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Design and simulation of utilization of solar cells as battery chargers CC-CV (Constant Current-Constant Voltage) method with fuzzy control

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Abstract

In a country with a tropical climate, the use of the sunlight is very important. Thus, to be able to apply, a solar power conversion system is needed into a source of electrical energy. The use of electrical equipment that is quite high will increase the consumption of electrical power so that people spend more and more on electricity costs. A battery is a device consisting of electrochemical cells that can store electrical energy. Overcharging the battery causes the battery to be susceptible to damage. So that the process of charging the battery becomes important, to get maximum attention and good efficiency. In this study, the use of solar cells with battery chargers using the CC-CV (Constant Current-Constant Voltage) Fuzzy Control method uses a solar cell to convert sunlight into electrical energy. The specifications of the solar cell used are 100 WP, while the charging process uses a DC-DC Sepic Converter. DC-DC Sepic Converter can increase efficiency and output polarity that is not reversed. This system is used to charge the lead-acid battery of 12 Volt 20 Ah. The charging method used is constant current-constant voltage (CC-CV) using Fuzzy Logic Control to adjust the duty cycle so that the converter output is by the constant current - constant voltage (CC-CV) planning. The constant current - constant voltage (CC-CV) method was chosen because it can provide good efficiency in charging time and the addition of the Constant Voltage method after Constant Current is enabled to keep the voltage at the setpoint and avoid overvoltage during the charging process. Sepic Converter is used to maintain the value of the voltage set point at 14.4 Volts and 6 Ampere for battery charging current.

1. Introduction

With the development of technology, the demand for energy in the world is increasing. Along with the community's energy needs, where some of the energy consumed as the main energy source still comes from non-renewable fossil energy (renewable resources). So that this energy demand continues to increase along with the increase in population growth and can experience the threat of scarcity with large-scale and continuous use [1]. Generally, Indonesian people still often rely on electrical energy that cannot be renewed (renewable resources) / energy sources from PLN. This will increase power consumption so that electricity costs will increase. Under these conditions, new alternative energy sources that can be renewed (renewable resources) are needed to replace fossil energy sources.

As a country that has a tropical climate, solar energy as renewable energy is very suitable to be developed in Indonesia. In utilizing solar energy, it does not directly produce electricity, but it is necessary to have energy conversion equipment commonly called solar cells. So that with this system solar energy is converted into electrical energy which can be stored in batteries (accumulators) [2]. Batteries support the provision of reliable and continuous energy supply for a relatively long time. The use of batteries is one of the most attractive energy storage systems because it has fairly high efficiency and low air pollution. Thus, of course, we need an alternative that can help the community in meeting their electricity needs by applying a solar power system as a source of electrical energy. The system that will be designed utilizes solar cells as a source and will be used for charging batteries.

Electrical energy from solar panels is not always stable, this is caused by changes in the weather in the environment, so we need a converter that can adjust the output voltage of the solar panels according to the needs of charging the battery. The energy generated by the solar panels is used to charge the battery with a capacity of 20 Ah. A DC-DC converter is a power electronics circuit that converts DC voltage to DC voltage with different values, according to the type and output settings [3]. The DC-DC converter performs two functions, namely changing the output voltage level (increasing or decreasing) and providing a constant load voltage [3]. Using a DC-DC converter, namely SEPIC to increase or decrease the output voltage so that when charging the battery it can run properly and can maintain battery life so that it lasts a long time [4].

The control system that will be used is the Fuzzy Logic Controller to regulate the charging voltage to remain constant. The battery charging process used is constant current constant voltage using the Fuzzy Logic Control algorithm [10]. In the fuzzy logic controller, a simple conclusion is drawn from vague information. There are rules derived from observational data providing knowledge about the system being simulated [5]. The reliability of fuzzy logic does not depend on the mathematical model of the controlled system but on experimental activities and experience [7].

2. Research Merhod

In this system, the design and simulation of the use of solar cells as a charging system will be carried out using Fuzzy Logic Control.

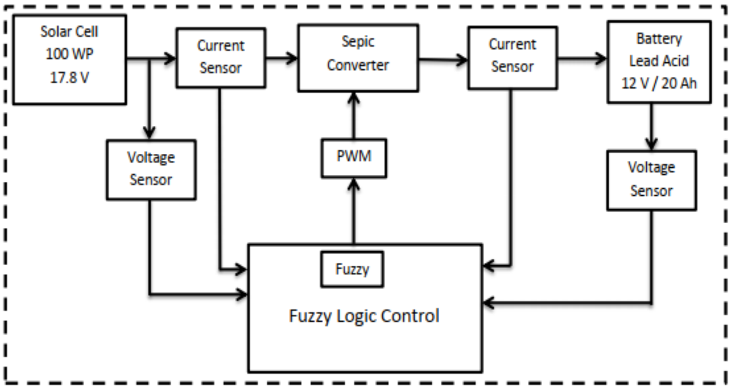


Figure 1. Solar Cell Utilization System as a Battery Charging System using Fuzzy Logic Control

In Figure 1. It is a charging system from the use of solar cells in charging the battery with Fuzzy Logic Control. Battery charging uses a 100 WP solar cell. This system is equipped with a Sepic converter which reduces or increases the voltage by adjusting the output duty cycle of the system. The output voltage that comes out of the Sepic converter will be used to supply the battery. Determination of the value of the charging point setting used in this charging system by the method of constant current constant voltage. Where for the voltage used are 14.4 V and 6 A for charging the battery. The output of the converter will be controlled using Fuzzy Logic Control for better performance and response.

