International Journal of Recent Technology and Applied Science
p-ISSN: 2721-2017, e-ISSN: 2721-7280

Original Research Paper

Solar Panel Remote Monitoring and Control System on Miniature Weather Stations Based on Web Server and ESP32

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Article history
Received:
31.12.2019

Revised:
08.02.2020

Accepted:
16.03.2020

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Abstract: The weather station helps in planning socioeconomic activities such as agriculture, tourism, transportation, marine activities and plantations. The station needs an energy source, an electric energy source to operate, and is needed to get continuous assistance. This study aims to build a system for using two sources of electrical energy to support electricity stations that can be monitored and control remotely and provide information on the use of electrical energy in miniature weather stations into a web server. This research produces a remote monitoring and control system that can automatically switch primary energy sources to backup energy sources. When taking the main current source goes out, the system is able to carry the energy source back to the main source back to the main source alive again. The system can make changes manually using a web server that can be controlled remotely. When the battery reaches a voltage above 14.40 volts, the charging process stops and the system uses electrical energy from the battery. When the battery voltage reads 11.89 volts, do the battery charging process again. Electrical energy system information on miniature stations can display information about voltage, current, power, temperature and intensity of sunlight in the form of graphical visualization in real time.

Keyword: Microcontroller, Monitoring, Remote Control, Solar Panel, Web Server.

1. Introduction

Weather stations can be described as instruments or devices, which provide weather information in our environment. For example it provides information about ambient temperatures such as barometric pressure and humidity. Therefore, the weather station basically detects temperature, pressure, humidity, light intensity and rain value [1]. The weather station helps in planning socioeconomic activities such as agriculture, tourism, transportation, marine activities and plantations. Weather stations require energy sources especially electrical energy sources to operate them and periodic monitoring is needed to be able to operate continuously. If the source of electrical energy is lost, a backup energy source is needed which can be used to supply electrical energy to the weather station. One source of electrical energy that can be used is solar panels.

Solar panels are the main equipment of solar power generation systems that function to convert sunlight energy into electrical energy directly [2]. The performance of a solar panel can be placed in certain environmental conditions and can be determined by directly monitoring its output parameters such as voltage, current and power [3].

The system for recording solar panel output data based on microcontrollers can be done through monitoring solar panel output by using current sensors and voltage sensors to get the voltage, current and output power values of solar panels stored on Secure Digital (SD Card) [4]. The method of monitoring solar panels in previous studies only collected data on solar panel output parameters in the form of text files with the txt format. This data cannot be retrieved directly in real time conditions [5]. Collection of solar panel output data can be monitored and controlled remotely to obtain data in real time. The use of solar panels can be monitored and controlled as a source of electrical energy apart from the State Electricity Enterprice (PLN). Utilization of these two sources needs to be managed intelligently by using a web server and microcontroller. Use a variety of weather parameters such as sunny, cloudy, and rain to determine the conditions of use of electrical energy sources.

2. Literature Review

2.1. Miniature Weather Station

Basically a miniature weather station, adopting a system used by the automatic weather station Automatic Weather Station (AWS), but not as sophisticated and as perfect as AWS. There are some parts of measurements that are not included in this miniature weather station, including the measurement of solar radiation and other specific measurements. This is what underlies why experiments or devices made are called miniature weather stations. Measurements that can be carried out on these miniature weather stations include measurements of wind speed, temperature and humidity, and rainfall. Most of these miniature weather stations use sensors designed to function like AWS [6].

2.2. Internet of Things

IoT is a new revolution on the internet. IoT makes certain objects or devices can recognize themselves, gain intelligence, exchange information about those devices that have been integrated by other devices. IoT can allow users and devices to be connected anytime, anywhere, anyone, using any road or line and service [7]. IoT makes activities interact with each other and is done by utilizing the internet. By applying a computational concept that describes the future in which every physical object can be connected to the internet and can identify itself among other devices.

