# Dc Microgrid Network Design For Household Dc Load Management

Electronics Engineering Polythecnic Institute of Surabaya, Surabaya, Indonesia
renny@pens.ac.id
Electronics Engineering Polythecnic Institute of Surabaya, Surabaya, Indonesia
mahadi@pens.ac.id
Electronics Engineering Polythecnic Institute of Surabaya, Surabaya, Indonesia
fitri.handayani2897@gmail.com

Renny Rakhmawati[1], Putu Agus Mahadi Putra[2], and Fitri Handayani[3]

**Abstract -** Pembangkit Listrik Tenaga Surya or called PLTS Microgrid is one solution to meet the needs of electricity. Microgrid is a system designed by utilizing 2 sources of electrical energy, one of the energy sources can be obtained from PV with a PLN grid source. In this system, the management is carried out with different treatments on each load. For lights and fans, the load is regulated by the PIR sensor. both will light up when the sensor detects the presence of humans. Meanwhile, the charger itself can be used at any time. The microgrid system can work with a switching process for 1 second with the condition that when the voltage on the battery is less than 12,1 V, the system will receive a supply from PLN. PV is capable of charging the battery with a voltage in the morning and afternoon of 18V with the output voltage generated by the Buck Boost Converter still not reaching the set point, which is still at 12,5 v until 13 V. This is due to the control on the hardware still not working perfectly. The use of PIR sensors to regulate load ignition can reduce excessive load usage. In this system the current sensor readings are not good when integration testing is carried out, so the load power that is read does not match the power in the plan, which is 8 W while in the planning it is 26 W.

***Index Terms*— Battery, DC Microgrid, Management, Photovoltaic, PLN, STM32F4.**

## I. Introduction

INDONESIA is a tropical country that has abundant heat energy because it gets sunlight all year round. This has become a potential to be used as a source of electricity which is generally known as a *solar cell*. Utilization of solar energy as a source of electricity can be designed in several types of systems, namelysystems *on grid, hybrid,* and *off grid*. Based on Law No. 30 of 2015 concerning Energy, it states that the condition of electricity in Indonesia is in a critical condition. The increasing demand for electricity that is faster than the ability to meet the supply of electrical energy causes electrical problems. The increase in electrical energy capacity is 5.1% (KEN, 2011) while the need for electrical energy is 7.2%. This shows that there is a need for the use of renewable energy that can increase the supply of electrical energy, one way that can be done is by utilizing solar energy. With Indonesia's location at the equator, Indonesia will get sunlight for 10 to 12 hours. Therefore, in this final project utilizing solar power as an alternative to be used as a *supply* of electrical energy.

Currently, the use of electrical energy has become a basic need for humans. A common electrical problem is the consumption of power that exceeds its capacity, causing *an overload*. The power consumption of the load must not exceed the specified current limit, because when the load power increases, there will be an increase in current and can make the system stop. So it is necessary to regulate the load to avoid such things from happening to maintain the *continuity of the* system.

The microgrid network with ansystem *on-grid* is one of the efforts that can be done to increase the supply of electrical energy, as well as being an alternative electrical energy that can be used to reduce household energy consumption, especially DC loads, so that it is expected to save the use of electrical energy. However, the use of power that cannot be controlled according to the user's wishes because it can affect the performance of electronic equipment, so that what can be done is to control energy consumption by monitoring the amount of consumption regularly. Therefore, in this final project, a microgrid network will be designed using ansystem *on-grids*, namely utilizing 2 sources of electricity from PLN and utilizing solar power.

## II. METHODS

The methods used in this final project research are as follows:

a. Conducting literature study to collect references and development of previous research.
b. Perform partial tool testing
c. Perform integration testing of tools to determine whether the system is running according to the plan
d. Perform characteristic data analysis and from testing

### A. Diagram Block

The goal to be achieved in working on this final project is to create a system or tool that can work according to the plans that have been made. That is asystem *microgrid* with two sources, namely PLN and PV, which is expected to be able tosystem *switch the* with certain parameters that have been planned.