2.1 *Solar Cell* Modeling

A solar cell is a technology that functions to convert or convert sunlight into electrical energy [13]. To determine the power capacity of the solar cell to be used, it is necessary to consider environmental factors and internal equipment losses, because the electrical power produced by the solar cell is not directly channeled to the battery, but through the DC-DC converter first, the efficiency of the converter affects the electrical power produced. into the battery, with the specifications in Table 1.

Table 1. Solar Cell Specifications

Polycrystalline SP 100 W (P) Silicon Sola PV Module		
Pm	100	W
Voc	21.8	V
Isc	6.05	A
Vmp	17.8	V
Imp	5.62	A
Max System V	1000	V
Dimension	1125x670x30	mm
Test Condition	AM 1.5 1000 W/m2 25 0C	

Assuming the working efficiency of the sepic converter is 80%, the total power produced by the solar panels must be balanced with the optimal length of sunlight on the solar cell, which is 4.5 hours a day, so to determine the capacity requirement of the solar cell WP can be obtained from the following Equation 1.

$$P_{wp} = \frac{P_{total}}{T_{irradiation}} \quad (1)$$

Information:
P_{wp} = Power Capacity (W)
P_{total} = Total power required (Wh)
$T_{irradiation}$ = Optimal time of sunshine (h)

By considering the minimum $\boldsymbol{P_{wp}}$ of PV used is 100 Wp, it is determined that the total $\boldsymbol{P_{wp}}$ to be used is 100 Wp. In this condition, 100 Wp PV is used because, in real conditions, most of the PV can't produce 100 Wp completely, at least it only produces $\pm \boldsymbol{60\ Wp}$, this condition still fulfills the required capacity. With specifications such as the table above, the parameters obtained are:

$\boldsymbol{P_{max} = 100\ Watt}$
$\boldsymbol{V_{oc} = 21.8\ Volt}$
$\boldsymbol{I_{sc} = 6.05\ Ampere}$
$\boldsymbol{V_{mp} = 17.8\ Volt}$
$\boldsymbol{I_{mp} = 5.62\ Ampere}$

2.2 *Sepic Converter* Modeling

A power converter called the Single Ended Primary Inductance Converter (SEPIC) is a converter with a topology derived from the buck-boost converter, both of these converters can produce an output voltage that can be higher or lower than the input but the polarity of the output voltage of the buck-boost is reversed, while SEPIC without changing the polarity, besides the addition of capacitors and inductors in the sepic converter can also reduce the current ripple value [14].

$$V_O = V_s(\frac{D}{1-D}) \tag{2}$$

atau,

$$D = \frac{Vo}{Vo + Vs} \tag{3}$$

Information:
Vo = Output Voltage (V)
Vs = Input Voltage (V)
D = Duty Cycle

The result of this Equation 2 and Equation 3 is similar to that of a buck-boost converter, with the important difference that there is no reverse polarity between the input and output voltages. The ability of the Sepic Converter to have a voltage output greater or less than the input makes this converter suitable for many applications. The duty cycle value in this system is used to adjust the output of the Sepic Converter circuit to produce the appropriate charging voltage. The components in Equation 4, Equation 5, and Equation 6 used are the same as other converters in general, namely, inductors, capacitors, diodes, and switching transistors [14].

$$R = \frac{V_{out}}{I_{out}} \tag{4}$$

$$C = \frac{V_{out} \times D}{R \times \Delta Vo \times Fs} \tag{5}$$

$$L = \frac{V_{in} \times D}{\Delta IL \times Fs} \tag{6}$$

Information:
R = Resistance (Ω)
C = Capacitance (F)
L = Inductance (H)
V_{out} = Converter Output Voltage (V)

I_{out} = Converter Output Current (A)
ΔVo = Voltage ripple
Fs = Frequency (kHz)
V_{in} = Converter Input Voltage (V)
ΔIL = desired current ripple

The design of the Sepic Converter includes the magnitude of the duty cycle given with the input voltage parameters used to produce the appropriate output as in Equation 2. To reduce voltage ripple, a filter made of capacitors is added to the output and input of the converter. The output current used in this system is obtained from 30% of the battery capacity used. As for the determination of the value of Resistance, Capacitance, and Inductance obtained in Equations 4-6. So, from this explanation, the value of each component used to determine the sepic converter output parameters is shown in Table 2 below.

Table 2. Specifications of the Sepic Converter

Parameter	Nilai
Input Voltage (Vin)	17.8 V
Input Current (Iin)	5.62 A
Output Voltage (Vo)	14.4 V
Output Current (Io)	6 A
Frequency (fs)	40 kHz
Resistance (R)	2.4 Ω
Inductance (L)	176.97 μH
Capacitance (C)	4.6 mF

2.3 Battery Charging Method

In accelerating the optimal battery charging time, the charging process can cause overvoltage if the optimal battery charging time is not considered, so this can also shorten the battery life and can also cause the battery to be damaged. So, to overcome the overvoltage on the battery, the CC-CV (Constant Current Constant Voltage) charging method is used which can be seen in Figure 2.

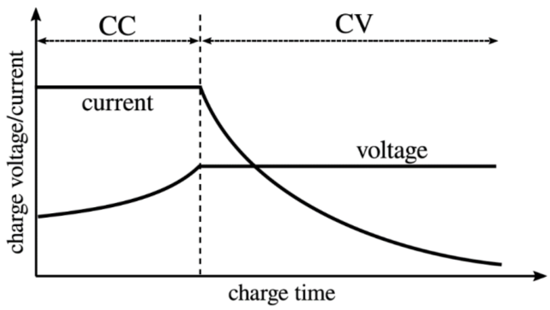


Figure 2. Charging Method for CC-CV (Constant Current Constant Voltage)[15]

The CC-CV (Constant Current Constant Voltage) charging method is a combination of 2 methods, namely constant current charging (CC) and constant voltage charging (CV). In the initial process of charging the battery using the Constant Current method, namely, the battery will be filled with a predetermined constant current and the voltage will increase slowly linearly with time until it reaches the maximum value limit. Then proceed with the battery charging process using the Constant Voltage method, namely the battery will be charged with a predetermined constant voltage and cause the charging current to decrease continuously. In the Constant Voltage charging process, the charging time is longer, because the use of the charging current decreases. This Constant Voltage method will end when the current has decreased to a predetermined point and the battery capacity has been fully charged [16].

