V2G And G2V System Design As An Alternative Power On Microgrid With Smart Switching Method Based On Microcontroller

1st Alvian Aji Pangestu
Dept. of Electrical Engineering
Sebelas Maret University
Surakarta, Indonesia
alvianaji18@student.uns.ac.id

2nd Muhammad Nizam
Dept. of Electrical Engineering
Sebelas Maret University
Surakarta, Indonesia
muhammad.nizam@staff.uns.ac.id

3rd Agus Ramelan
Dept. of Electrical Engineering
Sebelas Maret University
Surakarta, Indonesia
agusramelan@staff.uns.ac.id

***Abstract*—Solar energy is very easy to get in Indonesia because it is located in the tropics and equatorial regions. With the abundance of solar energy, the PLTS system is very suitable for use in Indonesia. Apart from these advantages, the microgrid system with a PV mini-grid still has drawbacks, namely intermittent sun exposure, so the reliability of the PV mini-grid system is affected by time, climate, and weather. Therefore, the PLTS system requires electrical energy storage technology in the form of batteries. In addition to the use of batteries, the use of battery electric vehicles (BEV) can also be used as an alternative to help supply power to the microgrid system. Its application uses the Vehicle to Grid (V2G) and Grid to Vehicle (G2V) methods. In this study, the design of the V2G and G2V systems was made with the Smart Switching method as an alternative power source to the microgrid system. The Smart Switching method is used to consider the condition of the battery to prevent overheating, overcharging, and deep discharging. It is equipped with a battery condition monitoring system that can be monitored on the LCD screen. The results of this study showed that the design of the V2G and G2V switching systems can run according to the plan. The system can provide power to the microgrid busbar. The system can automatically cut off when the maximum temperature, the upper and lower limits of the battery voltage, and the monitoring system can provide information in the form of battery conditions, temperature values, voltages, and currents. Thus, the V2G and G2V systems with the Smart Switching method can already be applied as an alternative power source to the microgrid system.**

Keywords - PLTS, V2G and G2V, Overheat, Over Charge, Deep Discharge, Smart Switching.

I. Introduction

In the territory of Indonesia, energy from sunlight is very easy to obtain because Indonesia is a tropical area and is located on the equator [1]. With the abundance of solar energy, the microgrid system with a Solar Power Plant (PLTS) is very suitable for use in Indonesia. Apart from the advantages of energy conversion, and abundant electrical energy, microgrid systems with PV mini-grid still have drawbacks, namely low solar illuminance, and intermittent sunlight, so that PV mini-grid systems are affected by time, climate, and weather. Therefore, the PLTS system requires technology that can store electrical energy in the form of batteries [2].

In 2019 the Indonesian government intensified the manufacture of electric vehicles as regulated in Presidential Regulation (Perpres) Number 55 of 2019 as an effort to realize the clean energy transition and reduce the use of fossil fuels. Therefore, the use of electric vehicles in Indonesia is increasing. Use of electric vehicles can be used as an alternative to help supply power so that it can improve from the microgrid system. The application uses Vehicle to Grid (V2G) and Grid to Vehicle (G2V), the V2G method is the process of moving from an electric vehicle to the network called power transfer (discharging) and the G2V method is a transfer from the network to electricity by charging. [3][4].

The use of Battery Electric Vehicles (BEV) needs to be considered, especially the temperature and switching systems so that they are not damaged quickly. To prevent damage to the battery, we need a controller that functions to complete the G2V process when the battery is fully charged and can discharge the battery for electrical energy to the load when needed, then can stop the V2G process when the battery runs out and can stop V2G and G2V when the battery hot.

This tool will run using 2 modes, namely G2V mode and V2G mode using the smart switching method. Smart Switching is a system that can work automatically for charging and discharging and is equipped with a temperature, voltage, and current monitoring system for batteries and PV. The advantage of this system is that it regulates the G2V and V2G energy processes in the battery automatically with a temperature cut-off system, the upper and lower limits of the battery so that overheating, overcharging, and deep discharging does not occur.

Based on the problems above, the researcher focuses on designing V2G and G2V systems with the Smart Switching method which aims to help supply power using BEV as an alternative power to improve the microgrid system.

II. LITERATURE REVIEW

A. Microgrid

The microgrid system is a small-scale distribution system, consisting of distributed energy sources such as wind turbines, fuel cells, PV, and so on, equipped with an energy storage system in the form of batteries. This system operates at low voltage and must be able to work in normal conditions (grid-connected) and emergency conditions when there is a power outage (islanded) to increase reliability [5].

B. Solar Power Plant (PLTS)

Solar Power Plant called PLTS is a power plant that uses solar panels to produce electrical power. The PLTS system is renewable energy and environmentally friendly, but the PLTS system still has shortcomings, such as the temperature factor in solar panels. factors of climatic and weather conditions and the intensity of sunlight obtained. The PLTS system utilizes sunlight which is then converted into electrical energy in the form of DC, so the implementation of the PLTS system requires a component that functions to convert DC into AC current, namely an inverter [6].

C. V2G and G2V

V2G and G2V are methods used for the process of charging and discharging the BEV, using this method the BEV can discharge power or discharging on the grid network (V2G) and can receive power from the grid to the BEV (G2V).

By combining BEV and utility grid to effectively reduce the use of fossil energy. And operating EVs to microgrids with renewable sources can more effectively reduce fossil energy consumption and carbon dioxide emissions. This study uses the G2V and V2G methods to be applied to the BEV to be able to charge and discharge the BEV so that it can supply the load needs of the microgrid system created [7].

D. Battery

The battery is an energy storage technology that can charge and discharge. A battery is an electronic device that can convert chemical energy into electrical energy (discharging), and vice versa convert electrical energy into chemical energy (charging). In the application of power generation systems such as PLTS and other power plants, batteries are needed to store electrical energy[8].

E. DC-DC Converter

The DC-DC converter is a power electronic circuit that functions to change the amount of DC voltage. The DC-DC converter circuit has very important uses, with the DC-DC converter circuit the output voltage value can be adjusted. The application of this circuit is used to increase or decrease the input voltage to the required output voltage value. The output voltage on the DC-DC converter is regulated by changing the duty cycle value (the ratio of on/off time on switching)[9].

III. METHODOLOGY

The research method used is to study references in the form of papers, datasheets, research reports with similar topics, and books. The focus of researchers in designing V2G and G2V switching systems with the smart switching method on a microgrid system is to focus on switching control circuits by identifying component specifications, switching system designs and monitoring designs. Can be seen in Fig 1 shows the flow chart in this study.

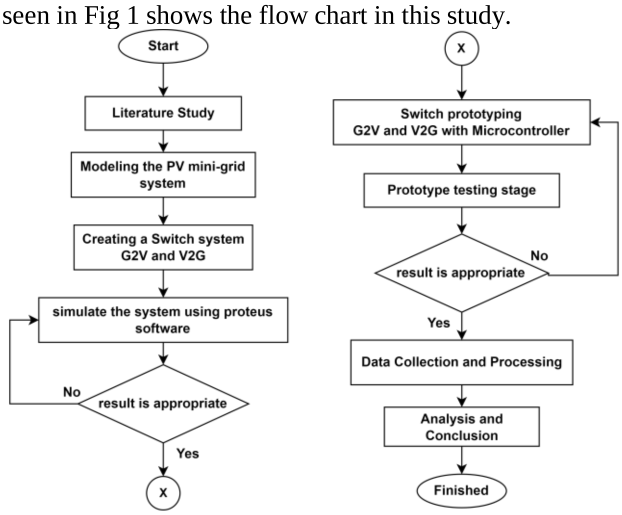


Fig. 1 Methodology

A. PLTS system design

In this study, the design of the PLTS system has several components consisting of solar panels (PV), MPPT, switching systems (charge and discharge) using a microcontroller, buck converter, and battery (BEV). Fig 2 shows the schematic of the PV mini-grid system that will be made in this study.