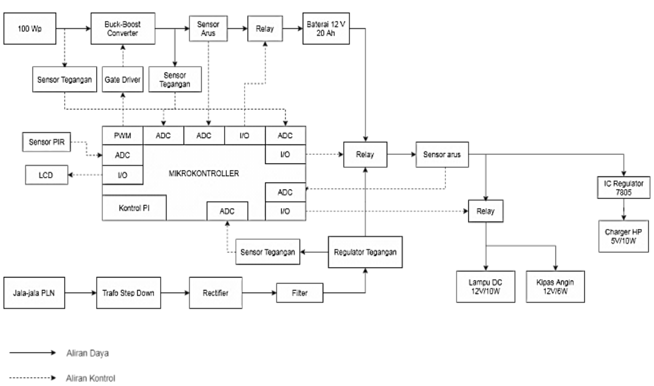


Fig. 1 Diagram Block System

### B. Characteristic Photovoltaic

PV is used as a medium to receive sunlight which is then used to convert it into electrical energy using the principle of theeffect *photovoltaic.* The characteristics for the amount of power that can be emitted by PV depends on the level of light intensity and temperature received on the PV surface.

Table 1. Specification of Photovoltaic

| Characteristic | Value |
|---|---|
| Maximum Power (Pmax) | 100 W |
| Power Tolerance | 3% |
| Maximum Power Voltage (Vmp) | 17,80 V |
| Maximum Power Current (Imp) | 5,62 A |
| Open Circuit Voltage (Voc) | 21,8 V |
| Short Circuit Current (Isc) | 6,05 A |

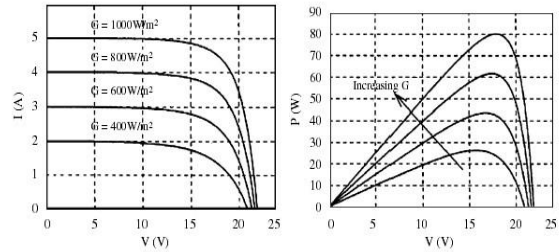


Fig. 2 Effect of Sunlight Intensity on Solar Cells Graph IV (left) and PV Graph (right)

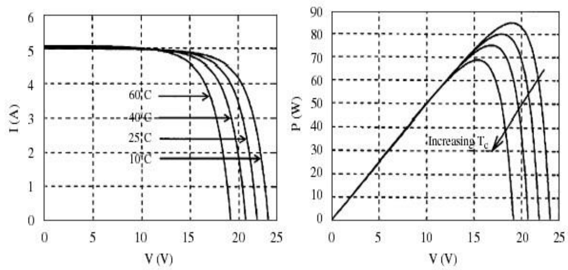


Fig. 3 Effect of Temperature on Solar Cells Graph IV (left) and PV Graph (right)

### C. Buck-Boost Converter

*Buck-Boost Converter is a type of converter that can produce anvoltage output that is lower or higher than the input voltage. In the buck-boost converter the polarity of the output voltage is reversed with the input voltage. Figure 4 is a circuit of a buck-boost converter.*

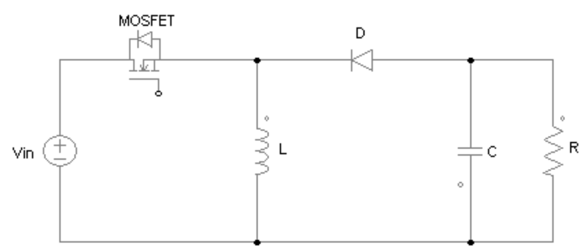


Fig. 4 Circuit of Buck-Boost Converter

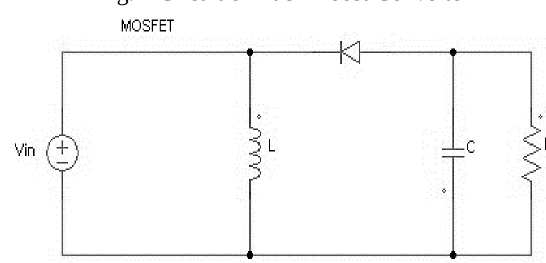


Fig. 5 Buck-Boost Circuit when switch closed and diode off

When the gate mosfet obtains saturation voltage, the mosfet can function the same as a switch. The diode will open at t=0s. The current flowing through the inductor will increase. Because the voltage across the capacitor is 0 causing the load to not get a supply [5]. This is shown by Figure 5.