2.4 Close Loop Integration Simulation Modeling (MATHLAB)

Close loop integration simulation (closed circuit) is a simulation of the entire system using controls. With a solar panel source, then the solar panel output voltage will be regulated by the Sepic converter using fuzzy logic control. This close-loop integration simulation was carried out in a simulation using MATLAB R2016b software, the simulation circuit can be seen in Figure 3.

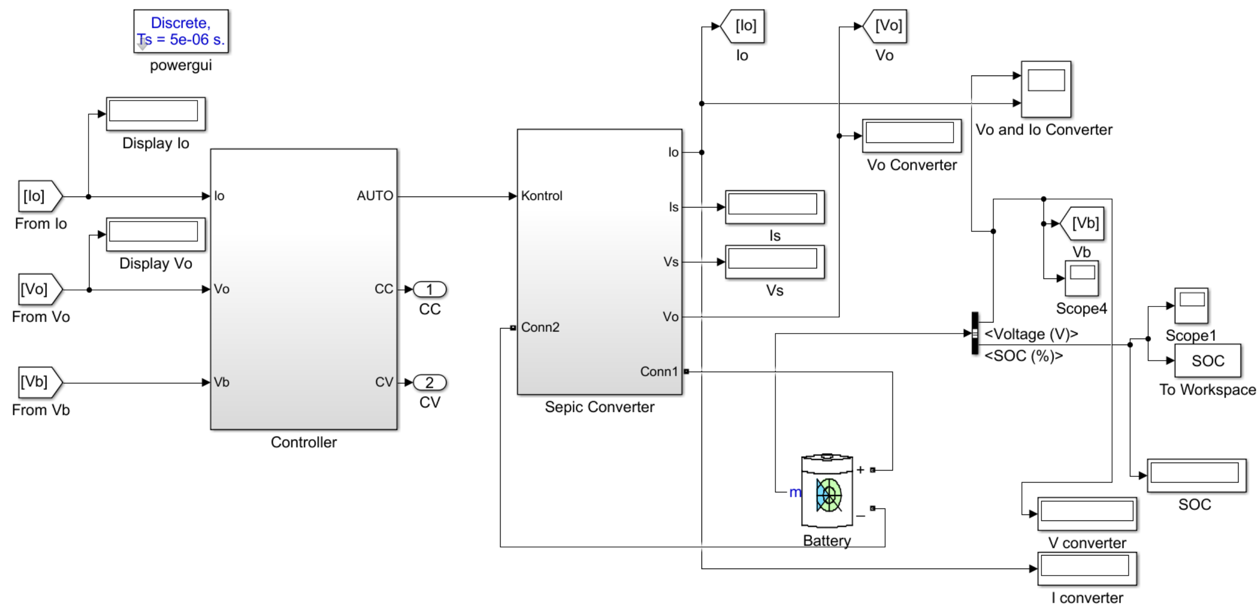


Figure 3. Close Loop Integration Simulation Circuit

Figure 3, above is a simulation circuit of close loop integration, where the Sepic converter is connected to the battery load. In the simulation circuit, the output of the Sepic converter will be used as charging the battery.

2.5 *Fuzzy Logic Controller*

Fuzzy Logic combines mathematical calculations and algorithms. In processing each input, the fuzzy method uses range-to-point control. Each parameter (input/output) is classified as a linguistic variable [4].

The Fuzzy Logic Control method used in this system is the Mamdani Method. The Mamdani method is more intuitive, very flexible with data, and has been used by many parties. Fuzzy Logic Control is used to control the PWM generation which functions to control the output voltage of the Buck Converter to keep it constant.

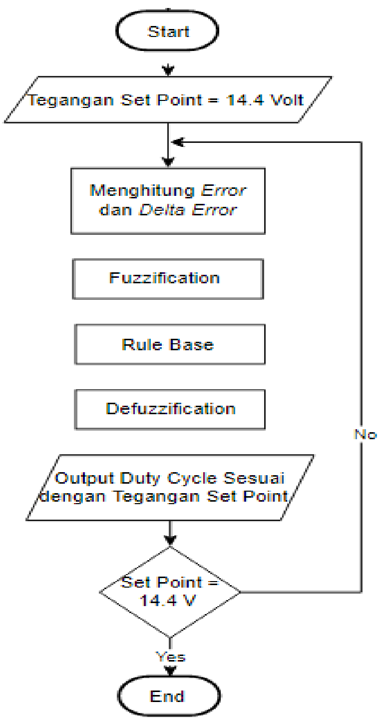


Figure 4. Fuzzy Logic Control Flowchart

Figure 4, is a Fuzzy Logic Control flowchart where the parameters that will be used as input are voltage and current parameters. This parameter will be converted into two fuzzy variables, namely *error (e)* and *delta error (de).*

These two variables will later be processed through Fuzzification, Fuzzy Inference System, and Defuzzification which will produce output in the form of duty ratio for PWM generation as switching from Buck Converter. Fuzzification is a domain transformation from crisp to fuzzy input [11].