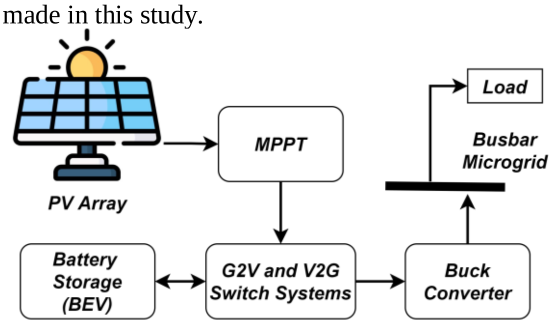


Fig. 2 PLTS system design

The design of PLTS system serves to generate electrical power that will be used as a loaded supply and charge the battery. The V2G and G2V switch systems are made using the smart switching method which will automatically switch between V2G and G2V so that they can work in 2 modes, namely charging and discharging the battery. The application uses the value of the PV voltage and the battery as input then relay as output which will be used as a trigger contactor to charge and discharge the battery. The following are four variations of the mode that will be applied in this study:

1) Variation Mode 1 : Charging

In the variation of mode 1, it is focused on charging the battery. When the solar panel generates power, the G2V mode will turn on, and the solar panel power will be used for charging the battery. As in Fig 3 below:

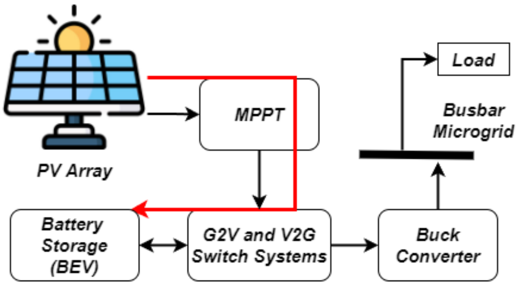


Fig. 3 Power Flow Variation Mode 1

2) Variation Mode 2 : Supply load from solar panels

In variation mode 2, when the battery is fully charged or exceeds the set point of the upper limit of the battery voltage, the system will cut off the battery and the remaining solar panel power will be used to supply the load on the microgrid as shown in Fig 4.

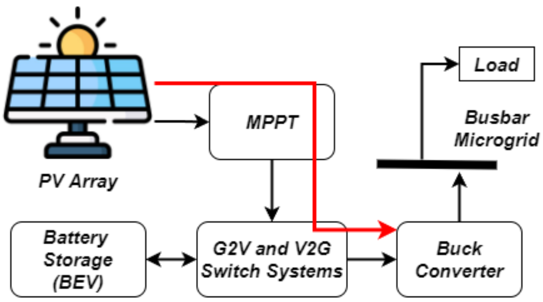


Fig. 4 Power Flow Variation Mode 2

3) Variation Mode 3 : Discharging

In this mode, when the solar panel cannot get energy from the sun or the voltage on the solar panel is less than the battery voltage, the system will turn on V2G (discharging) mode. The battery control system is designed to use V2G switching to supply the required load power by discharging the battery. So that all the power requirements of the microgrid load will be supplied by the battery. As shown in Fig 5.

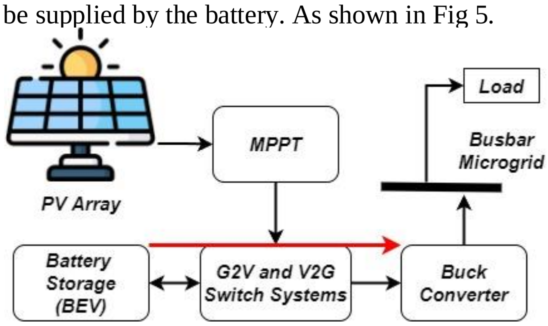


Fig. 5 Power Flow Variation Mode 3

4) Variation Mode 4 : Hybrid Charge + Load

In this mode, it uses a hybrid mode, which is used to supply loads and batteries. This mode variation is an option between mode 1, if the load requirements have been met, the remaining power from the solar panel will be used for charging the battery. The way to activate this mode is by using the V output on the MPPT and then connecting it to the Buck Converter input.

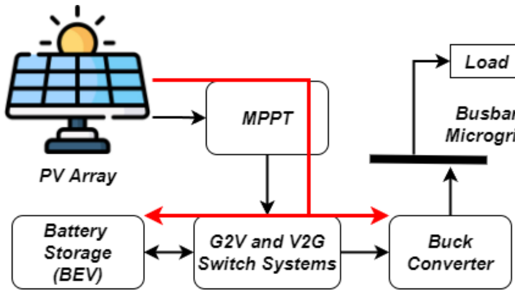


Fig. 6 Power Flow Variation Mode 4

B. *Hardware System Design*

The design of the contactor control unit and monitoring system uses a relay as a contactor trigger to activate charge and discharge modes. The relay is controlled using Arduino Uno with ACS712 current sensor, voltage divider, and temperature sensor as inputs. Arduino is supplied using a 12V 5A power supply and then the voltage is lowered using the LM2596 buck converter according to the required voltage for Arduino, which is 5V. The system made uses 2 types of batteries with different voltages so the design is made using 2 switches to activate the type of battery used.

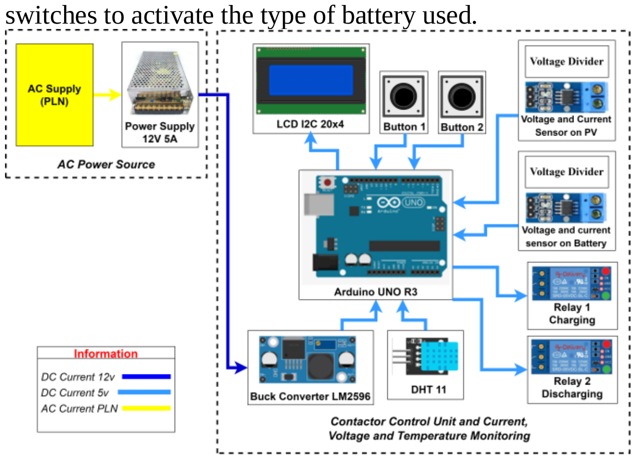


Fig. 7 Contactor and Monitoring Control Unit Circuit

The design of the contactor control system functions as a V2G and G2V switching, in this study using 2 contactor components. Contactor 1 is used for charging mode (G2V) and contactor 2 is used for discharging mode (V2G). The contactor component was chosen because the current and voltage in the system used are quite high, reaching 90V and 30A, so the selected contactor uses a Mitsubishi SN-21 contactor.