2.3. Solar Panel

Solar cells are an active element that converts sunlight into electrical energy through a process called photovoltaic (PV). Photo refers to light and voltaic refers to voltage. This terminology is used to describe electronic cells that produce direct current electrical energy from solar radiant energy. Photovoltaic cells are made from semiconductor materials, especially silicon, which are coated by special additives. If sunlight reaches the cell, the electrons will be separated from the silicon atoms and flow to form electrical circuits so that electrical energy can be generated. Solar cells are always designed to convert light into electrical energy as much as possible and can be combined in series or in parallel to produce the desired voltage and current as stated by Chenni, Makhlouf and Bouzid [8].

The work of a photovoltaic cell is very dependent on the sunlight it receives. Climatic conditions (eg clouds and fog) have a significant effect on the amount of solar energy that a cell receives so that it will also affect its performance as evidenced in the research of Younes, Claywell and Muneer [9] and Pucar and Despic [10].

Figure 1. Solar Panel

2.4. Battery

A battery or accumulator is an electric cell in which a reversible electrochemical process takes place with high efficiency. Referred to as a reversible electrochemical reaction is that in the battery the process of converting chemicals into electricity (emptying process) and vice versa from electric power to chemical power (charging process) by means of the regeneration process of the electrodes used by passing an electric current in the direction of polarity the opposite in the cell [11].

Batteries by nature consist of two types, primary batteries and secondary batteries. Primary batteries are batteries that run out in one use and secondary batteries are batteries that can be refilled because the chemical reactions they have can be reversed. One type of secondary battery is the Lead Acid Battery. Lead Acid Battery or commonly called a battery is a type of battery that uses lead acid as its chemical material. In general there are two types of lead-acid batteries: (a). *Starting Battery*, and (b). *Deep Cycle Battery* [12].

Figure 2. Battery

2.5. Charger Controller

Basically a charger is a device used as a battery charger or other energy storage area against the electric current. As technology advances, a regulator is added to the charger. Serves to regulate the energy entering the battery and prevent overcharging when the battery is full, overvoltage, and other things that can reduce battery life [12].

Figure 3. Charger Controller

2.6. ESP32

ESP32 developed by Espressif company. Espressif or commonly called Espressif Systems Pte. Ltd. is a manufacturer of semiconductor network components. ESP32 is a single chip combined with Wi-Fi and Bluetooth 2.4 GHz which is designed with ultra-low-power technology. ESP32 can function as a complete standalone system, reducing the communication overhead stack on the main application processor. ESP32 is very integrated with the built-in antenna switches, power amplifiers, low-noise, filters and power management modules. In addition to ESP32 used for mobile devices, the IoT application is also capable of functioning reliably in industrial environments, with operating temperatures ranging from -40 ° C to + 125 ° C and supported by sophisticated calibration circuits [13].

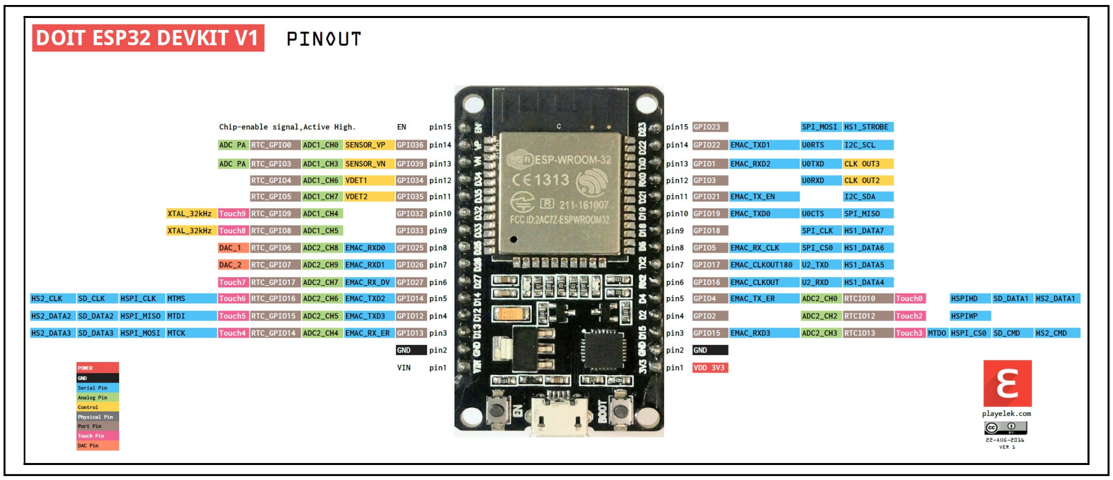
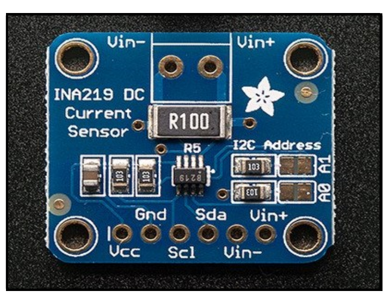


