DC-MICROGRID DESIGN WITH PV HYBRID SYSTEM AND PLN NETWORKS FOR DC LOADS

[1]Electronics Engineering Polytechnic Institute of Surabaya, Surabaya, Indonesia
renny@pens.ac.id
[2]Electronics Engineering Polytechnic Institute of Surabaya, Surabaya, Indonesia
epyk@pens.ac.id
[3]Electronics Engineering Polytechnic Institute of Surabaya, Surabaya, Indonesia
siskaarachma@gmail.com

Renny Rakhmawati[1], Epyk Sunarno[2], and Siska Rachma Putri Syafitri[3]

Abstract - The microgrid system is an interconnected network system of various energy sources distributed into a small network that can operate independently or connected to the main network (PLN). The purpose of using the system microgrid is to create a more efficient method of generating electrical energy by utilizing renewable energy as a source of electrical energy. In this final project, a DC system microgrid with hybrid PV and PLN is made to supply a 12 V 19 W DC pump used in the pond. Two 50Wp PVs are installed in series and one 12V 33Ah lead acid battery is used as storage energy for PV output. Two 50 Wp PVs arranged in series are capable of producing a maximum voltage of up to 34 V when the irradiation value is above 1000 Wb/m^2. With the use of PID control, the buck converter is able to reduce the PV output voltage from 34 V to a constant with an average output voltage of 13.798 V. The output of the buck converter is used as the value of the voltage charging on the battery. By doing test charging a battery close loop, the original battery voltage value was 12.48 V to 12.77 V with a charging time of 80 minutes. For the backup source, namely the PLN grid, used uncontrolled fullwave rectifier is as a rectifier from 220Vac to 24 Vdc. Because the required load voltage is 12 V, used voltage regulator is which regulates the output of the uncontrolled fullwave rectifier from 24 Vdc to 12 Vdc. The process switching between the PV source and the PLN grid source is carried out using the battery voltage value parameter. When the battery voltage value is more than 11.96 V the microcontroller will condition the main source relay (PV) to be ON and the backup source relay (PLN grid) is OFF, but when the battery voltage value is less than 11.96 V the microcontroller will condition the relay. the main source (PV) is OFF and the backup source relay (PLN) is ON.

***Index Terms*— DC Microgrid, photovoltaic, PLN grid, buck converter, PID control.**

I. INTRODUCTION

Conventional energy sources or non-renewable energy sources are one of the most widely used energy sources in the world, even though they are limited in number. However, the need for energy sources is increasing day by day along with the increasing number of people who use these energy sources. Therefore, to overcome the limited number of conventional energy sources, technology is now also developing that utilizes renewable energy sources as a substitute for conventional energy sources. Based on data from the National Energy Council in 2017 Indonesia has the potential for renewable energy in the form of solar power of 207,898 MW with a total utilization of 78.5 MW or around 0.04%. As a tropical country with a fairly large area, Indonesia has the potential of renewable energy resources that are quite abundant. With Indonesia's geographical condition being at the equator, Indonesia has a radiation radiation of 4.80 kWh/m^2/day[1].

With such conditions, it is possible for Indonesia to be able to utilize sunlight as a source of renewable electrical energy. Now has developed a new method in the generation of electrical energy sources called microgrid. The concept of a microgrid network was first developed in 2002 by R, H. Lasette, where what is meant by the microgrid itself is a network of distributed generation patterns consisting of various energy sources such as fossils or renewable energy sources such as biogas, solar power, or wind[2]. The microgrid network works by interconnection between one generator and another through various energy sources which are then distributed into a small-scale network either by operating alone or by staying connected to PLN. Meanwhile, the concept of a microgrid according to the United States Department of Energy Microgrid Exchange Group is a group of loads and distributed energy resources (DER) that are interconnected within clear electrical boundaries that act as a single entity that can be controlled with respect to the grid. Microgrids are an important technology for combining distribution energy sources, including wind turbines, solar photovoltaic panels, and energy storage devices or batteries [3].

Therefore, here trying to develop a microgrid concept on a small scale to supply power to DC loads with the hope that through this system can still ensure the availability of electrical energy other than the main electrical energy source, namely from PLN grids but using renewable energy sources in the form of electricity. solar energy that can be converted to electrical energy. Besides being able to increase the generation capacity of electrical energy sources, it can also increase efficiency in the use of electrical energy required by loads which are direct current (DC).