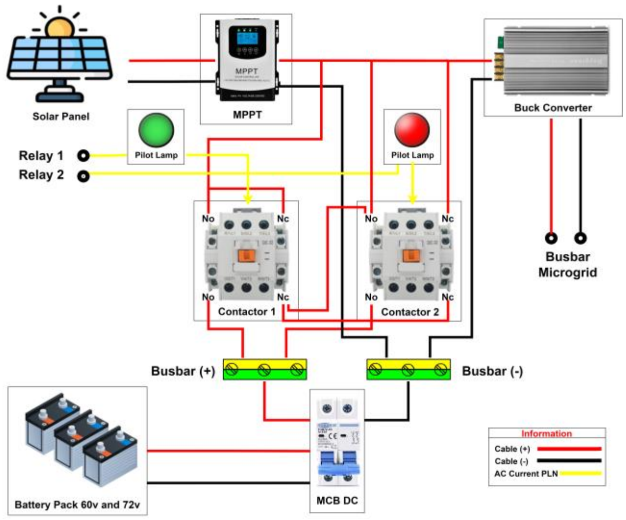


Fig. 8 Contactor Circuit

C. Algorithm Design

Fig. 9 Monitoring Flowchart Diagram and Button Reading

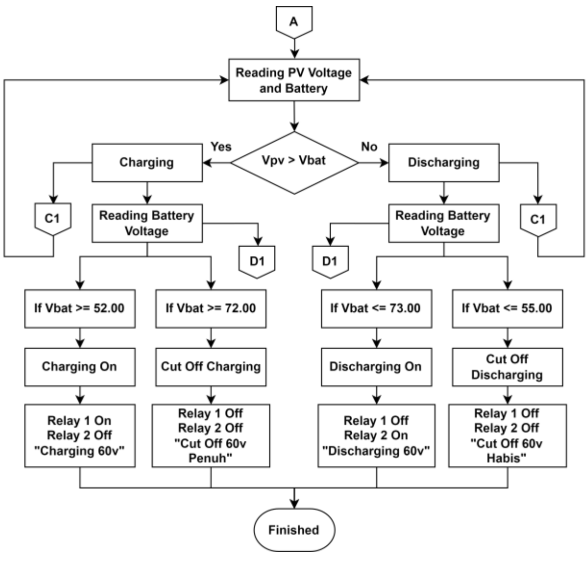


Fig. 10 60V Battery Charge and Discharge System Flowchart

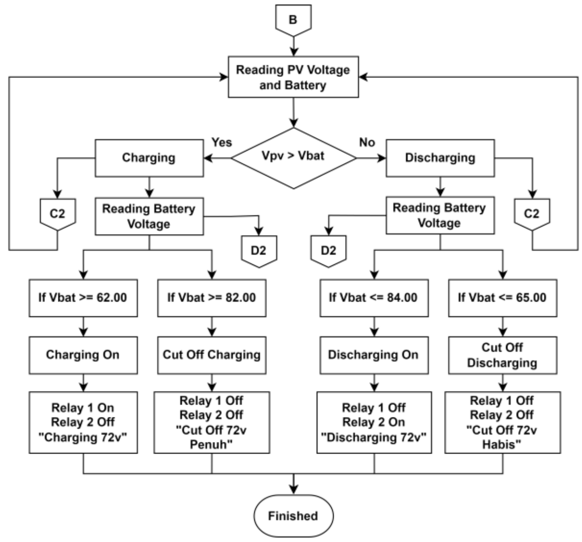


Fig. 11 72V Battery Charge and Discharge System Flowchart

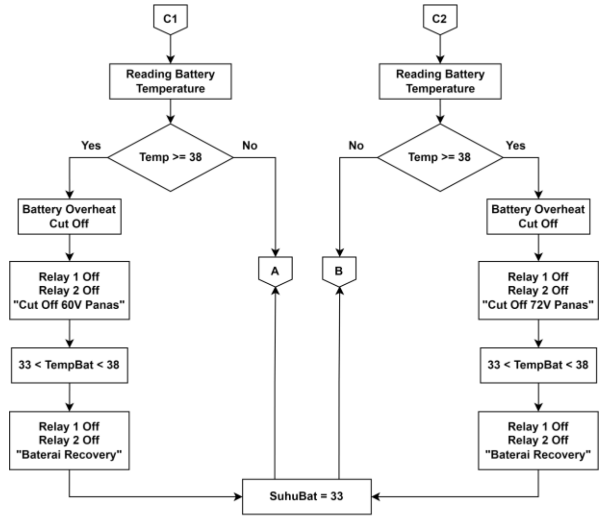


Fig. 12 Battery Overheat Cut Off System Flowchart

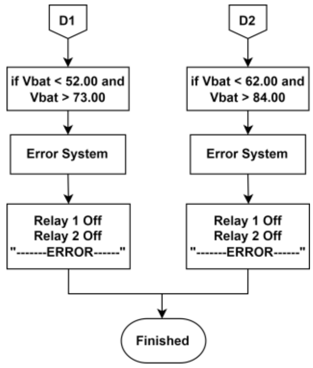


Fig. 13 Voltage Reading Flowchart does not Match The Set Point

D. Simulation Design

After designing the system, before the stage of making the tool, a simulation is carried out to get results that are by the system design created. In this section, the design of the control unit of the contactor and the monitoring system for temperature, voltage, and current on the PV and battery is carried out. This simulation was carried out using Proteus 8.0 software. The components used are Arduino, voltage sensors, current sensors, temperature sensors, relays, switches, LCDs, and LEDs as indicators of charging and discharging modes.

It can be seen in Fig 14 shows a simulation circuit of the contactor control system and monitoring of temperature, current, and voltage on the PV and battery.

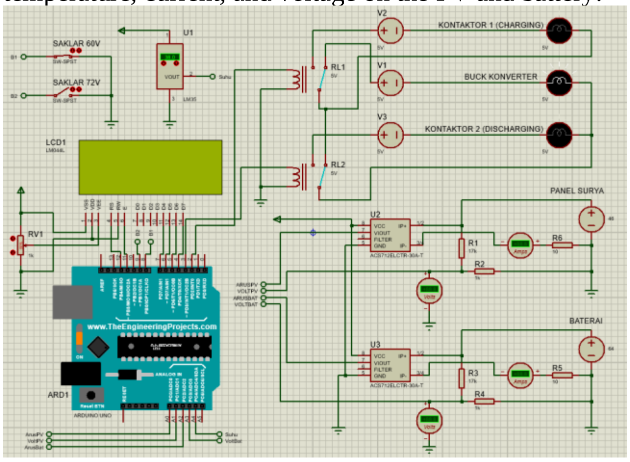


Fig. 14 Contactor Control and Monitoring Unit Simulation Circuit

IV. Result And Analysis

In this study, testing was carried out on simulations and tools that had been made. The results were obtained in the form of sensor readings in the form of temperature, voltage, and current, readings of the V2G and G2V switching systems from each battery, readings of the battery temperature cut-off system, and readings of the cut-off charge and discharge system on the battery. Then the results of the sensor readings are used as accuracy test data in the form of temperature, current, and voltage accuracy values. The following is a picture of the tool that has been made:

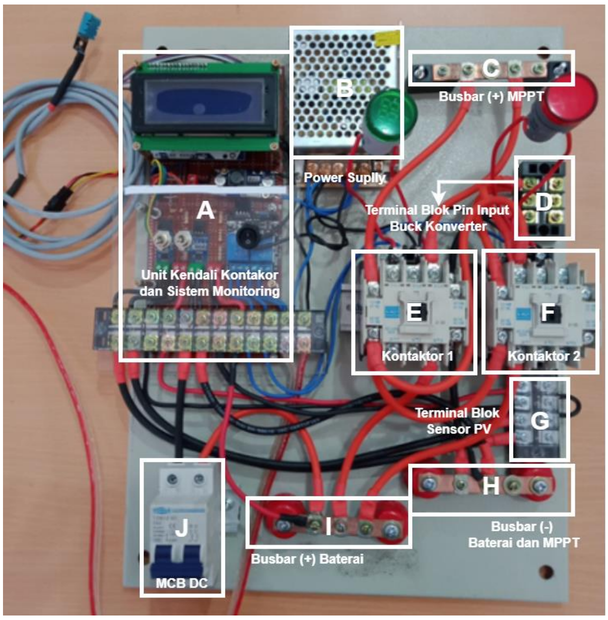


Fig. 15 Hardware Design

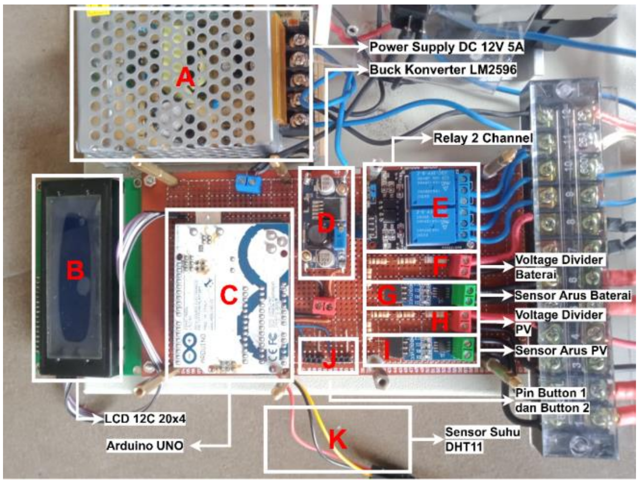


Fig. 16 Contactor Control and Monitoring

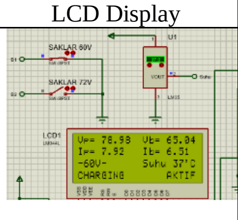
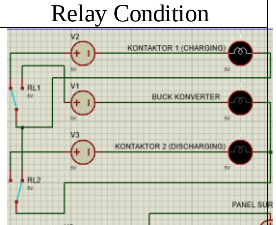
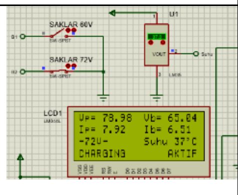
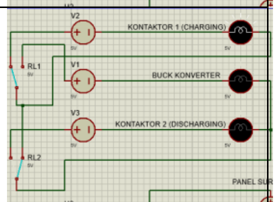
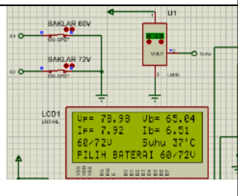
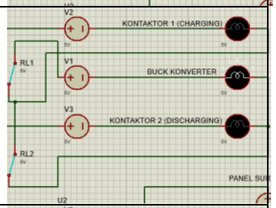
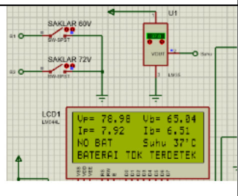
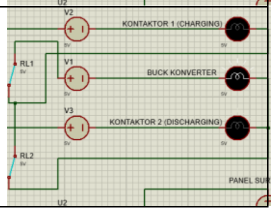
A. *Simulation Test Results*

In the simulation that has been carried out with the circuit in Fig 14. Then obtained several results, namely the condition of the relay reading and display on the LCD screen. The following are the results of the tests that have been carried out:

1) *Simulation of Switch Reading*

Taking the results of the switch readings in the simulation is done by turning on and off switch 1 and switch 2. The results of the readings can be seen in the table below:

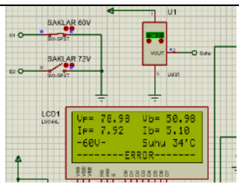
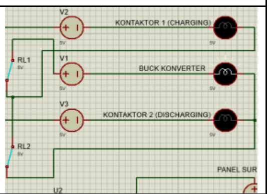
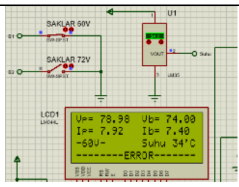
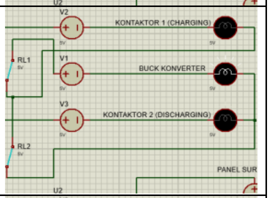
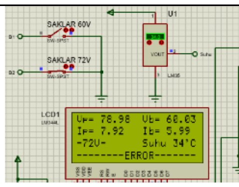
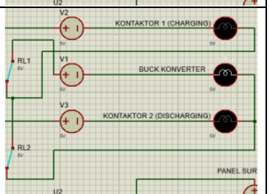
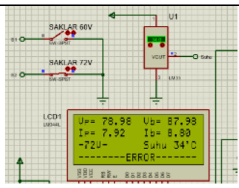
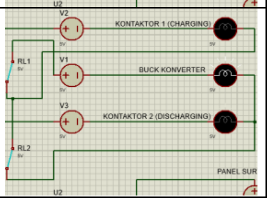
TABLE. 1 V2G AND G2V SWITCHING SIMULATION RESULT

Button	LCD Display	Relay Condition
Button 1 On		
Button 2 On		
Both Buttons On		
Both Buttons Off		

2) Simulation of Battery Voltage Reading

This test is carried out to determine the battery voltage used and to test the coding on the flowchart Fig 13. If the battery voltage does not match the set point of the battery type, the system cannot work. In this study, the set point for the upper and lower limits of the battery has been determined, for the upper limit set point for the 60V battery type is 72V and 55V for the lower limit, while the set point for the upper limit for the 72V battery type is 84V and 65V for the lower limit. The test method is by increasing and decreasing the battery voltage value. The following is a table of results from reading the battery voltage when it does not match the set point.

TABLE. 2 BATTERY VOLTAGE SIMULATION RESULTS DO NOT MATCH THE SET POINT

Battery Type	LCD Display	Relay Condition
60V type if Vbat < 52V		
60V type if Vbat > 73V		
72V type If Vbat < 62V		
72V type if Vbat > 84V		

3) 60V Battery Charge and Discharge Simulation

The results of the 60V battery charging and discharging readings in the simulation of the V2G and G2V switching system are carried out by increasing and decreasing the PV voltage and battery voltage manually with reference to the coding that has been made in Fig 9 and 10. Before doing the simulation test, the first step is to activate switch 1 The type of battery used is 60V. When switch 1 is active and the battery voltage reading is more than the lower limit of the 60V battery and less than the upper limit of the 60V battery, the system will be able to work.