Figure 4. ESP32

2.7. Voltage, Current and Power Sensors

INA219 is a sensor module that can monitor voltage, current and power in an electrical circuit. INA219 is supported by an I2C or SMBUS-COMPATIBLE interface where this equipment is capable of monitoring shunt voltages and bus voltage supply, with program times and filtering conversions. INA219 has a maximum input amplifier of ± 320 mV and can measure currents up to ± 3.2 A. With internal 12 bit ADC data, the resolution is in the range of 3.2 A and 0.8 mA. Maximum ± 400 mA and resolution of 0.1 mA. INA219 can measure shunt voltages on buses 0–26 V [14]. The current value reading on the INA219 sensor works both ways where it is negative if there is an electric load and positive if there is no electricity load.



Gambar 5. INA219 Sensor

2.8. Light Intensity Sensor

The light intensity sensor used in this study is MAX44009. MAX44009 is a digital light sensor that has a digital signal output, so it does not require complicated calculations. The MAX44009 light sensor displays an ideal I2C digital output for a number of portable applications such as smartphones, notebooks and industrial sensors. With an operating current of less than 1µA, the light sensor is the lowest power in the industry and has an ultra-wide dynamic 22-bit range from 0.045 lux to 188,000 lux [15].

Wardana and Jehuda [16] in their research that applied the value of light intensity in each condition and environment as follows: Night (0.001 - 0.02), Cloudy in the room (5 - 50), Cloudy outdoors (50-500), Bright in the room (00-1000), and Outdoor light (1000 – 5000).

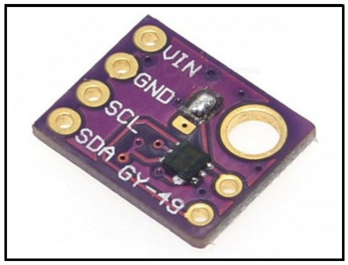


Figure 6. MAX44009 Sensor

2.9. Temperature Sensor

The temperature sensor used in this study is the DS18B20 temperature sensor. DS18B20 temperature sensor has a digital output even though it is small (TO-92), to access it is by the serial method of 1 wire. This sensor really saves the microcontroller port pin, because 1 pin microcontroller port can be used to communicate with several other devices. This sensor also has a fairly high accuracy rate, which is 0.5 ºC in the temperature range of -10 ºC to ± 85 ºC, so it is widely used for temperature monitoring system applications [17].

Figure 7. DS18B20 Sensor

2.10. Relay

The relay in Figure 7 is an electrically operated device and mechanically controls the connection of electrical circuits, useful for remote control and for controlling high voltage and current devices with low voltage and current control signals.

Work based on the formation of electromagnets that move the electromechanical connecting of two or more connecting points (connectors) of the circuit so that it can produce conditions ON contact or OFF contact or a combination of both [18].

According Saleh & Haryani [19] that relay contact consists of 2 types is:

1) Normally Close (NC), which is the initial condition before being activated will always be in the CLOSE position (closed).
2) Normally Open (NO), which is the initial condition before being activated will always be in the OPEN position (open).