II. METHODS

The method used in making this final project is as follows:

a. Conduct a literature study to collect references from previous research
b. Perform testing and partial data retrieval
c. Perform testing and data retrieval in an integrated manner
d. Perform data analysis from partial and integration tests

A. Diagram Block

The goal of this final project to create a DC microgrid electrical network system that can be connected between PLN grids and renewable energy. Here, what is used as the object of the renewable energy system is photovoltaic which utilizes sunlight to produce electrical power so that later it can supply DC loads.

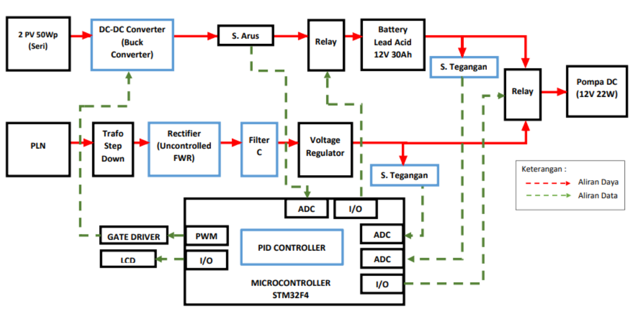

Fig 1. Diagram Block System

In the block diagram Fig1. it is explained that in the design of this final project it has two inputs or sources, namely PV and PLN grids, these two sources will work alternately in supplying the load. The load used is a DC pump which is used as a mini waterfall with a rating of 12V 19W. In PV, there is a battery that is installed to store the energy of the PV output. The battery used is a 12V 33Ah lead acid battery with a charging voltage of 13.8V. Two 50Wp PVs are used in series, where the output of this PV will be lowered by the buck converter before supplying the load. Buck converter was chosen as a voltage-lowering converter because for one 50Wp PV used in the system it can produce a maximum output of up to 17 V while the voltage value required to charge the battery before supply to the load is 13.8 V.

For the existing system at PLN, a rectifier is used as a rectifier from AC to DC. The type of rectifier used in this system is an uncontrolled fullwave rectifier with a C filter to reduce the ripple value of the rectifier output. For switching between PLN and the battery, one relay is used, where the switching process is controlled by the determination of the program.

B. Photovoltaic

PV is a field of technology and research related to devices that directly convert sunlight into electricity. Solar cells are the basic element of PV technology. Solar cells are made of semiconductor materials, such as silicon. One of the most useful properties of a semiconductor is that its conductivity can be easily modified by introducing the mixture into its crystal lattice [4]. Solar panels are components that can convert sunlight energy into electrical energy using the photovoltaic effect. The photovoltaic effect is a phenomenon of the emergence of an electric voltage due to the connection of two electrodes, in obtaining light energy the two electrodes can be connected to a solid or liquid system. The emergence of an electric current in the solar panel due to the photon energy of sunlight has succeeded in freeing the electrons in the N-type and P-type semiconductor junctions to flow.

In this final project, two 50 Wp PVs are used in series. The PV arrangement made in series is done to increase the value of the output voltage from the PV which will then be lowered by the buck converter to charge the battery.

Table 1. Spesification of Photovoltaic

Characteristic	**Value**
Peak Power	50 Wp
Maximum Power Voltage (Vmp)	17.8V
Maximum Power Current (Imp)	2.81 A
Open Circuit Voltage (Voc)	21.8 V
Short Circuit Currnet (Isc)	3.03

C. Buck Converter

DC to DC Buck-Converter is a converter that works to lower the voltage. The working principle of the Buck converter is to use a switch that works continuously (ON-OFF). Buck converter is used to lower the voltage to a voltage that suits the needs of the module.

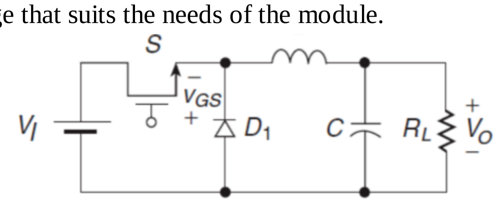

Fig 2. Circuit of Buck Converter

As shown in Figure 2. The buck converter circuit consists of several components, namely inductors, capacitors, diodes, resistors and MOSFETs as switches. When designing a buck converter, parameters are needed to get the correct component values in order to produce a good output. Using the wrong component values can result in poor output, such as the appearance of too large or too small voltage and current ripples [5].