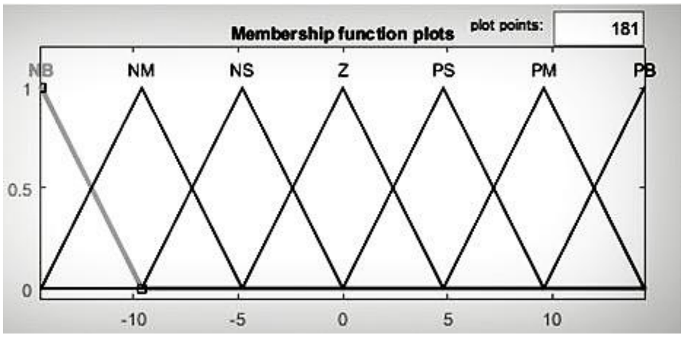


Figure 5. Membership Function Variable Error

Figure 5, shows the membership function of the error variable with a range of -14.4 to 14.4.

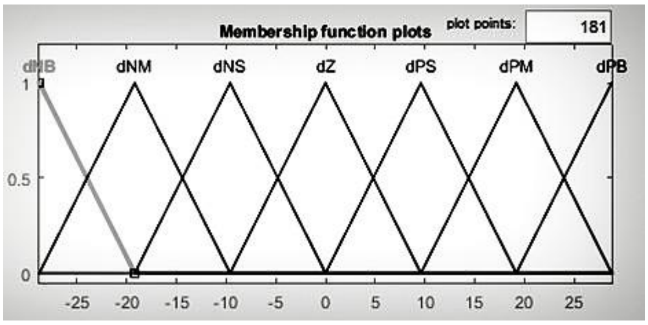


Figure 6. Membership Function Delta Error Variable

Figure 6, shows the membership function of the delta error variable with a range of -28.8 to 28.8.

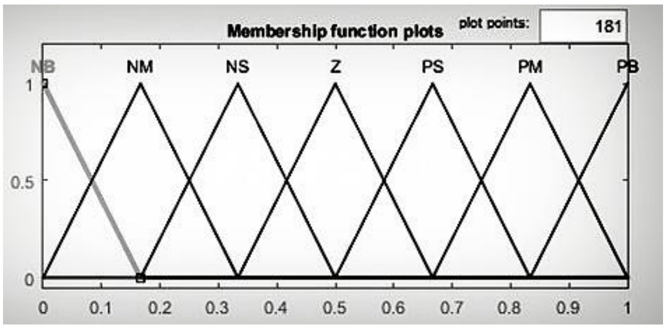


Figure 7. Membership Function Output Duty Cycle Variable

Figure 7, is a membership function of the fuzzy output in the form of a duty cycle with a range of 0 to 1. The output of the fuzzification will be processed by the fuzzy inference system by considering the predetermined rules.

Table 3. Rule Base Fuzzy

E dE	NB	NM	NS	ZO	PS	PM	PB
dNB	NB	NB	NB	NB	NM	NS	ZO
dNM	NB	NB	NB	NM	NS	ZO	PS
dNS	NB	NB	NM	NS	ZO	PS	PM
dZO	NB	NM	NS	ZO	PS	PM	PB

dPS	NM	NS	ZO	PS	PM	PB	PB
dPM	NS	ZO	PS	PM	PB	PB	PB
dPB	ZO	PS	PM	PB	PB	PB	PB

Table 3 it is the basic rule that determines the control action to determine the amount of output, namely the duty cycle. The output of the fuzzy inference system will be processed as a defuzzification input which is expressed in the form of a fuzzy set to a real number.

Defuzzification is the process of converting the fuzzy output value back into crisp output data or classical output to control objects [12]. The defuzzification method used is the Centroid method. Where the crisp solution output is obtained by taking the center point. The output is a large duty cycle value of 0 – 1 to keep the setpoint value constant, in this system 2 separate controls are used for setting the voltage point at a value of 14.4 Volts and the current set point at 6 A. As seen in the Fuzzy Logic Control circuit design as follows.