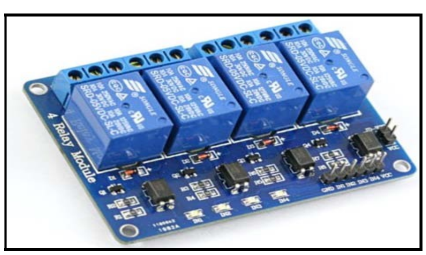


Figure 8. Relay 4 Channel

2.11. Message Queuing Telemetry Transport (MQTT)
It is a very simple and lightweight publish / subscribe topicbased communication protocol, designed for devices that have limited capabilities, low bandwidth, high latency or less reliable networks. The principle of this design is to minimize the use of network bandwidth and the need for resources on the device and at the same time also try to ensure the reliability and certainty of sending data [20].

3. Research Methods
Stages of research procedures are needed so that research can be structured so that the results obtained are in accordance with the research objectives. Figure 8 is a description of the flow of the research procedure.

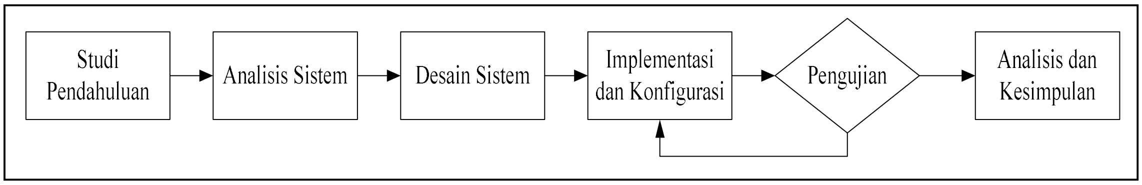


Figure 9. Research Methods

3.1. Introduction Studies
Introduction studies are carried out with various techniques such as data collection that are accurate, relevant and reliable in order to expedite the system design process. Data collection is carried out by means of literature study to collect and collect appropriate data in research by reading, reading, and reading literature from various books, journals and from the internet both containing theories, research reports or findings previously related to research and reviewing research literature which addresses research objectives.

3.2. Analysis of Miniature Weather Station Systems
At this stage the process of decomposition, identification and evaluation of miniature weather stations has been applied previously. Figure 9 is a general description of a miniature weather station that was previously designed by Cahyati [20]. This miniature weather station has a weather measurement tool that can measure the value of air temperature and humidity, wind speed, air pressure and rainfall. The data generated by each sensor has an increase and decrease caused by several factors, such as errors in providing treatment to sensors, or zero values that have been distorted.

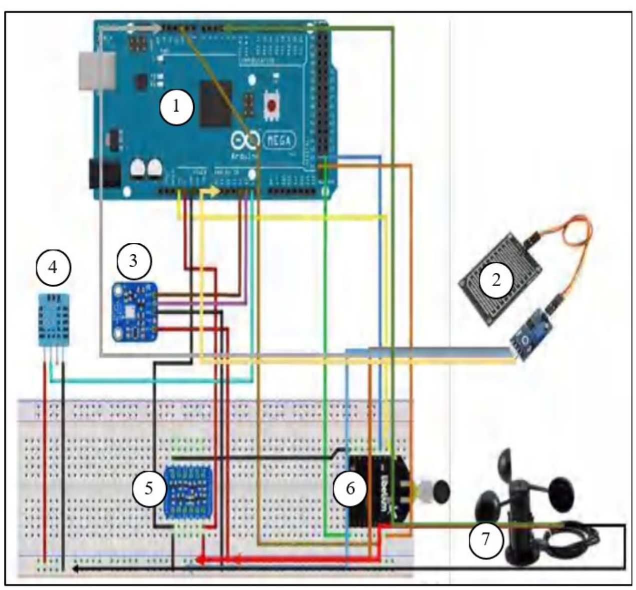


Figure 10. Overview of Miniature Weather Station Systems

There are also some weaknesses in this system including:

1) There needs to be an IoT application development.
2) Use of Uninterruptible Power Supply (UPS) as a backup of power input to the appliance when the power goes out.
3) The system can be added so that it can work in real time and can store data that is read in a memory or computer.
4) The system can be added to several sensors that are considered important to predict the weather such as measuring the intensity of light, so that the device can predict the weather.