Buck converter works on the principle of switching, there are two modes used in the switching principle of the buck converter. Namely when the switch is ON and when the switch is OFF. In the switching process, two terms will be known, namely PWM (Pulse Width Modulation) and Duty Cycle in controlling the speed (frequency) of the switch. PWM works by generating the output signal in high and low periods, setting the length of time for high and low conditions can be adjusted as needed. Meanwhile, what is meant by a duty cycle is a condition that represents a high condition in one period of a signal expressed in percent [6].

$$D = \frac{T_{ON}}{T} = \frac{T_{ON}}{T_{ON} + T_{OFF}} = f_s \,.T_{ON}$$

Where :
D = Duty cycle
T = Period
T_{ON} = Period in ON condition
T_{OFF} = Period in OFF condition
f_S = switching frequency

a. Switch ON mode

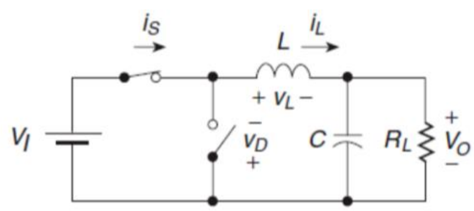

Fig 3. Buck-Converter when the switch is in the ON position

When the switch is ON, the MOSFET will be closed (ON) and the diode will be open (OFF). The current from the source will flow to the inductor to charge the inductor, then the capacitor is filtered to the load and back to the source.

b. Switch OFF mode

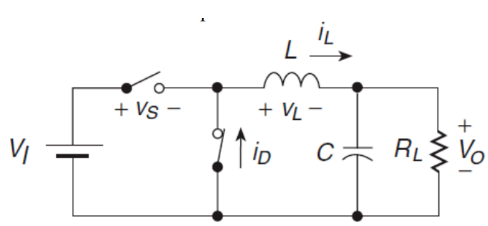

Fig 4. Buck-Converter when the switch is in the OFF position

When the switch is OFF, the MOSFET will be open (OFF) and the diode will be closed (ON). Then current flows from the source to the maximum inductor, capacitor, load and diode. The current in the inductor will drop when the transistor is turned into the ON state. The energy stored in the transistor will be transferred to the load.

D. Modelling Buck Converter

In this final project, two 50 Wp PVs are used which are arranged in series with the output voltage value of 34 Volts. Then lowered to 13.8 Volts for battery charging needs. So that the buck converter modeling is carried out with the following parameters.

$$D = \frac{Vo}{Vin}$$

$$L_{min} = \frac{(1-D)R}{2fs}$$

$$L = 10\ x\ L_{min}$$

$$C = \frac{Vo(1-D)}{8Lfs^2 \Delta Vo}$$

Where :
D = Duty Cycle
Vo = Output Voltage
Vin = Input Voltage
L = Inductor
C = Capacitor

Table 2. Parameter of Buck Converter

Vo (V)	Vin (V)	D (%)	L (mH)	C (uF)
13,8	34	40,6	17,67	270

E. Lead Acid Battery

Lead acid battery is one type of battery that is often used. The advantages of this type of battery include that it is easy to maintain so it is suitable for industry, can work with good performance for high and low temperature conditions, and is available in various capacities [7].

In this system, the battery is used as an energy store from the PV output to supply power to the load.

Table 3. Lead Acid Battery Parameters

Parameter	Nominal
Cells Per Unit	6
Voltage Per Unit	12 V
Nominal Capacity	33 Ah
Internal Resistance	Approx. 9 mΩ
Max. Charging Current	9,9 A
Float Charging Voltage	13,6 V – 13,8 V @25^{0}C
Cycle Use Voltage	14,6 V – 14,8 V @25^{0}C

F. PID Controller

PID control is implemented in the system to reduce the error value in a plant. PID control is done by calculating the difference between the output error value and the set point value (reference). In each controller P, I, and D will mutually reduce the error value of a plant.