The charging mode will be active if the PV voltage sensor reading is greater than the battery voltage. Cut-off charging is active when the battery is fully charged, cut-off is used to prevent overcharging of the battery. The discharging mode will be active if the PV voltage sensor reading is less than the battery voltage. Cut-off battery discharging will be active when the battery is exhausted, cut off is used to prevent deep discharging of the battery. The following are the results of the simulation tests that have been carried out:

TABLE. 3 SIMULATION RESULTS OF CHARGING AND CUT-OFF ON A BATTERY 60V

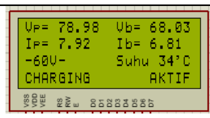
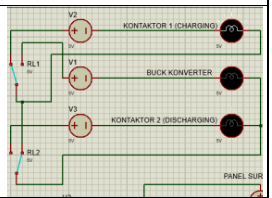
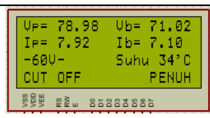
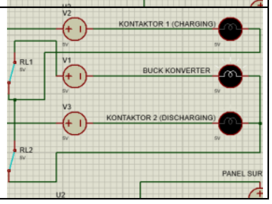
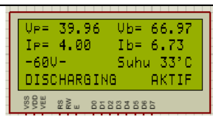
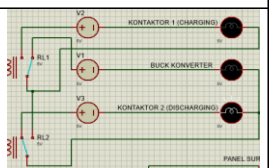
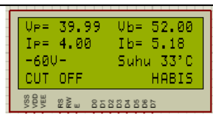
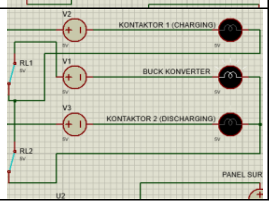
Battery Condition	LCD Display	Relay Condition
Charging		
Cut Off Full Battery		

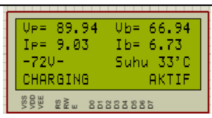
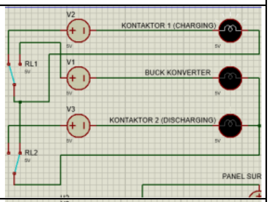
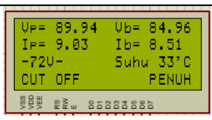
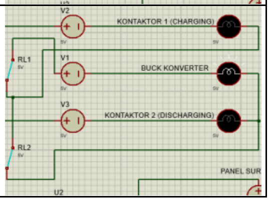
TABLE. 4 SIMULATION RESULTS OF DISCHARGING AND CUT-OFF ON A BATTERY 60V

Battery Condition	LCD Display	Relay Condition
Dis-charging		
Cut Off Empty Battery		

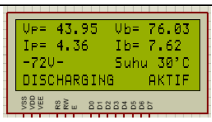
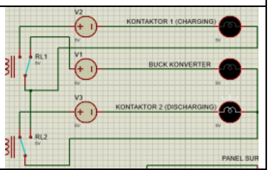
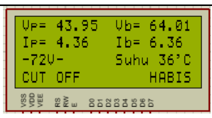
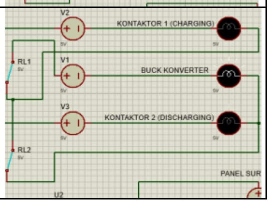
4) 72V Battery Charge and Discharge Simulation

The results of the 72V battery charging and discharging readings on the V2G and G2V switching system simulations were carried out in the same way on the 60V battery. The test is carried out by activating switch 2 for the type of battery used, namely 72V. When switch 2 is active and the battery voltage read is not less than the lower limit of the 72V battery and no more than the upper limit of the 72V battery, the system will be able to work. The following are the results of the simulation tests that have been carried out:

TABLE. 5 CHARGING AND CUT OFF SIMULATION RESULTS ON 72V BATTERY

Battery Condition	LCD Display	Relay Condition
Charging		
Cut Off Full Battery		

TEBLE. 6 DISCHARGING AND CUT OFF SIMULATION RESULTS ON 72V BATTERY

Battery Condition	LCD Display	Relay Condition
Dis-charging		
Cut Off Empty Battery		

From the test results in tables 3, 4, 5, and table 6, the results of the readings of the charging and discharging system of the device can work according to the design made. The system is capable of performing full battery cut-off and depleted battery cut-off based on the upper and lower limit voltages of each battery. So that the battery does not experience overcharging and deep discharging which can accelerate battery life.

5) 60V and 72V Battery Temperature Cut Off Simulation

Cut Off temperature in this study is used so that the battery does not overheat. The specified overheat limit value is as large as can be seen in the flowchart diagram of the temperature cut-off system in Fig 12. The test is carried out by increasing and decreasing the temperature sensor value, aiming for simulation testing to obtain results that are by the system and coding made.

Testing of battery temperature cut-off readings is carried out when charging and discharging batteries, both 60V and 72V batteries. The results obtained in the cut-off test simulation of 60V and 72V battery temperatures are as follows:

TABLE. 7 SIMULATION RESULTS OF CUT-OFF TEMPERATURE WHEN CHARGING BATTERIES 60V

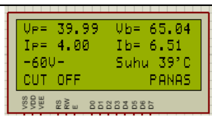
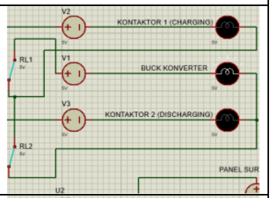
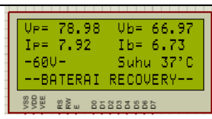
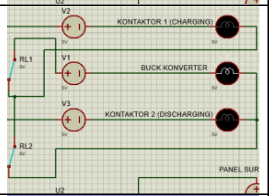
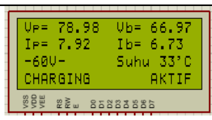
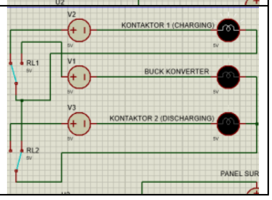
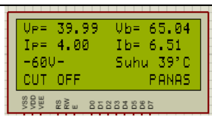
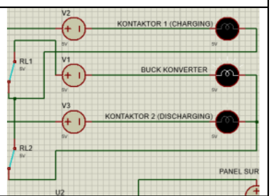
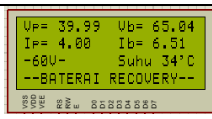
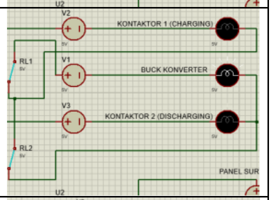
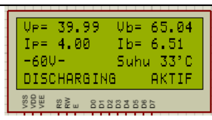
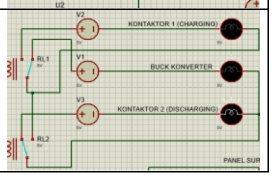
Battery Condition	LCD Display	Relay Condition
Cut Off Overheat		
Recovery		
Recharge		

TABLE. 8 RESULTS OF SIMULATION OF CUT-OFF TEMPERATURE WHEN DISCHARGING BATTERIES 60V

Battery Condition	LCD Display	Relay Condition
Cut Off Overheat		
Recovery		
Re-discharge		

From Tables 7 and 8, the experimental results of the cut-off temperature simulation when charging and discharging a 60V battery are obtained. The system can automatically cut off the flow of voltage and current when the temperature reaches 38 ℃ and perform battery recovery or decrease the temperature to 33℃. When the temperature reaches 33℃, the system will recharge and discharge the battery.