From Figure 10, we can observe a general description of a weather station miniature system consisting of several sensor devices and a microcontroller. Following is an explanation of each miniature weather station device:

1) Arduino Mega 2560 is a microcontroller board based on Atmega 2560. It has 54 digital input / output pins (of which 14 can be used as Pulse Width Modulation (PWM) outputs, 16 analog input pins, 2 Universal Asynchronous Receiver Transmitters (UARTs) (UARTs) Hardware serial ports), a 16 MHz cristal oscillator, a USB connector, a power jack, ICSP header, and a back button.
2) Rain sensor is a type of sensor that functions to detect the occurrence of rain or not.
3) BMP180 sensor is a sensor to measure air pressure (barometer).
4) DHT11 sensor is one sensor that can measure two environmental parameters at once, namely temperature and humidity (humidity).
5) Optocoupler is a device consisting of 2 parts, namely transmitter and receiver, that is, between the light with the detection of a separate light source.
6) Long Range (LoRa) is a format produced using frequency modulation (FM). The core in processing produces a stable frequency value.
7) Anemometer is a measuring instrument used to measure or determine wind speed.

3.3. System Design

System design is the defining stage of system analysis that describes the design of the system being designed. In this study there are several systems that are tested in order to get the results of system design that can be used as material for analysis. 10 is a picture of a system design that is designed on a miniature weather station. From this figure, it discusses the parameters of monitoring and control of solar panels to supply electrical energy.

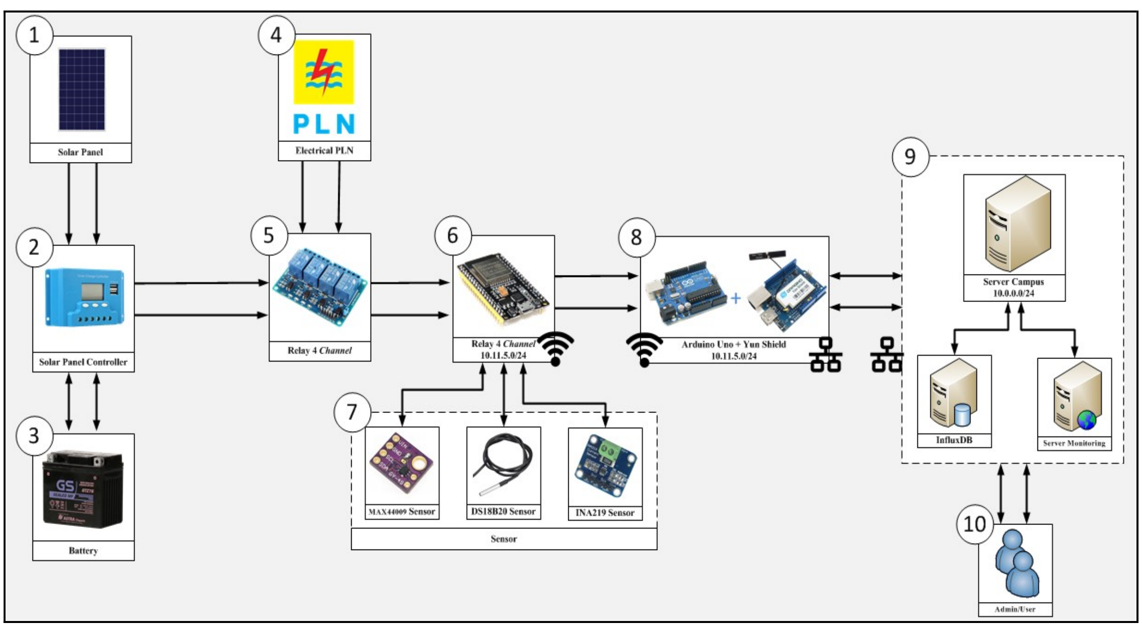


Figure 11. System Design

In Figure 11 is a picture of the design of the system being built. System design overview consists of:

1) Solar panels are used to produce electricity from sunlight as a primary energy source.
2) Solar control panel as a charging path or a place to pass electrical energy.
3) Batteries are used to store electricity generated from solar panels.
4) PLN electricity source as a secondary electrical energy source.
5) Relays are used as a regulator of the transfer of electrical energy sources.
6) ESP32 is used as a control of sensors and actuators using IP Address 10.11.5.0/24.
7) Sensors are used such as the MAX44009 Light Intensity Sensor, DS18B20 Temperature Sensor and INA219 Voltage Sensor.
8) Arduino Uno and Yun Shield are used to manage communication and as a bridge to the server using IP Address 10.11.5.0/24.
9) Data stored in the database server is then displayed in the monitoring server web application using IP Address 10.0.0.0/24.
10) Users who can access from the system created.

The next step after the description of the system being built is to build several parameters to measure the performance of solar panel monitoring and control on a miniature weather station. Some parameters that are applied shown in Table 1.

Table 1. Measurement Parameters

No.	Parameter	Description
1	Primary Solar Panel, Secondary Electricity	a. The weather is sunny and allows charging the battery with solar panels. b. The battery still has power and is not at its low end.
2	Electricity as primary, secondary solar panels	a. Nighttime conditions. b. Rainy weather conditions. c. The use of electricity when the source of the solar panel dies. d. Battery energy usage is low.
3	Disconnection of Battery Charging	The voltage has reached 14.40 Volts so, the battery charging is disconnected and all devices are supplied by batteries.
4	Battery Charging Back	The minimum battery usage limit given is 11.89 Volts.

After setting the parameters applied, the next step is to determine the conditions for sending data and using the protocol.

a. Data Transmission Conditions

Data transmission starts with sensor and actuator initialization. Furthermore, the sensor reads and makes a data packet that has been read by the sensor before it is sent to the server. Make a connection to the network and data is sent to the server. Data is parsed and a query is made to display data visualization on the website.

Conditions for sending data on miniature weather stations can be seen in Figure 12.

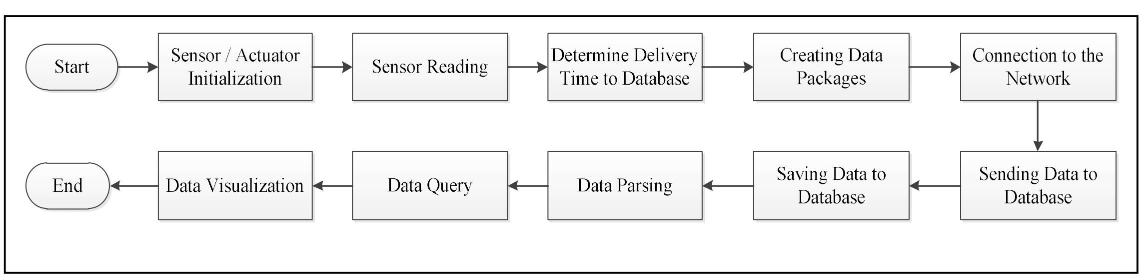


Figure 12. Data Transmission Path

b. Use of Protocols

In the process of sending data, there are several protocols used, such as the MQTT and HTTP protocol. The use of the protocol used can be seen in Figure 13. The use of data transmission protocols starts from:

1) Data comes from sensors and actuators.
2) ESP32 microcontroller acts as a station.
3) Sending data to the server using the MQTT protocol to the server.
4) Data is forwarded to the server using a network from Arduino and Yun Shield.
5) Controlling Relay from the server using http requests.
6) Data is stored on the server using the InfluxDB database and data visualized using Lumen Microframework.