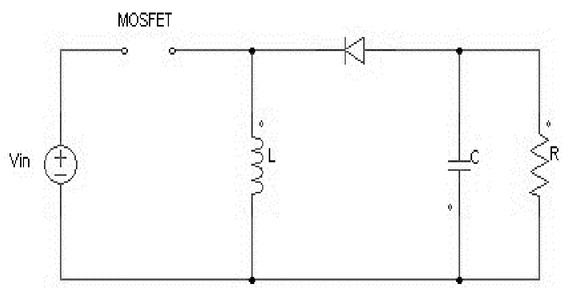


**Fig. 6** Buck-Boost circuit when switch opened and the dioda on

In thecircuit mode buck-boost converter when the switch is open and the diode is on when the switch is off. The diode will forward and provide current to the inductor so that current appears in the circuit, which flows from the inductor to the capacitor and load. The inductor current will decrease and flow to the load [5]. The equivalent circuit for these conditions is shown in Figure 6.

From the explanation above, the equation for the output voltage is obtained as follows:

$$Vo = -Vin.\left(\frac{D}{1-D}\right)$$

Where:
Vo = Output Voltage
Vin = Input Voltage
D = Duty Cycle

With the provisions for Buck-Boost Converter are as follows:

1. If the duty cycle is less than 0.5 it will function as buck
2. If the duty cycle is more than 0.5 it will function as a boost

*D. Modelling Buck-Boost Converter*

With a maximum PV voltage of 17.8 V, a characteristic test has been carried out so that the minimum irradiation voltage is 14.3 V. The purpose of selecting the voltage when the minimum irradiation is so that the system can still work when the voltage is low. The converter will be connected to a battery with a voltage of 12 V with a charging current of 13.8 V. Based on these data, other parameters will be obtained through the following equation:

$$L = \frac{1}{f}(Vo + Vf)x\frac{Vsmin}{VsminxVoxVf}x\frac{1}{\Delta iL}$$

$$C = \frac{D}{\pi rf}$$

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

Tabel 2. Parameter of Buck-Boost Converter

| **Vin (V)** | **Vo (Vo)** | **L** | **C** |
|---|---|---|---|
| 14,3 | 13,8 | 76,88µH | 14,206mF |

*E. Battery*

In this system the battery is used as an energy storage medium from the PV which will then be used to supply the load.

Table 3. Specification of Battery

| **Parameter** | **Nilai** |
|---|---|
| Floating Use | 14,5 – 14,9 V |
| Cycle Use | 13,6 – 13,8 V |
| Initial Current | Less than 6A |

*F. PI Control*

Control PI atau pengendali PI merupakan sistem pengendali gabungan antara pengendali *proportional* dan pengendali *integral.* Dalam waktu c*continue*, sinyal keluaran dari pengendali PI dapat dirumuskan sebagai berikut[7]:

$$u(t) = K_p\left(e(t) + \frac{1}{T_i}\int_0^t e(t).dt\right)$$

Keterangan :
u(t) = sinyal keluaran pengendali PI
$K_p$ = konstanta proporsional
$T_i$ = waktu integral
$K_i$ = konstanta integral
e(t) = sinyal kesalahan
e(t) = referensi – keluaran *plant*

sehingga fungsi alih control atau pengendali PI dapat dinyatakan dalam persamaan sebagai berikut :

$$G_c(s) = K_p + \frac{K_i}{s}$$

Untuk diagram blok dari control PI digambarkan seperti dibawah ini :

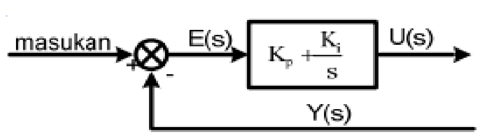


Fig. 7 Diagram Block of PI Control

## III. RESULT AND DISCUSSION

*A. Photovoltaic Characteristic Test*

Testing of solar panels is carried out with the aim of knowing the characteristics of the panels against exposure to sunlight on the surface of the panels. This needs to be done because the amount of current generated by the solar panel is influenced by the amount of light intensity received by the solar panel. From this test, the PV . characteristic graph is obtained.