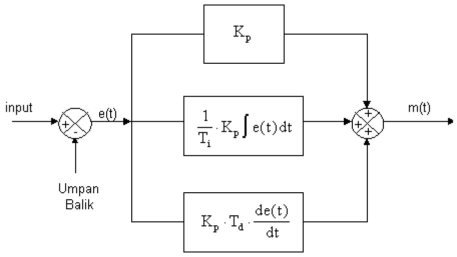

Fig 5. Block Diagram of PID Control

The PID controller is the result of the sum of the integral controller output signal and the derivative controller output signal [8]. The biggest problem in the design of the PID controller lies in the process of determining the values of Kp, Ki, and Kd. To get the value of Kp, Ki and Kd from the controller [9]. There are several methods used in the PID control system. One of them is the Ziegler Nichol Type 1 method.

Table 4. Ziegler Nichols Type 1 formulation

Tipe Pengendali	Kp	Ti	Td
P	$\frac{T}{L}$	∞	0
PI	$0.9\frac{T}{L}$	$\frac{L}{0.3}$	0
PID	$1.2\frac{T}{L}$	$2L$	$0.5L$

III. RESULT AND DISCUSSION

A. *Photovoltaic Characteristic Test*

PV testing is carried out with the aim of knowing the characteristics of PV against sun exposure on the PV surface. This needs to be done because the amount of current and voltage produced by PV is influenced by the amount of light intensity received by the PV itself. In this PV characteristic test, two 50 Wp PVs are used in series. PV characteristic testing was carried out for 7 hours with different irradiation values. Each data is taken every 1 hour from 08.00 WIB to 15.00 WIB. Tests are carried out to measure the value ofvoltage *open circuit*, current *short circuit*, voltage *output*, andcurrent *output*. From testing 50Wp solar panels arranged in series, the results and characteristics are as follows.

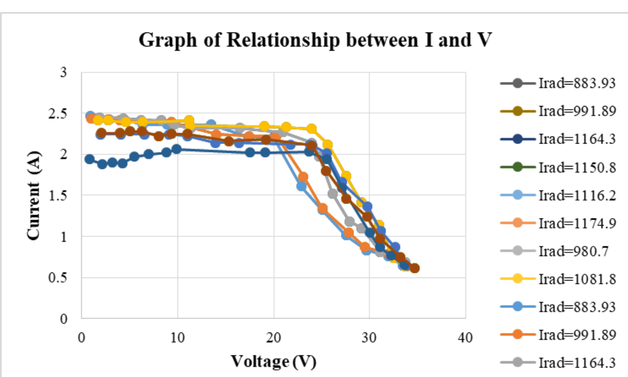

Fig 6. Graph of Relationship between I and V

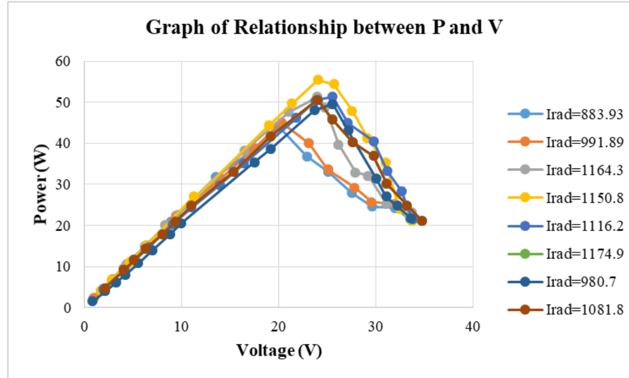

Fig 7. Graph of Relationship between P and V

PV characteristics are influenced by the magnitude of the measured irradiation value. With the irradiation value that varies in each condition, it causes the value of the PV output current and voltage to also change in value [10]. With such results, the magnitude of the irradiation value will also affect the efficiency and output power of the PV itself.

B. *Buck Converter Test*

Testing Partial buck converter is done to obtain partial data from the *buck converter* that has been made in conditions open loop. The parameters of each component for the buck converter are adjusted to the design that has been made.

Fig 8. Hardware of Buck Converter

The test is carried out by changing the duty cycle value from 10% to 80% to determine the value of the output voltage, output current, output power and efficiency of the buck converter.