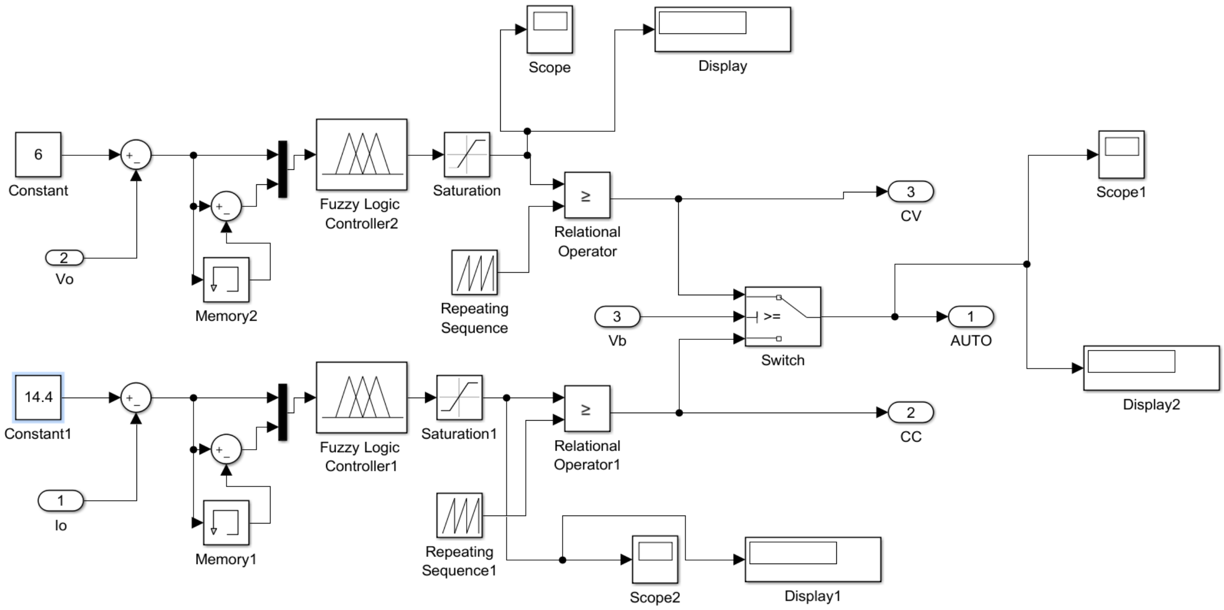


Figure 8. Fuzzy Logic Control Circuit

As seen in Figure 8. is a separate control circuit with setpoint parameters for input voltage and current. In each parameter, both voltage and current are processed into two fuzzy variables (error and delta error) to be processed into output in the form of duty cycle values. Because this system uses 2 separate fuzzy logic controls, there is a switch as a replacement from the constant current (CC) charging process to the constant voltage (CV) process.

3. Results and Discussion

The simulation is carried out by designing the use of solar cells for the charging system in the system, where the utilization of this solar cell will be seen for the output response of the Sepic converter to be used as a charging system. The following is a condition by varying the irradiation value from the solar panel which will then be simulated using the MATHLAB R2016b software. Where this simulation will be carried out in *Open Loop* and *Close Loop*.

3.1 Open Loop and Close Loop Integration Testing Simulation

The integration simulation is carried out in an *open-loop* (open circuit) and a close-loop using fuzzy logic control. An open-loop integration test simulation (open circuit) is a simulation of the entire system without control. With a solar panel source, then the solar panel output voltage will be regulated by the *sepic converter* manually with the duty cycle value that has been calculated in the *sepic converter* plan. Data retrieval in this simulation is done by changing the solar panel irradiation value in the range of 1000 W/m² to 500 W/m² while the temperature input value is constant at 25℃. Data collection on the irradiation value with a range of 1000 W/m² to 500 W/m² is carried out by considering the output voltage value that can still be generated to charge the battery with the lowest irradiation value. Equation 1 above is used to determine the output voltage value based on the input voltage. generated. Then the close loop test simulation (closed circuit) is a simulation of the entire system using controls. With a solar panel source, then the output voltage from the solar panel will be regulated by the Sepic converter to produce a charging voltage, where the output of this converter will be regulated by the duty cycle obtained from the planning design using fuzzy logic control. To find out whether the fuzzy logic control designed with the toolbox on Simulink is working well, then the simulation data retrieval is carried out with the solar panel irradiation value in 1000 W/m² to 500 W/m², by maintaining steady-state conditions when the charging method is *Constant Current* and *Constant. Voltage (CC-CV).*

Table 4. System Simulation Test Results

Irradiation (W/m²)	Open Loop				Close Loop			
	Vin (V)	Iin (A)	Vout (V)	Iout (A)	Vin (V)	Iin (A)	Vout (V)	Iout (A)
1000	20.06	3.174	14.98	4.594	36.86	6.12	14.4	5.997
950	19.95	3.156	14.89	4.568	36.78	6.08	14.4	6
900	19.83	3.135	14.8	4.539	36.7	6.07	14.4	5.999
850	19.69	3.112	14.69	4.505	36.61	6.05	14.4	5.998
800	19.52	3.084	14.56	4.465	36.52	6.01	14.4	6
750	19.32	3.05	14.4	4.417	36.42	6.01	14.4	6
700	19.07	3.008	14.2	4.355	36.32	6	14.4	5.999
650	18.73	2.95	13.93	4.273	36.2	6	14.4	5.997
600	18.24	2.869	13.55	4.156	36.08	5.99	14.4	5.99
550	17.48	2.742	12.95	3.973	35.94	5.98	14.4	5.998
500	16.34	2.551	12.06	3.699	35.8	5.98	14.4	6

In Table 4 above, the results of the simulation of the open-loop integration with the load resistor show that the converter output voltage is in the irradiation range of 1000 W/m² - 500 W/m² with a duty cycle value according to the calculation resulting in an input-output voltage and current that is not constant, this is due to the value of the duty cycle used is fixed so that when there is a change in irradiation which causes the input voltage and current to change, the resulting output voltage and current also changes quite significantly (not constant). Then for the close loop integration test simulation, the sepic converter is connected to the battery load. It can be seen in Table 4. Above for the simulation results in a close loop using fuzzy logic control the resulting voltage and current values are quite constant with changes in the irradiation value in the range of 1000 W/m² - 500 W/m², so in this case, it can be said that the control Fuzzy logic functions to generate the duty cycle value in the system that is used to adjust the output of the Sepic Converter circuit to produce the appropriate charging voltage. After getting the results of changes in irradiation and the value of the output voltage both the open loop and closed loop, then it can be seen in the graph below the relationship between changes in irradiation and the resulting output voltage.

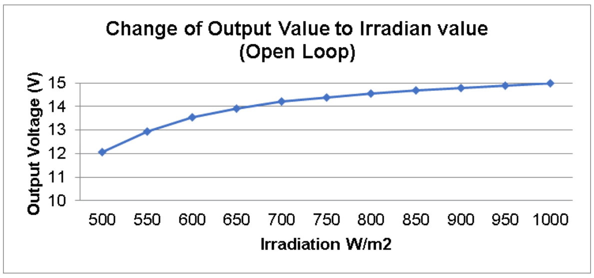


Figure 9. Graph of the Relationship of Irradiation Changes to the Resulting Output Voltage

Seen in the graph Figure 9, above is the relationship between changes in the irradiation value to the resulting output voltage, for the output voltage value increases when the irradiation value and input voltage increase.