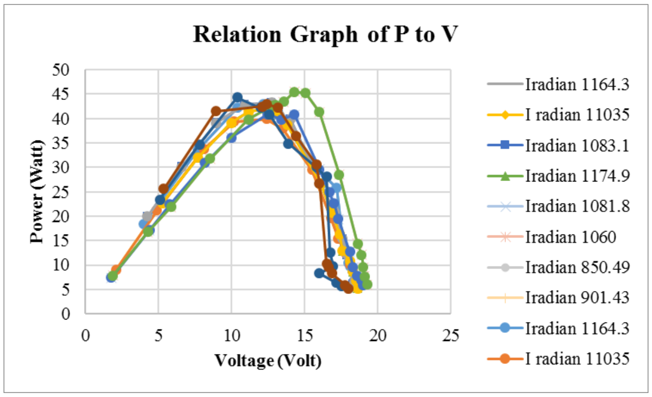


Fig. 8 Relation Graph of Power to Voltage

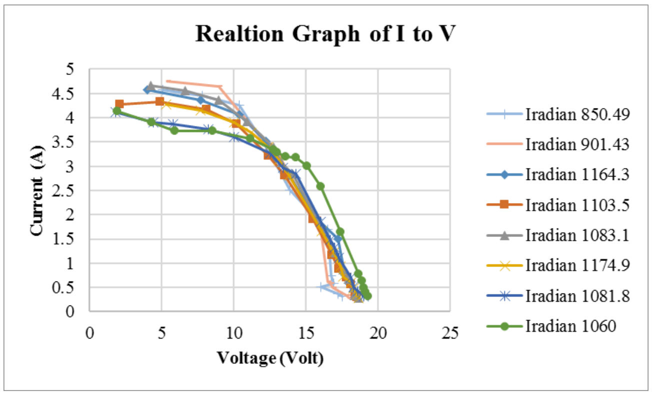


Fig 9. Relation Graph of Current to Voltage

*B. Buck-Boost Converter Test*

The test Buck-Boost Converter serves to determine the function and how the converter responds when an input voltage is given according to the design that has been made, by changing the duty cycle variable. In testing the buck-boost converter is done in an open loop.

Table 4. Data of Buck-Boost Conveerter

| D (%) | Vin Conv. (v) | Vo Conv. (v) | Effisiensi (%) |
|---|---|---|---|
| 10 | 14,12 | 1,736 | 67,620 |
| 15 | 14,1 | 2,563 | 73,618 |
| 20 | 14,08 | 3,441 | 66,596 |
| 25 | 14,04 | 4,252 | 67,888 |
| 30 | 13,96 | 4,99 | 70,596 |
| 35 | 13,96 | 5,196 | 60,948 |
| 40 | 13,79 | 7,55 | 72,847 |
| 45 | 13,58 | 8,9 | 70,112 |
| 50 | 13,31 | 10,6 | 71,463 |
| 55 | 11,18 | 10,34 | 68,029 |
| 60 | 10,74 | 11,8 | 66,453 |
| 65 | 10,18 | 13,06 | 63,006 |
| 70 | 9,44 | 13,9 | 58,043 |

Based on Table 4.10, data is obtained that the converter can increase and decrease the voltage, where the converter will work to reduce the voltage at a duty cycle of 10% to 55% and will start to increase the input voltage when the duty cycle is above 55% or start at a duty cycle of 60%. In testing this converter, the average error presentation is 19.196%. With the highest converter efficiency reaching 73.618%. Based on the design that has been made, the expected output value is when the duty cycle is 49% with an input of 14.31V, the output voltage is 13.8 V. Based on Table 4.10 the desired output voltage of 13.8% can be achieved when the duty cycle is 70% with a voltage input 9.44 V. which means that the converter will work on the boost side.

*C. Open Loop Test for Charging Battery*

Charging the battery is done using a buck-boost converter as a charger. The charging parameter is carried out when the battery voltage value has reached a voltage of 12.1 V, which is at 50% battery SOC condition. This test is carried out in an open loop, that is without using controls.

Table 5. Data of Open Loop Test

| Waktu | Vin(V) | Vo(V) | Io(A) | Po(W) |
|---|---|---|---|---|
| 10:00 | 18,83 | 12,52 | 1,578 | 19,757 |
| 10:15 | 18,86 | 12,55 | 1,575 | 19,766 |
| 10:30 | 18,86 | 12,58 | 1,568 | 19,725 |
| 10:45 | 18,85 | 12,59 | 1,563 | 19,678 |
| 11:00 | 18,86 | 12,61 | 1,558 | 19,646 |
| 11:15 | 18,86 | 12,63 | 1,547 | 19,539 |
| 11:30 | 18,86 | 12,65 | 1,536 | 19,430 |
| 11:45 | 18,89 | 12,67 | 1,525 | 19,322 |
| 12:00 | 18,89 | 12,71 | 1,514 | 19,243 |

In the charging test using this PV source, an experiment was previously carried out to test in the afternoon, at 15:00 WIB but the output voltage from the PV was unable to supply the system, so this test was carried out to collect data at 10:00 WIB until 12:00 WIB as sample data to determine whether PV is capable of charging the battery. Data collection was carried out in 15 minute steps, so that in 2 hours of testing, the PV output voltage was stable at 18.8 V and the output voltage for the first charging was 12.52 V. The battery was charged for 2 hours from 12.52 V to 12.71 V with the current getting smaller and smaller.