TABLE. 9 SIMULATION RESULTS OF CUT-OFF TEMPERATURE WHEN CHARGING BATTERIES 72V

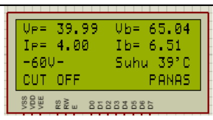
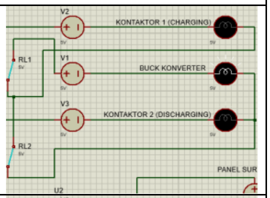
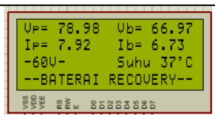
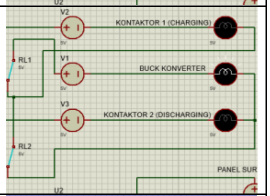
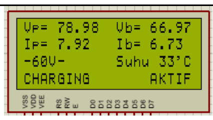
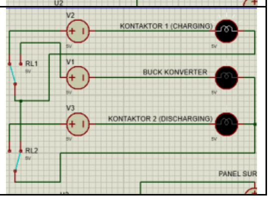
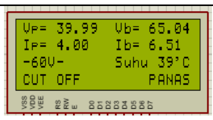
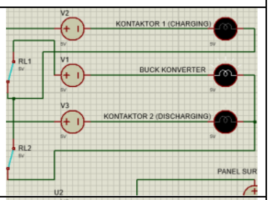
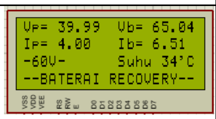
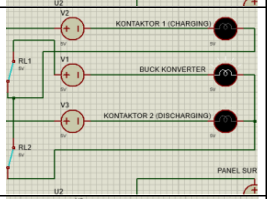
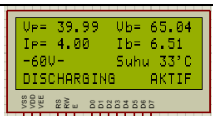
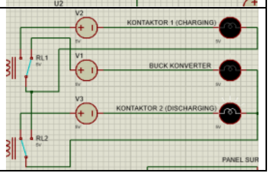
Battery Condition	LCD Display	Relay Condition
Cut Off Overheat		
Recovery		
Recharge		

TABLE. 10 SIMULATION RESULTS OF CUT-OFF TEMPERATURE WHEN DISCHARGING BATTERY 72V

Battery Condition	LCD Display	Relay Condition
Cut Off Overheat		
Recovery		
Re-discharge		

From Tables 9 and 10, the experimental results of the cut-off temperature simulation when charging and discharging a 72V battery are obtained. The system can automatically cut off the flow of voltage and current when the temperature reaches 38 ℃ and perform battery recovery or decrease the temperature to 33℃. When the temperature reaches 33℃, the system will recharge or discharge the battery.

B. *Tool Test Results*

Tool testing in this study was carried out by measuring the accuracy of sensor readings and comparing the system readings on the tool with the coding system created. If the reading of the tool goes according to the code, then the tool can be said to be successful. The following are some of the tests carried out, including:

1) *Sensor Accuracy Testing*

Testing the accuracy of sensors for temperature, voltage and current in the design of the tool uses several measuring instruments, namely the NICE-POWER power supply, the chroma series 17020, the UNI-T clamp meter, and the FLUKE multimeter. The test is done by comparing the results of the sensor measurements made with the measurement results of the measuring instruments. Can be seen in the table is the result of testing the accuracy of the sensor tool:

TABLE. 11 TEMPERATURE SENSOR ACCURACY TEST RESULTS ON THE TOOL

Number	PV Voltage		Error (%)
	Sensor	Chroma	
1	19.40	20.20	3.96
2	20.50	21.20	3.30
3	20.50	21.40	4.21
4	20.80	21.80	4.59
5	21.40	22.10	3.17
6	21.90	22.50	2.67
7	22.50	23.20	3.02
8	24.00	24.60	2.44
9	24.80	25.40	2.36
10	24.80	25.50	2.75
Avg Error (%)	3.25		
Accuracy	96.75		

The results of testing the temperature sensor of the tool made in table 11 obtained an average error value of 3.25% so the accuracy value obtained is 96.75%.

TABLE. 12 PV VOLTAGE AND CURRENT SENSOR TEST RESULTS

Number	PV Voltage		Error (%)	PV Current		Error (%)
	Sensor	Multimeter		Sensor	Clamp Meter	
1	75.15	75.10	0.07	1.08	1.15	6.09
2	89.25	89.30	0.06	1.67	1.70	1.76
3	90.03	90.10	0.08	1.78	1.74	2.30
4	92.48	92.50	0.02	1.69	1.64	3.05
5	98.35	98.40	0.05	1.52	1.57	3.18
6	102.02	101.90	0.12	1.52	1.56	2.56
7	103.49	103.50	0.01	1.44	1.49	3.36
8	106.43	106.40	0.03	3.02	3.07	1.63
9	110.25	110.30	0.05	3.15	3.18	0.94
10	111.00	111.09	0.08	3.15	3.15	0.00
Avg Error (%)	0.06			2.49		
Accuracy	99.94			97.51		

TABLE. 13 BATTERY VOLTAGE AND CURRENT SENSOR TEST RESULTS

Number	Battery Voltage		Error (%)	Battery Current		Error (%)
	Sensor	Multimeter		Sensor	Clamp Meter	
1	62.01	62.00	0.02	2.41	2.37	1.69
2	64.74	64.70	0.06	3.15	3.25	3.08
3	65.99	66.00	0.02	3.22	3.29	2.13
4	70.43	70.40	0.04	2.87	2.96	3.04
5	72.26	72.20	0.08	2.93	2.97	1.35
6	76.70	76.70	0.00	2.85	2.81	1.42
7	76.74	76.80	0.08	2.70	2.79	3.23
8	80.57	80.60	0.04	2.48	2.59	4.25
9	83.99	83.90	0.11	2.00	2.10	4.76
10	86.15	86.20	0.06	2.08	2.15	3.26
Avg Error (%)	0.05			2.82		
Accuracy	99.95			97.18		

For the test results from sensor readings, the temperature sensor accuracy values are 96.75%, PV voltage and current sensors are 99.94% and 97.51%, and the battery voltage and current sensor accuracy values are 99.95% and 97.18%. The temperature and current sensor accuracy value is less than 99% because the sensor calibration is not carried out and the current accuracy value test uses a small current value of less than 5A so that the percentage error result will be greater. The current sensor readings are very good, it can be seen in tables 12 and 13 that the difference between the current sensor readings and the clamp meter measuring instrument is only 0.05A. According to the MAPE approach used in this study, if the results of the accuracy rate value are more than 95%, it can be said that the sensor accuracy value is very good.

2) Testing of Switching and Cut Off Systems

Tool testing in this study was carried out by comparing the system readings on the device with the coding system created. If the reading of the tool goes according to the code, then the tool can be said to be successful. Testing of switching and cut-off systems is carried out using PV voltage and power supply as a substitute for batteries whose voltage values can be adjusted.