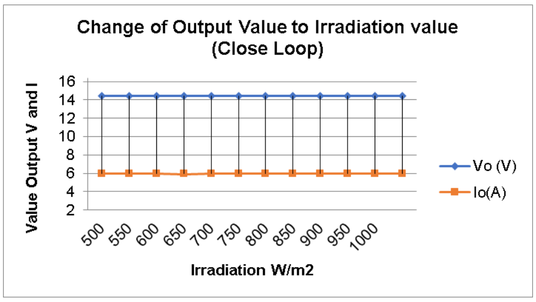


Figure 10. Graph of the Relationship of Irradiation Changes to Output Voltage & Output Current (Close loop)

As seen in the graph Figure 10, above is the relationship between changes in the value of irradiation to the value of the output voltage and output current generated, because in this study we used the Constant Current and Constant Voltage methods so that based on the results obtained, this method was used to speed up battery charging time or (Charging), this method is also used to avoid overvoltage because keeping the voltage constant at the desired setting point can maintain a stable battery condition to prevent damage to the battery. From the experimental data in Table 4. above, it has been proven that the use of Fuzzy Logic Control in the Constant Current method produces a current that is maintained constant at 6 A, and then the voltage will continue to rise until the voltage setpoint is 14.4 V, the Constant Voltage method will maintain a constant output voltage, according to the data obtained, this is by the desired theory.

The charging process during the open-loop condition and the close-loop condition produces a different charging output voltage, during the open-loop the resulting output voltage continues to increase because it has no control. Meanwhile, in the close loop condition, the output voltage produced is by the desired set point, because fuzzy logic control will produce a duty cycle that regulates the converter output to remain constant. The following is a comparison of the output voltage produced in the open-loop condition or when the close loop condition.

Table 5. Comparison of Output voltage results when Constant Voltage is Open Loop and Closed Loop

Output Voltage (*Open Loop*)	Output Voltage (*Close Loop*)
12.79 V	14.4 V
14.39 V	14.4 V
14.45 V	14.4 V
16.83 V	14.4 V
16.68 V	14.4 V

Constant Current and Constant Voltage methods used in the charging process of this system have several benefits, one of which is to maintain the stability of the battery condition, because during the charging process it is feared that overvoltage conditions will occur which cause the battery to be damaged quickly and it is difficult to keep the battery full. So that in this condition it can be seen in Table 5 above that the control when the constant voltage condition is very necessary to maintain the voltage according to the set point in maintaining the stability of the battery condition.

3.2 Close Loop Integration Testing Simulation (SOC Crash)

Close loop integration testing in the simulation to see changes in the charging method produced during the Charging Process with different SOC values. Simulation data retrieval was carried out with the solar panel irradiation value within 1000 W/m² with a variable SOC value while the temperature input value was constant at 25℃. The *state of charge* (*SoC*) on the battery will continue to increase or charge as the transition from the Constant Voltage method to the Constant Current method progresses. The transition at the maximum battery voltage is done to avoid overvoltage in the battery. *Constant current-constant voltage* is done to maximize power and speed up battery charging time. Table 5 below shows the integration simulation test data in a close loop with SOC changes.

Table 6. Integration Simulation Testing Data in Closed Loop with Changes in SOC

Irr W/m²	SOC (%)	V_{in} (V)	I_{in} (A)	V_{out} (V)	I_{out} (A)
1000	30	36.86	5.932	*13.44*	*6*
	40	36.86	5.932	*13.58*	*6*
	50	36.86	5.932	*13.66*	*6*
	60	36.86	5.932	*13.73*	*6*
	70	36.86	5.932	*13.78*	*5.99*
	80.02	36.86	5.932	*13.9*	*5.998*
	80.03	36.86	5.932	*14.2*	*5.998*
	80.054	36.86	5.932	*14.38*	*5.997*
	80.065	36.86	5.932	*14.39*	*5.997*
	80.095	36.86	5.932	**14.4**	**2.657**
	80.100	36.86	5.932	**14.4**	**1.989**
	80.103	36.86	5.932	**14.4**	**1.876**
	80.104	36.86	5.932	**14.4**	**1.787**

In Table 6 iIt can be seen that the transition occurs when the voltage is 14.4 V and the current is 6 A. The simulation test data in Table 6. above is a condition when Constant Current and Constant Voltage occur, where the Constant Current condition is shown in the yellow table, this condition maintains the current value. constantly at 6 A until the Constant Voltage transition condition is at SOC 80,066, while the green table represents a condition in the system when Constant Voltage occurs where this condition will maintain the voltage at 14.4 Volts and the current continues to decrease until it reaches full charge.

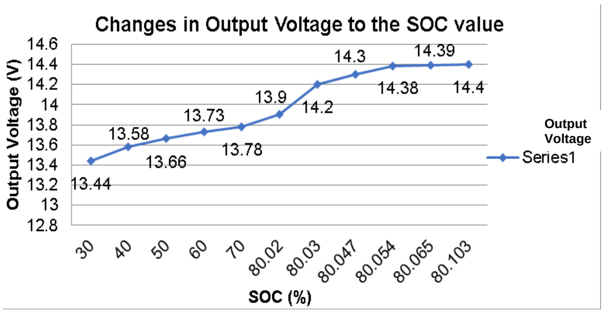


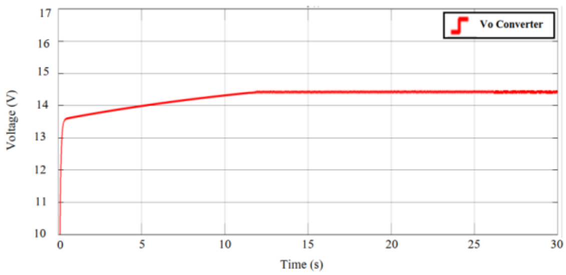
Figure 11. Graph of Relationship Changes in the output voltage value to the SOC value