*D. Close Loop Test for Charging Battery*

Close Loop Test is a converter test using control. In this final project, PI control is used. The purpose of using this PI control is to adjust the output voltage to match the set point so that the voltage is constant.

Based on the results of the close loop test, data obtained that the PI control on the buck-boost converter can already run. The desired set point of the system is 13.8 V which will be used as the charging voltage for the battery. In the test, the output voltage is 10.04 V to 10.7 V. However, when the voltage is increased, the input voltage will drop and the current will increase. This is because the DC supply used only has a current rating of 5A with a maximum voltage of 25 V while the converter used is a buck-boost type so that when the voltage drops, the control will work to catch up to the set point.

*Close loop test also doing with simulation use MATHLA Software.*

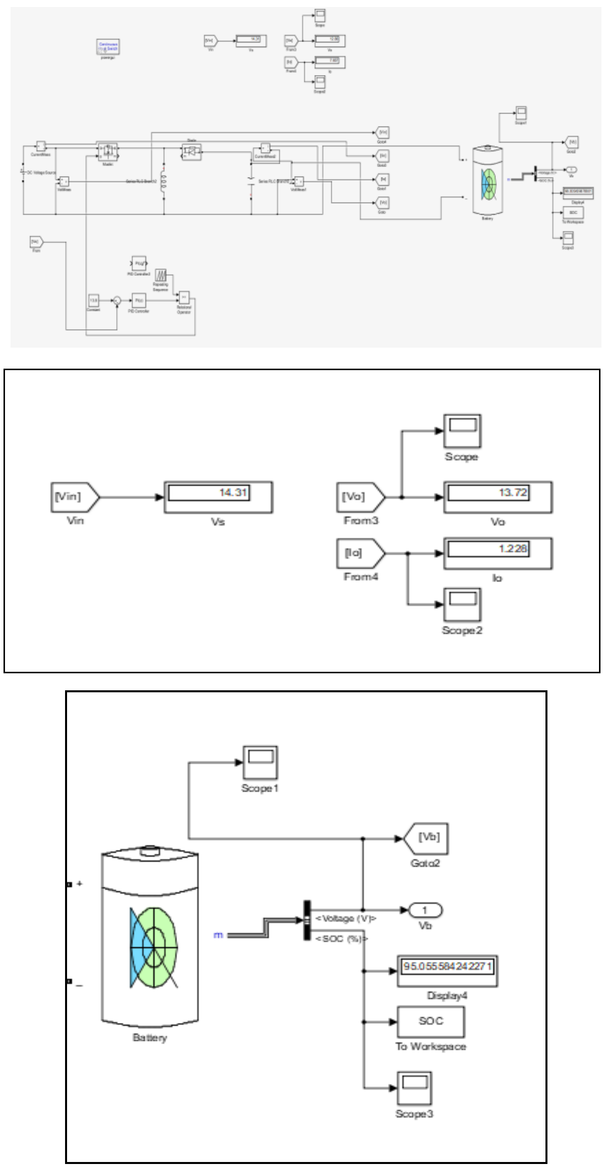


Fig. 10 Close Loop Simulation with MATHLAB

Based on the simulations that have been carried out, it is obtained data that with an input voltage of 14.3 V and when the SOC of the battery is 95%, the resulting output voltage is 13.72 V. While the desired set point voltage is 13.8 V so that there is an error of 0.57%.

*E. Discharge Test*

In this battery test there is a charging and discharging process. Charging is the process when charging the battery through the converter. As for the discharging process, that is when the battery is used as a load supply.