In testing the V2G to the G2V switching system and cutting off the upper and lower limits of the battery, it is done by applying a voltage to the PV voltage sensor and the battery. Then observations were made regarding the V2G to G2V switching process and the cut-off process for the upper and lower limits based on the algorithm made in Fig 10 and 11. The temperature cut-off test was done by heating the DHT11 temperature sensor with a lighter, then observing the cut-off. temperature, battery recovery and recharge and discharge the battery. The following results were obtained:

TABLE. 14 SUMMARY OF SYSTEM TESTING RESULTS ON SIMULATION AND TOOLS

Num	Test	Condition	Test result	
			Simulation	Hardware
1.	Button Reading	Button 1 On	Succeed	Succeed
		Button 2 On	Succeed	Succeed
		Both Buttons On	Succeed	Succeed
		Both Buttons Off	Succeed	Succeed
2.	Battery Voltage Reading does not Match The Set Point	Battery 60V, if Vbat<52V	Succeed	Succeed
		Battery 60V, if Vbat>73V	Succeed	Succeed
		Battery 72V, if Vbat<62V	Succeed	Succeed
		Battery 72V, if Vbat>84V	Succeed	Succeed
3.	*Charge* and *Discharge* Battery 60V	Charge Battery 60V	Succeed	Succeed
		Cut Off Full Battery	Succeed	Succeed
		Discharge Battery 60V	Succeed	Succeed
		Cut Off Empty Battery	Succeed	Succeed
4.	*Charge* and *Discharge* Battery 72V	Charge Battery 72V	Succeed	Succeed
		Cut Off Full Battery	Succeed	Succeed
		Discharge Battery72V	Succeed	Succeed
		Cut Off Empty Battery	Succeed	Succeed
5.	*Cut Off* Battery Temperature 60V	Charging 60V	Succeed	Succeed
		Cut Off Max Temp	Succeed	Succeed
		Recovery	Succeed	Succeed
		Recharge	Succeed	Succeed
		Discharging 60V	Succeed	Succeed
		Cut Off Max Temp	Succeed	Succeed
		Recovery	Succeed	Succeed
		Redischarge	Succeed	Succeed
	Cut Off Battery Temperature 72V	Charging 72V	Succeed	Succeed
		Cut Off Max Temp	Succeed	Succeed
		Recovery	Succeed	Succeed
		Recharge	Succeed	Succeed
		Discharging 72V	Succeed	Succeed
		Cut Off Max Temp	Succeed	Succeed
		Recovery	Succeed	Succeed
		Redischarge	Succeed	Succeed

Based on table 14, the results show that the design of the V2G and G2V switching system with the smart switching method has been successfully created and running with the desired design, the percentage of success is 100%.

C. Tool Experiment Results

The experiment was carried out using a 60V voltaic battery and a 72V agile battery to charge and discharge based on the voltage reference from the PLTS. If the PLTS voltage is greater than the battery voltage, the PLTS power will be used for charging the battery, and when the PLTS voltage is less than the battery voltage, the battery discharging will turn on. In the battery discharge mode before going to the microgrid busbar, the battery voltage will be lowered using a buck converter to 24V based on the voltage on the microgrid busbar. The following is a picture of the battery used in this research experiment:

Fig. 17 Volta Battery (left) and Gesits Battery (right)

The first experiment of the tool was carried out by charging the 60V Volta battery to full using PLTS. This experiment was carried out using a voltaic battery that can be monitored via a smartphone to determine the cut-off system for the upper limit of the battery used so that the battery can be charged 100%. Then the measurement of the charging time is carried out to full, the initial condition of the 60V voltaic battery is 40%, charging up to 100%. In this experiment, observations were made and it was found that when charging the battery from 40% to 100% it took 1 hour 3 minutes. The length of the charge time depends on the intensity of sunlight which can be converted by PV into electrical energy.

Fig. 18 Charging Battery Volta 60V

From Fig 18 above, the voltage value on the PV is 112.59V and the current flowing is 11.44A, for the voltage value on the battery is 71.12 and the battery current is 16.77. From this value, the panel power efficiency value can be found that can enter the battery. By calculating the efficiency value as follows:

$$Efficiency = \frac{Daya\ Baterai}{Daya\ PV} x\ 100\%$$

$$Efficiency = \frac{71.12\ x\ 16.77}{112.59\ x\ 11.44} x100\%$$

$$Efficiency = 92.59\%$$

The efficiency obtained is 92.59%, this value is very good because it has system losses on the MPPT and the sensor readings of the tool made. Then when the battery voltage when charging reaches the upper limit value of the 60V battery, the system will cut off. As in Fig 19 below:

Fig. 19 When The Battery is Full

From Fig 19 it is found that when the battery voltage when charging reaches the upper limit of the 60V battery, the system will cut off indicating the condition of the battery is full, and stop the flow of power so that the current cannot flow for charging the battery. The value of the battery voltage when charging or discharging is obtained with the actual battery voltage value being different. In the cut-off charging condition, the actual battery voltage will decrease and in the cut-off discharging condition, the actual battery voltage will increase. The battery cut-off voltage can be adjusted as needed, if the battery voltage is increased or can be used to charge the battery up to 100%, it can be set in coding by changing the upper limit value on the battery.

When PV is still producing electrical power, the remaining power will be directly used to supply the microgrid load. In the experiment the tool was found when the cut-off system on the battery was on, the process of distributing power from the MPPT to the buck converter was carried out through the contactor circuit that was made. As a result, the system can transmit power from the PV mini-grid to the microgrid busbar to supply the load but it takes a long time because the experiment was carried out with the microgrid system in the Off state.

Then discharging the 60V battery with the microgrid system off, this experiment is only to find out whether the switching system can run and the monitoring system can display the temperature, voltage, and current values or not. The experiment was carried out by turning off the MCB on the PV. So that the PV voltage is equal to 0, then the discharging mode will be active. Can be seen in Fig 20 below, is an experiment discharging on a 60V Volta battery.

Fig. 20 Discharging Battery Volta 60V

Fig. 21 Display on Grid Tie Inverter

Can be seen in Fig 21 is a display of power when discharging a 60V Volta battery. The output current value is 1.67A and the battery voltage using a 60V voltaic battery is 66.68V. The LCD indicator provides information that the battery is in a state of discharging. And in Fig 4.14 is a display on the Grid Tie Inverter (GTI) which provides information about the power needed to supply to the load. From Fig 20 and 21, the efficiency value of 93.41% can be calculated as follows:

$$Efficiency = \frac{Daya\ Out\ Baterai}{Daya\ GTI} x\ 100\%$$

$$Efficiency = \frac{66.68\ x\ 1.67}{119.2} x 100\%$$

$$Efficiency = 93.41\%$$

Furthermore, in the second experiment, charging and discharging were carried out on the Gesits 72V battery. In this experiment, it was found that the agile battery cannot charge the battery because the BMS system of the agile battery has security. So that the current reading when the agile battery is charging is 0, and the agile battery can only be charged using a battery charge from agile. It can be seen in Fig 22 below:

Fig. 22 Charging Battery Gesits 72V

Then the Gesits battery was discharging and it was observed that the system could run and the Gesits battery was able to transmit power to the microgrid busbar. Can be seen in Fig 23 is a discharging experiment on the Gesits battery.

Fig. 23 Discharging Battery Gesits 72V

From the experimental results of discharging the agile 72V battery, it was found that the agile battery can provide power to the microgrid busbar in the off state of the microgrid system or is unable to supply power to the load. On the LCD screen in Fig 23, it can be seen that the agile battery is actively discharging the battery and the current flowing is 13.8 A.

The third experiment was carried out without using a battery so that when the switch was turned on either the 60V or 72V switch, the system would have an error and could not charge or discharge the battery. So that when the PLTS system produces energy, the energy is directly used to supply the microgrid load. This experiment was conducted to determine whether the system is running or not. It can be seen in Fig 24, 25, and 26 that the results show that the system is running well and can supply the microgrid load.

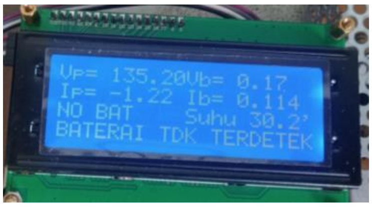


Fig. 24 Experiment Without Battery

From Fig 24 it is found that the PLTS is supplying the microgrid load with a PV voltage value of 135.2V and a current flowing of 1.22A so that the power value used to supply the microgrid load is 164.9 Watt.

