Circuit with the Voltage Regulator

The experiment was conducted with the MPPT system on the SEPIC side with input irradiation of 500 W/m², 1000 W/m², 800 W/m², 600 W/m², and 200 W/m² with 5 Ω load. The first experiment when the voltage regulator side is not working is shown in Figure 8.

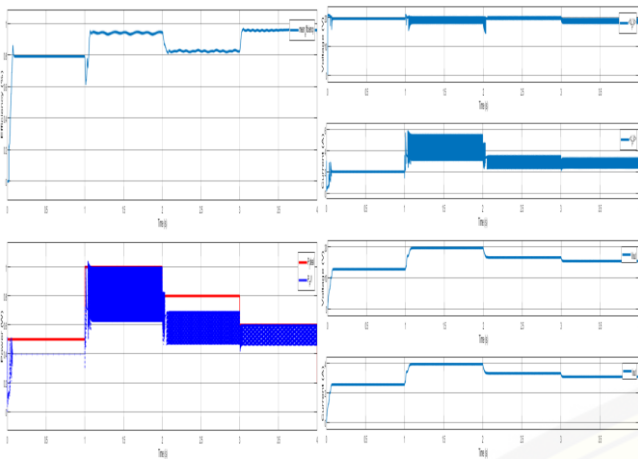


Figure 8. MPPT System Test Graph when Voltage Regulator IS OFF

When the voltage control side works the experiment was carried out by changing the duty ratio value on the voltage regulator. The curve of the duty ratio variation test on the voltage regulator is shown in Figures 9 to 11.

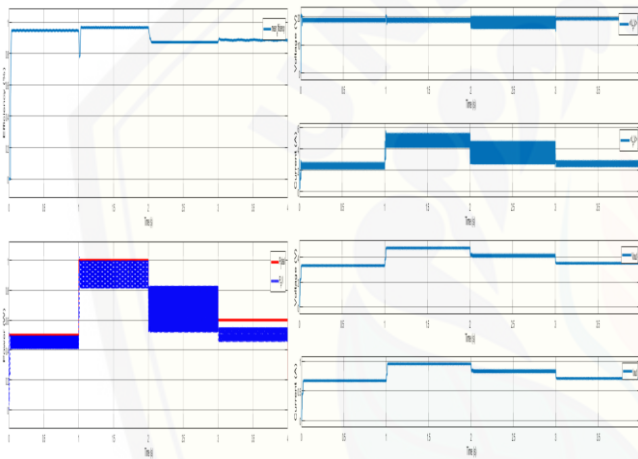


Figure 9. MPPT System Test Graph with Voltage Regulator when Duty Ratio Variation 20%

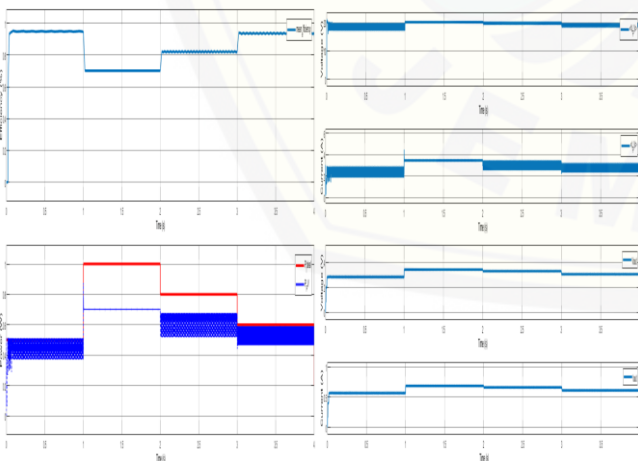


Figure 10. MPPT System Test Graph with Voltage Regulator when Duty Ratio Variation 30%

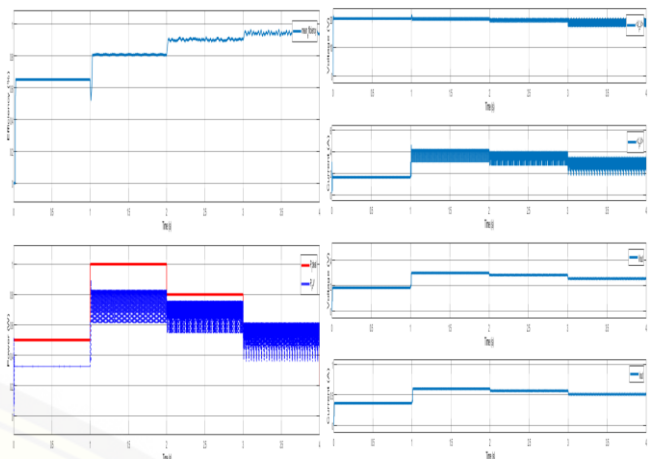


Figure 11. MPPT System Test Graph with Voltage Regulator when Duty Ratio Variation 40%

Based on some of the above experimental scenarios, the voltage regulator works by cutting the SEPIC side's output voltage. When given a duty ratio of 30% and 40%, there are consequences in the current form that will follow the large output voltage from the voltage regulator side. On the other hand, voltage regulators can increase the efficiency between the input and output sides, as shown in Figure 9. When the voltage regulator is given a duty ratio value of 20%, the system was obtained the lowest average efficiency of 80% and the highest about 95%, this does not happen when the voltage regulator's duty ratio is more than 20%. Due to the effect of the voltage regulator on the output side of the converter, the input power to the converter using the MPPT technique is more optimal as shown in the picture above, namely the efficiency of input and output power from the large ratio of irradiation that can be converted by PV to be higher.

V. CONCLUSION

Based on the trial results conducted using Matlab Simulink that has been done can be obtained some conclusions as follows: First, the working system of the voltage regulator is to cut the output voltage from the DC Converter side. Second, when the duty ratio given on the voltage regulator side exceeds 20%, the system will become inefficient. This is because the current will follow the voltage output voltage. Third, when the duty ratio is 20%, it can increase the system's average efficiency with the lowest value of about 80% and the highest about 95%.

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