As seen in the graph in Figure 11, above is the relationship between changes in the value of the resulting output voltage to the SOC value. With the same Irrationation value, at SOC 30-80% the output voltage produced has increased to the desired set point, namely at 14.4 Volts. Then from the constant current condition, it will switch to a constant voltage condition when the voltage has reached 14.4 Volts and the current which was initially kept constant at 6 A will decrease drastically, this is following the desired theory. Then the following is a simulation result of the integration of battery *charging* with the CC-CV method using *Fuzzy Logic Control*. The *charging* process is simulated as shown in Figure 12, below is carried out for approximately 36 minutes with the initial condition that will be kept constant is the current at 6 A at Constant Current condition within 14 minutes, then it will change position from constant current to constant Voltage at 14.4 Volts. The use of the CC-CV (*Constant Current - Constant Voltage*) *charging* method is used to overcome time efficiency when charging the battery, it is necessary to pay attention to the optimal battery charging time during the charging process because excessive battery charging can cause Overvoltage, causing damage to the battery and can shorten battery life. The explanation will be shown in Table 7 below, for the process of charging a battery with a capacity of 20 Ah using the CC CV method takes the following Table 7.

Tabel 7. Simulation of System Integration Testing Time in Close Loop

Charging Condition	Parameter Value Constant	Time
Constant Current	6 A	*44 minutes*
Constant Voltage	14.4 V	*78 minutes*
Constant Current – Constant Voltage	6 A then 14.4 V	*36 minutes*

Table 7, above is a comparison of the charging process when using the *Constant Current, Constant Voltage,* and *Constant Current – Constant Voltage methods*, it can be seen that from the three conditions that have been carried out for the *Constant Current* condition, it is relatively faster than the *Constant Voltage* condition, but this condition is less effective because it can cause Overvoltage, and the charging process using the *Constant Voltage* method is relatively long so that in terms of effectiveness it is not good and takes quite a long time. For the charging process using the *Constant Current - Constant Voltage* method, the efficiency of the time required is relatively less and the effectiveness is quite good because it can avoid the occurrence of Overvoltage.



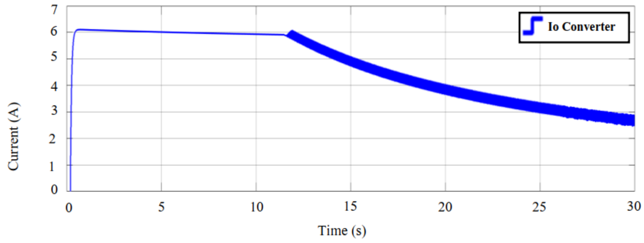


Figure 12. Simulation Results of Battery Charging Integration with CC-CV Method using Fuzzy Logic Control

In Figure 12, The output response is seen in the charging condition with constant current-constant voltage. This system uses a set point of 6 A at constant current and 14.4 V at constant voltage as charging power for the battery. The CC to CV transition occurs when the voltage reaches a maximum voltage of 14.4 V. Where these two conditions are carried out using two separate control systems.

3.3 Test Simulation with Solar Panel Irradiation Interference Conditions

After performing a test simulation with the solar panel condition being at STC or normal conditions, namely at 1000 W/m^2 and 25°C irradiation as shown in Figure 12, above, then tested with a derived irradiation value to prove the performance of fuzzy logic control. As explained in the above analysis regarding the minimum limit of the output voltage value that can be generated on changes in the irradiation value of the Solar Panel, then the following will be made a disturbance with the irradiation value below the minimum value of the output voltage that can be generated.

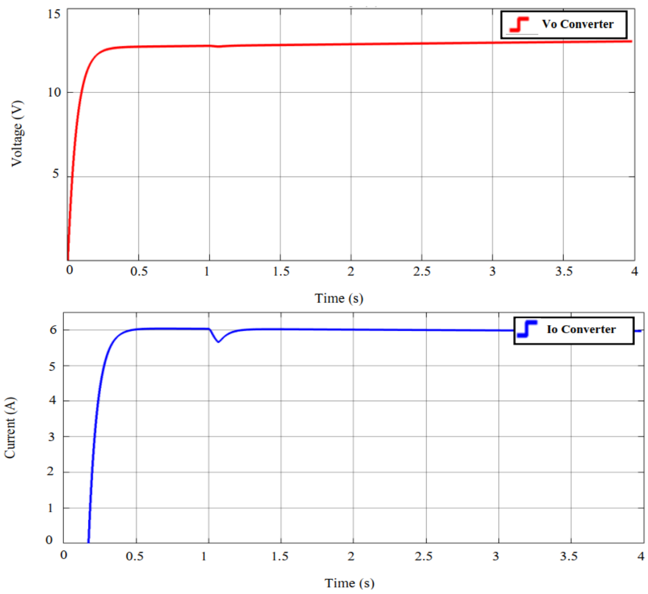


Figure 13. Voltage and Current Converter of CC-CV Mode with Irradiation Value Interruption of 200W/m2

Figure 13 is the result of a charging simulation with CC mode with interference from 1 s to 2 s, the irradiation value is reduced to 200 W/m2 with temperature 25 °C, resulting in a value by the plan, which is 6A but decreased by 5,712 A from 1 s to 1 s. 2 s and up again according to the set point of 6 A. For the simulation results of charging with CV mode with interference with the irradiation value on the solar panel, it produces a CV voltage according to the set point of 14.4 V and there is no visible decrease even though it is disturbed, due to the provision of the disturbance is still carried out in CC conditions so that what appears to be a decrease is in the current and in CV conditions the current requirement is relatively small so that the disturbance is not too significant.