Table 6. Data of Discharge Test

| Waktu | Vbatt(V) | Ibatt(A) | Po (W) |
|---|---|---|---|
| 11:15 | 12,68 | 1,11 | 14,075 |
| 11:30 | 12,66 | 1,11 | 14,053 |
| 11:45 | 12,63 | 1,1 | 13,893 |
| 12:00 | 12,6 | 1,09 | 13,734 |
| 12:15 | 12,57 | 1,08 | 13,576 |
| 12:30 | 12,55 | 1,08 | 13,554 |
| 12:45 | 12,54 | 1,08 | 13,543 |
| 13:00 | 12,52 | 1,07 | 13,396 |
| 13:15 | 12,52 | 1,07 | 13,396 |
| 13:30 | 12,5 | 1,07 | 13,375 |
| 13:45 | 12,47 | 1,07 | 13,343 |
| 14:00 | 12,46 | 1,06 | 13,208 |
| 14:15 | 12,44 | 1,06 | 13,186 |
| 14:30 | 12,42 | 1,05 | 13,041 |
| 14:45 | 12,39 | 1,05 | 13,010 |
| 15:00 | 12,38 | 1,05 | 12,999 |
| 15:15 | 12,35 | 1,05 | 12,968 |
| 15:30 | 12,33 | 1,05 | 12,947 |
| 15:45 | 12,31 | 1,04 | 12,802 |
| 16:00 | 12,29 | 1,04 | 12,782 |
| 16:15 | 12,29 | 1,04 | 12,782 |
| 16:30 | 12,28 | 1,03 | 12,648 |
| 16:45 | 12,25 | 1,03 | 12,618 |
| 17:00 | 12,23 | 1,02 | 12,475 |
| 17:15 | 12,2 | 1,02 | 12,444 |
| 17:30 | 12,18 | 1,01 | 12,302 |
| 17:45 | 12,16 | 1,01 | 12,282 |
| 18:00 | 12,15 | 1 | 12,150 |
| 18:15 | 12,14 | 0,99 | 12,019 |
| 18:30 | 12,11 | 0,99 | 11,989 |
| 18:45 | 12,09 | 0,99 | 11,969 |

Based on the data obtained in Table 4.22, it can be seen that the battery voltage will continue to decrease with increasing time as well as the current. The final condition of battery charging in Table 4.18 is 12.71 V but at the beginning of the discharging process the battery voltage condition is 12.68 V. The difference in this value is because the amount of voltage measured during the charging process is the voltage at the output converter, where the battery condition which is still connected to the network. While the voltage condition of the battery when the circuit is not connected is 12.68 V as the initial condition of the discharge process.

### *F. PIR Sensor Test*

The PIR sensor is a motion sensor which detects human movement by detecting it using infrared light. The function of the PIR sensor here is to detect if there are people in the room, so that it will control the lighting of the lights and fans. From the test results the sensor can detect when there is movement around the sensor and is very sensitive.

### *G. Switching*

The microgrid in this final project consists of two sources, namely PLN and PV. Where in this system a battery is used, so the switching process uses the voltage parameter on the battery. The voltage parameter for switching between PLN and the battery is by using a voltage of 12.1 V. Where the voltage is 12.1 V when the SOC condition of the battery is 50%. Determination of 50% battery SOC is to avoid battery damage caused by too long use. Because the battery working area is at 100% -40% SOC conditions [8].

Switching is done by relay, where when the battery voltage is < 12.1 V, the system will get a supply from PLN. However, when the battery voltage is > 12.1 V, the system or load will get a supply from the battery. Then when the battery undergoes a charging process and has reached a voltage of 12.9 V, the system will automatically be supplied by the battery again. switching speed between PLN and the battery is 1 second.

Table 7.Integration Data

| **Sensor PIR** | **V bat (V)** | **Vrec (V)** | **IL (A)** | **P (W)** | **PLN** | **Baterai** | **Beban ON** |
|---|---|---|---|---|---|---|---|
| ON | 12,4 | 12,11 | 0,671 | 8,367 | OFF | ON | Lampu, Kipas, Charger HP |
| ON | 12,05 | 12,11 | 0,671 | 8,126 | ON | OFF | Lampu, Kipas, Charger HP |
| OFF | 12,4 | 12,11 | 0,322 | 3,993 | OFF | ON | Charger HP |
| OFF | 12,05 | 12,11 | 0,322 | 3,899 | ON | OFF | Charger HP |

## IV. CONCLUSION

From the system that has been worked on starting from planning to obtaining test data, both partial and integration, the following conclusions can be drawn:

1. To design a DC microgrid with PLN and PV grid sources, a converter is needed as a DC rectifier on the PV side and a rectifier and a voltage regulator on the PLN side to be able to produce an output voltage of 12 V.
2. Switching from battery to PLN has been running according to the plan, which occurs when the battery voltage is 12.1 V with a switching speed of 1 second.
3. Buck-Boost Converter can be used for the 20Ah battery charging process but the battery charging voltage is not in accordance with the set point, which is still in the range of 12.5 V – 13 V.
4. At the time of integration testing, the ACS712 sensor was not good at reading so that the amount of power displayed was 8.367 W which was not in accordance with the load power, which was 26 W.

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