Table 5. The Result of Testing Buck Converter

Duty (%)	Vin (V)	Vo (V)	Iin (A)	Io (A)
10	34,03	4,09	0,03	0,17
15	33,69	5,49	0,05	0,23
20	33,39	6,92	0,07	0,26
25	33,12	8,2	0,1	0,35
30	32,78	9,27	0,13	0,39
35	31,87	10,33	0,16	0,43
40	31,8	11,9	0,21	0,49
45	31,32	12,76	0,25	0,54
50	30,7	14,05	0,31	0,59
55	30,25	15,27	0,37	0,65
60	29,97	16,51	0,43	0,7
65	29,4	17,72	0,5	0,75
70	29,07	18,89	0,57	0,8
75	28,6	19,98	0,65	0,85
80	28,43	21,24	0,73	0,9

Table 6. Efficiency Value of Buck Converter

Pin (W)	Pout (W)	Efisiensi (%)
1,02	0,70	68,11
1,68	1,26	74,96
2,34	1,80	76,98
3,31	2,87	86,65
4,26	3,62	84,84
5,10	4,44	87,11
6,68	5,83	87,32
7,83	6,89	88,00
9,52	8,29	87,10
11,19	9,93	88,68
12,89	11,56	89,68
14,70	13,29	90,41
16,57	15,11	91,20
18,59	16,98	91,36
20,75	19,12	92,11

Based on the test results, it can be seen that the *buck converter* made in this system has succeeded in reducing the voltage *input* according to the principle of the *buck converter* itself. The greatest efficiency value for the *buck converter* that has been made is 92.11%. Where, the efficiency value is obtained when the *buck converter is* at 80% duty cycle. Based on theoretical planning, the output voltage value that should be obtained to supply the battery is 13.8V with a duty cycle of 40.6%. At the time of testing, the voltage value of 13.29 V was obtained at a duty cycle of 65%.

C. Testing the Open Loop System for Battery Charging

To test the performance of the buck converter in supplying power to the battery, a battery charging test was carried out. In testing battery charging, it is necessary to pay attention to the voltage value measured on the battery before charging and also the battery voltage value after charging.

Table 7. Battery voltage conditions for testing open loop

Before Charging	After Charging
	
Battery Voltage = 12,6 V	Battery Voltage = 12,75 V

The test of charging battery was carried out for 80 minutes to measure the current and voltage values at the input and output of the buck converter. When measuring the battery voltage, it is known that the battery voltage value before charging is 12,6 Volts and after charging is 12,75 Volts.

Table 8. The Result of Testing Open Loop System for Battery Charging

Minutes	Vin (V)	Vo (V)	Iin (A)	Io (A)
0	29,64	12,84	0,959	1,76
5	29,6	12,97	0,922	1,69
10	29,56	12,99	0,913	1,66
15	29,74	13,01	0,942	1,66
20	29,06	13.01	0,915	1,67
25	29,11	13	0,83	1,51
30	29,2	13,01	0,836	1,52
35	29,08	13,02	0,814	1,48
40	29,02	13,01	0,791	1,46
45	28,99	13,03	0,798	1,46
50	28,91	13,03	0,777	1,46
60	28,87	13,04	0,772	1,42
65	28,89	13,05	0,767	1,41
70	29,01	13,06	0,785	1,43
75	28,98	13,08	0,785	1,42
80	28,91	13,08	0,778	1,42

In planning the buck converter, the voltage value input that should be used is 34 V with the output buck converter of 13,8 V to supply power to the battery. However, when tested, the value of the voltage input drops to the range of 29 V because the supply is not possible. Therefore, the output voltage value for charging the battery also drops to the range of 13 V. In this test, it can be seen that the performance of the buck converter is in accordance with the principle, namely to lower the voltage. Where, the output of the buck converter has also been able to charge the battery. From the battery voltage value which was originally 12,6 V, it increased to 12,75 V.

D. Testing the Close Loop System for Battery Charging

Testing the buck converter with a condition closed loop system to determine the output response of the buck converter after being given control. In this final project, the control used is the PID controller. When measuring, it is known that the battery voltage value before charging is 12,49 Volts and after charging is 12,78 Volts.

Table 9. Battery voltage conditions for testing close loop

Before Charging	After Charging
	
Battery Voltage = 12,49 V	Battery Voltage = 12,78 V

The test is carried out by adjusting the values of Kp, Ki, and Kd on the *controller* to get the output value according to the *set point* of 13.8 V. The values for Kp, Ki, and Kd are 30, 15, and 0.0009.