Fig. 25 Experiment Without Battery Volta 60V

Then in Fig 25, the same results are obtained, namely, the system error and the PLTS power are directly used to supply the microgrid load. With a PV voltage value of 134.91V and a current flowing of 1.37A, it can be calculated the power value to supply a microgrid load of 184.8 Watt.

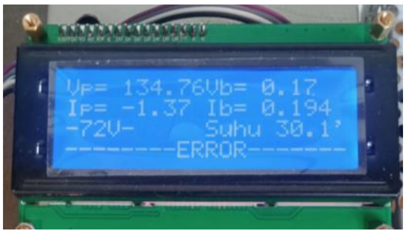


Fig. 26 Experiment Without Battery Gesits 72V

In Fig 26 it is found that the PLTS system is supplying power to the microgrid load with a PV voltage value of 134.76V and a flowing current of 1.37A, so the power value used to supply the microgrid load is 184.6 Watt.

Furthermore, experiments were carried out by activating the 4th mode, namely the charging and supply mode on the microgrid load as shown in Fig 6 in the off state of the microgrid system. From these experiments, it was found that the system is able to run well, the system can charge the battery and can supply the load on the microgrid. The implementation is by prioritizing power to supply the load first, when the load is fulfilled, the remaining power generated by the PLTS will be used for charging the battery.

The last experiment was carried out by discharging the 60V voltaic battery with the microgrid system on. Based on the experiments carried out, the tool runs well and is able to provide power to the microgrid busbar but has a drawback, namely there is a voltage difference between the output voltage of the buck converter and the voltage on the microgrid busbar of 2V. It is necessary to add a voltage sensor on the microgrid busbar as a voltage reference to activate the battery discharging condition so that there is no voltage difference. In addition, the tool can only be used on 60V voltaic batteries and 72V agile batteries. Therefore, for further research, a feature can be added that can adjust the upper and lower limit values of the battery so that it can be used on all batteries and add an IoT system to the monitoring system so that the state of the battery can be monitored in real time.

V. CONCLUSION

Based on the results of tests and discussions conducted on the Design of V2G and G2V Switching Systems using the Smart Switching Method, it can be concluded that:

1. The design of the V2G and G2V switching system using the Smart Switching method has been running well. The system is capable of charging and discharging batteries based on an algorithm that has been designed with a reference voltage on the PV.
2. The designed and designed algorithm has been successfully created and the temperature cut-off process, the upper limit and the lower limit of the battery voltage can run according to the maximum temperature set point, and the upper and lower limits of the battery voltage of 60V and 72V. So that in its application the battery does not overheat, overcharge, and deep discharge.
3. The monitoring system can run well and can display temperature, voltage, and current sensor readings on the LCD. With the results of testing the accuracy values of the voltage and current sensors on the PV are 99.94% and 97.51%, the results of testing the accuracy values of the temperature, voltage, and battery current sensors are 96.75%, 99.95%, and 97.18%.

REFERENCES

[1] Rahardjo, I., & Fitriana, I. (2005). Analisis Potensi Pembangkit Listrik Tenaga Surya di Indonesia. Strategi Penyediaan Listrik Nasional Dalam Rangka Mengantisipasi Pemanfaatan PLTU Batubara Skala Kecil, PLTN, dan Energi Terbarukan, P3TKKE, BPPT, Januari, 43-52.

[2] Sulistomo, P., Setiawan, I., & Facta, M. (2019). Implementasi Pengendalian Sistem Pengisian/Pengosongan Baterai pada Sistem Photovoltaic Stand-Alone Menggunakan Bidirectional Konverter dengan Metode Proportional-Integral Berbasis Mikrokontroler DSPIC30F4011. Transient: Jurnal Ilmiah Teknik Elektro, 7(4), 832-837.

[3] Ihsan, B., Hamdani, D., & Hariyanto, N. (2020). Pengaruh Strategi Pengisian Daya Terhadap Kenaikan Beban Puncak Akibat Penetrasi Kendaraan Listrik. Jurnal Nasional Teknik Elektro dan Teknologi Informasi, 9(3), 311-318.

[4] Sami, I., Ullah, Z., Salman, K., Hussain, I., Ali, S. M., Khan, B., ... & Farid, U. (2019, February). A bidirectional interactive electric vehicles operation modes: Vehicle-to-grid (V2G) and grid-to-vehicle (G2V) variations within smart grid. In 2019 International Conference on Engineering and Emerging Technologies (ICEET) (pp. 1-6). IEEE.

[5] Trisnasari, C. T., Soeprijanto, A., & Wibowo, R. S. (2016). Pemodelan dan Simulasi Sistem Proteksi Microgrid. Jurnal Teknik ITS, 5(2), B48-B52.

[6] Saputra, A. A. (2019). Smart Grid Hybrid System (Fotovoltaik-PT. PLN) Berbasis IoT (Internet of Things). Jurnal Online Mahasiswa (JOM) Bidang Teknik Elektro, 1(1).

[7] Kumar, G. V., Lu, M. Z., & Liaw, C. M. (2021). Interconnected Operations of Electric Vehicle to Grid and Microgrid. Journal of Energy and Power Technology, 3(2), 1-1.

[8] Daniel W. Hart, "Power Electronic", Mac Graw Hill, 2010, hal 196-220.

[9] King, B. F., Panjaitan, S. D., & Hartoyo, A. (2020). Sistem Kontrol Charging dan Discharging Serta Monitoring Kesehatan Baterai. Jurnal Teknik Elektro Universitas Tanjungpura, 1(1).

[10] Taif, M., Abbas, M. Y. H., & Jamil, M. (2019). Penggunaan Sensor Acs712 Dan Sensor Tegangan Untuk Pengukuran Jatuh Tegangan Tiga Fasa Berbasis Mikrokontroler Dan Modul Gsm/Gprs Shield. Jurnal PROtek Vol, 6(1).

[11] Situmorang, M. (2020). Proses Pengisian dan Pengosongan Backup Baterai pada Sistem Penyedia Tenaga Surya Menggunakan Konverter Dc ke Dc.

[12] Hidayat, K., Hasani, M. C., Mardiyah, N. A., & Effendy, M. (2021). Strategi Pengisian Baterai pada Sistem Panel Surya Standalone Berbasis Kontrol PI Multi-Loop. Jurnal Teknik Elektro, 13(1), 25-33.

[13] Siahaan, J. P., Handoko, S., & Darjat, D. (2021). Perancangan Sistem Monitoring dan Manajemen Baterai dengan Metode Switching berbasis Mikrokontroler Arduino UNO. Transient: Jurnal Ilmiah Teknik Elektro, 10(1).

[14] Rizqi, M. B., Pangaribuan, P., & Suhendi, A. (2019). Desain Dan Implementasi Smart Switching Pada Sistem Catu Daya Listrik On Grid. eProceedings of Engineering, 6(2).

[15] Prihananto, P. L. D., Facta, M., & Sudjadi, S. (2019). Perancangan Cut Off Sebagai Pemutus Tegangan dan Arus Sistem Charging Baterai. Transient: Jurnal Ilmiah Teknik Elektro, 7(4), 911-817.

[16] Farhan, F., & Irawan, I. (2018). Sistem Switching Energi Listrik Turbin Angin Dan Pln Berbasis Arduino. SKANIKA, 1(2), 635-641.