Figure 14 is the result of a charging simulation with CC mode with interference from 1 s to 2 s, the irradiation value is reduced to 300 W/m2 with temperature 25 °C, resulting in a value by the plan, which is 6 A but decreased by 5,616 A from 1 s to 1 s. 2 s and up again according to the set point of 6 A. For the simulation results of charging with CV mode with interference with the irradiation value on the solar panel, it produces a CV voltage according to the set point of 14.4 V and there is no visible decrease even though it is disturbed, due to the provision of the disturbance is still carried out in CC conditions so that what appears to be a decrease is in the current and in CV conditions the current requirement is relatively small so that the disturbance is not too significant.

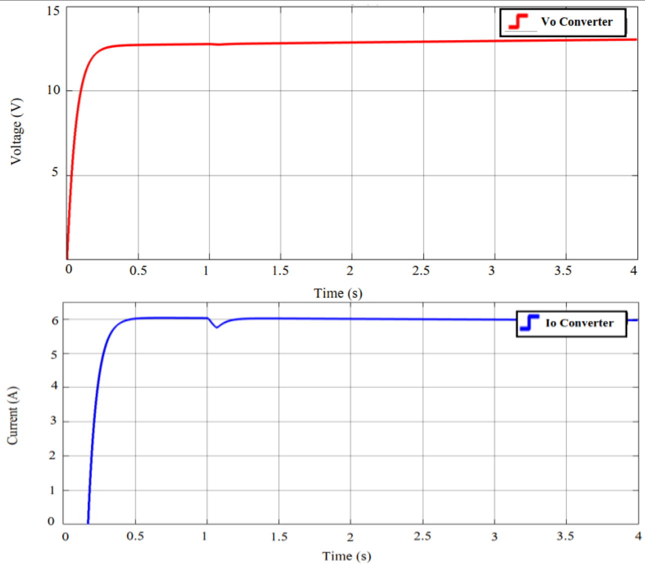


Figure 14. Voltage and Current Converter of CC-CV Mode with Irradiation Value Interruption of 300W/m2

Figure 15 is the result of a charging simulation with CC mode with interference from 1 s to 2 s, the irradiation value is reduced to 400 W/m2 with temperature 25 °C, resulting in a value following the plan, which is 6A but decreased by 5,712 A from 1 s to 1 s. 2 s and up again according to the set point of 6 A. For the simulation results of charging with CV mode with interference with the irradiation value on the solar panel, it produces a CV voltage according to the set point of 14.4 V and there is no visible decrease even though it is disturbed, due to the provision of the disturbance is still carried out in CC conditions so that what appears to be a decrease is in the current and in CV conditions the current requirement is relatively small so that the disturbance is not too significant.

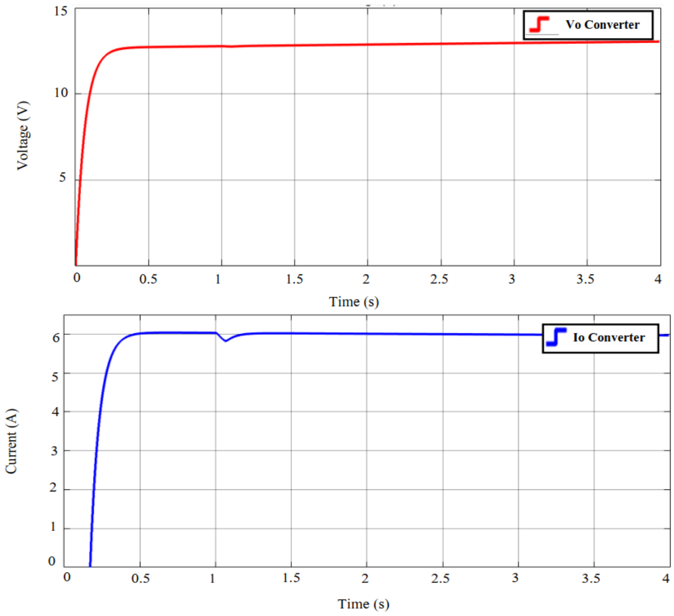


Figure 15. Voltage and Current Converter of CC-CV Mode with Irradiation Value Interruption of 400W/m2

4. Conclusion

This simulation is carried out in an open-loop condition to obtain the output voltage at a duty cycle of 44.7% with changes in the irradiation value from 1000 W/m2 to 500 W/m2. Then for conditions in the close loop or with fuzzy logic control on changes in irradiation value and changes in SOC value from constant current conditions, the current is kept constant at 6 A from soc 30 - 80 % then changes to constant voltage conditions with voltage being kept constant at 14.4 V at soc 80 % to full.

Simulationally, the Sepic converter which is controlled with Fuzzy Logic Control for charging with constant current constant voltage can maintain a constant current of 6 A under constant current conditions and a constant voltage of

14.4 V under constant voltage conditions. Because this system uses 2 battery charging methods, namely Constant Current and Constant Voltage from the simulation results obtained when this method is used to speed up battery charging so that it can overcome time efficiency when charging. When the Constant Voltage condition experiences a decrease in current starting from soc 80% to full with a fairly linear change, this condition is needed to avoid the occurrence of Overvoltage when switching from Constant Current to Constant Voltage. maintain the stability of the battery so that the battery does not get damaged quickly.

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