Table 10. Data on the test results of *charging* battery *close loop* system

Minutes	Vin (V)	Iin (A)	Vo (V)	Io (A)
0	24,716	1,1	13,79	1,8
5	25,108	1,07	13,724	1,78
10	24,89	1,09	13,86	1,74
15	24,796	1,05	13,81	1,72
20	24,798	1,05	13,89	1,69
25	24,86	1,03	13,88	1,67
30	25,011	0,98	13,9	1,63
35	24,912	0,95	13,9	1,59
40	24,588	0,93	13,832	1,55
45	24,668	0,89	13,821	1,53
50	24,657	0,87	13,873	1,51
55	24,528	0,86	13,818	1,48
60	24,613	0,84	13,861	1,46
65	24,655	0,83	13,779	1,43
70	24,576	0,81	13,819	1,41
80	24,552	0,79	13,858	1,39

In planning the *buck* converter, the voltage value *input* that should be used is 34 V to supply power to the battery. However, when testing, the value of the voltage *input* drops to the range of 24 – 25 V because the supply is not possible. After using the control in the system, the process *charging* battery which was previously carried out using an output voltage of 13 V changed to a constant in the range of 13,8 V. From the effect of the control, it also affects the amount of battery capacity in charging. At the same time, the battery charging process goes up faster when done in a *closed loop* condition than in any condition *open loop*. In a condition *close loop*, with a charging time of 80 minutes, it can *charge the* battery from 12,49 V to 12,78 V.

E. *Uncontrolled Fullwave Rectifier and Voltage Regulator Test*

In this final project, a voltage rectifier from AC to DC is used to supply the load when the solar panel is not possible to supply the battery in deviating energy reserves. The type of rectifier used is an uncontrolled fullwave rectifier. The value of the rectified voltage is from 220V to 24V. Furthermore, the output of the rectifier will be set to a voltage value of 12V using a voltage regulator. Then from the output voltage Regulator Will Be Used To Supply The Load.

Table 11. The Result of Uncontrolled Fullwave Rectifier And Voltage Regulator Test

FWR		Voltage Regulator	
Vout	Iout	Vout	Iout
23.93 V	1.4 A	12.63 V	1.39 A

F. *Discharging Battery Test*

Batteries in this system are used to store energy generated by solar panels. To find out the characteristics of the battery used, a test is carried out for battery discharging.

Table 12.The Result of Discharging Battery

Jam	Tegangan (V)	Arus (A)
10:00	12.53	1.51
10:30	12.57	1.48
11:00	12.55	1.47
11:30	12.51	1.45
12:00	12.48	1.43
12:30	12.43	1.42
13:00	12.37	1.41
13:30	12.31	1.4
14:00	12.28	1.39
14:30	12.25	1.39
15:00	12.23	1.39
15:30	12.21	1.39
16:00	12.17	1.39
16:30	12.15	1.39
17:00	12.12	1.38
17:30	12.09	1.37
18:00	12.05	1.37
18:30	12	1.36
19:00	11.97	1.36
19:30	11.95	1.36
20:00	11.91	1.35

Discharging battery test is carried out to determine the value of the voltage and current from the battery within a certain period of time when the battery is used to supply power to the load. In this test, for *discharging the* battery, a 12 V 19 W DC motor load is used. The test is carried out for 7 hours from 10.00 to 20.00.

G. *Switching Test*

The switching process is carried out to regulate the supply transition from the main supply, namely the battery, to the backup supply, namely the PLN grid. There are two relays used in this switching process, namely relays for battery supply and relays for supply from PLN grids.

Table 13.The Algorithm of Relay Switching

Relay	Parameter	
	Battery > 11.96 V	Battery ≤ 11.96 V
Battery	ON	OFF
PLN	OFF	ON

Table 14.The Result of Switching Test

Nilai Tegangan (V)		Kodisi Relay	
Baterai	Rectifier	Baterai	PLN
12.47	12.66	ON	OFF
12.39	12.67	ON	OFF
12.21	12.64	ON	OFF
12.09	12.66	ON	OFF
11.94	12.67	OFF	ON

The function of the relay to carry out the switching process can be known through the flashing of the indicator light on the relay. When the relay is active, the indicator light will light up. And also, when the relay is not active, the indicator light will turn off. The switching process is carried out using the battery voltage parameter. When the battery voltage exceeds 11.96 V, the load on the system will be supplied by the battery. However, when the voltage is below 11.96 V, the load on the system will be supplied from the PLN grid which is rectified by the rectifier. The switching process that occurs between the PV source and the PLN source will experience a delay of a few seconds as a form of response from the relay when it is working. Therefore, the pump will shut down for a few seconds when the switching process between the PV source and the PLN source occurs.

IV. Conclusion

After going through several processes of planning, making, and collecting data obtained from this final project, it can be concluded several things, namely:

1. PV characteristics are influenced by the magnitude of the measured irradiation value. With the irradiation value that varies in each condition, it causes the value of the PV output current and voltage to also change. The irradiation value will also affect the efficiency and output power of the PV itself.
2. In testing the buck converter with hardware functionally has been achieved, namely with an input of 30.7 V, it has been able to reduce the voltage to 14.05 V with a duty cycle of 50%.
3. When compared, with the same charging time of 80 minutes. The process of charging the battery in a closed loop condition is able to increase battery capacity faster than in an open loop condition.
4. Two relays work as switching between the battery and the PLN grid, when the battery voltage is less than 11,96 V, the microcontroller will condition the main source relay ON and the backup source relay OFF.

References

[1] Kementerian ESDM, “Jurnal Energi,” 2016, Available: https://www.esdm.go.id/assets/media/content/FIX2_Jurnal_Energi_Edisi_2_17112016(1).pdf.

[2] Budiyanto and R. Setiabudy, “Jaringan mikro arus searah (dc microgrid) sebagai upaya ketersediaan energi listrik dalam pengembangan energi terbarukan,” *Semin. Nas. Sains dan Teknol. Univ. Muhammadiyah Jakarta 2014*, no. November, pp. 1–7, 2014.

[3] Z. Miao, L. Xu, V. R. Disfani, and L. Fan, “An SOC-based battery management system for microgrids,” *IEEE Trans. Smart Grid*, vol. 5, no. 2, pp. 966–973, 2014, doi: 10.1109/TSG.2013.2279638.

[4] Pratiwi, Armadilla and Nugraha, Syechu and Sunarno, Epyk, “Desain dan Simulasi Bidirectional DC-DC Converter untuk Penyimpanan Energi pada Sistem Fotovoltaik”, Jurnal Nasional Teknik Elektro dan Teknologi Informasi, 2020, 9. 305-310. 10.22146/.v9i3.377

[5] Alim, Muhammad and Windarko, Ayub and Rakhmawati, Renny, “Fuzzy Logic Control Design On Buck Converter For Thermo Electric Air Cooler Power Supply”, JAREE (Journal on Advanced Research in Electrical Engineering), 2020, 4. 10.12962/j25796216.v4.i2.137.

[6] Pulungan, Ali Basrah and Sukardi and Ramadhani, Taslim, “Buck Converter Sebagai Regulator Aliran Daya Pada Pengereman Regeneratif”, Jurnal EECCIS, [S.l.], v. 12, n. 2, p. pp. 93-97, nov. 2018. ISSN 2460-8122.

[7] Barkah, Rahma, “Simulasi Charge Discharge Model Baterai Lead Acid”, Jurnal Ilmu dan Inovasi Fisika, 2019, 3. 128-134. 10.24198/jiif.v3i2.23257.

[8] N. T. Mooniarsih, “Simulasi dan Analisis Kinerja Prediktor Smith pada Kontrol Proses yang Disertai Tundaan Waktu,” *Elkha*, vol. 8, no. 2, pp. 6–13, 2016, doi: 10.26418/elkha.v8i2.18287.

[9] Rakhmawati, S. T.; MT, Renny, “Mobil Pintar Dengan Pid-fuzzy Sebagai Pengatur Kecepatan Berdasarkan Keramaian”, *Jurnal Fakultas Hukum UII*, 2008.

[10] Surya Negara, I B Kd; Arta Wijaya, I Wayan; Maharta Pemayun, A A Gd, “ANALISIS PERBANDINGAN OUTPUT DAYA LISTRIK PANEL SURYA SISTEM TRACKING DENGAN SOLAR REFLECTOR. Jurnal SPEKTRUM”, [S.l.], v. 3, n. 1, p. 7-13, mar. 2016. ISSN 2684-9186.