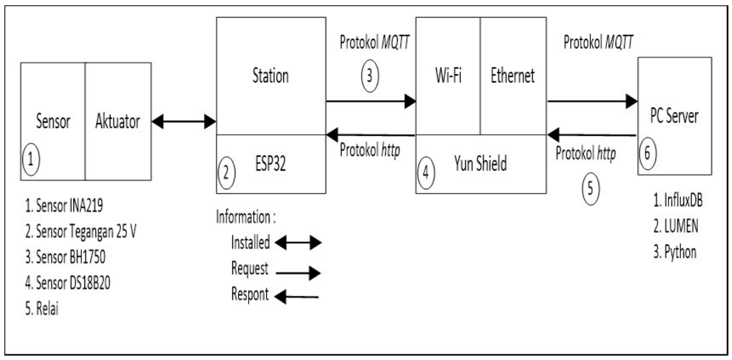


Figure 13. Flow of Data Transmission Protocol

3.4. Installation and Configuration

At this stage the system implementation starts from the procurement of the required equipment. Furthermore, the installation and configuration, starting from the installation of the application editor (Arduino IDE), device installation (sensors and actuators), library installation, compile programs and upload programs to the device. Then coding the monitoring and control scripts to test the system as needed. Following the flow of this step in Figure 14 and the circuit design in Figure 15.

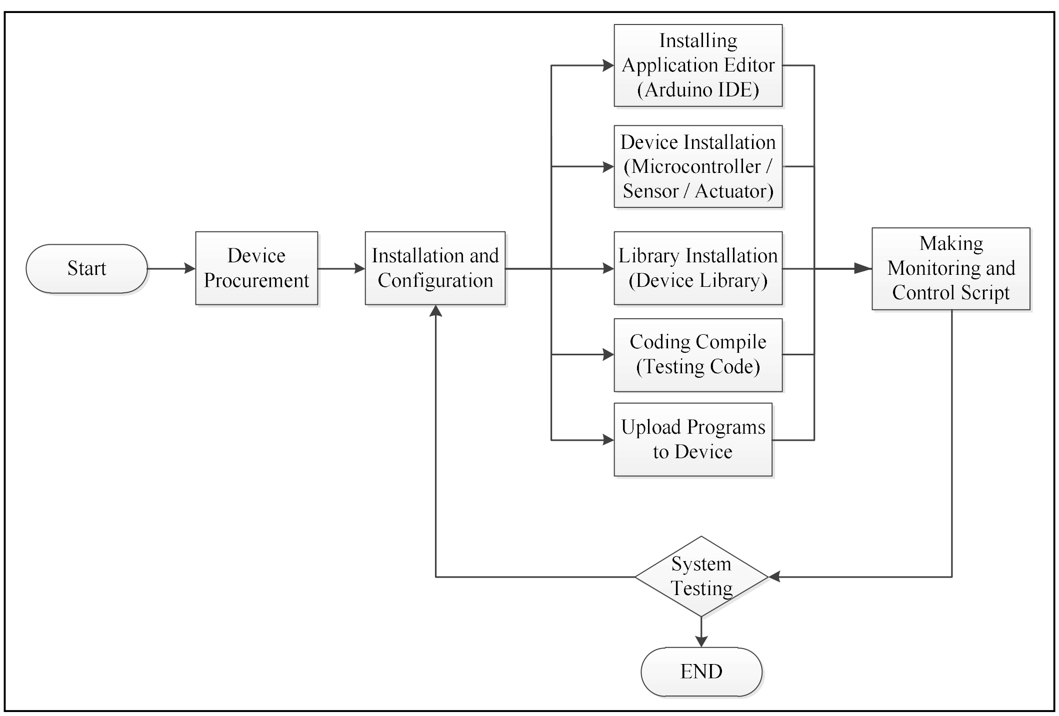


Figure 14. System Installation and Configuration Flow

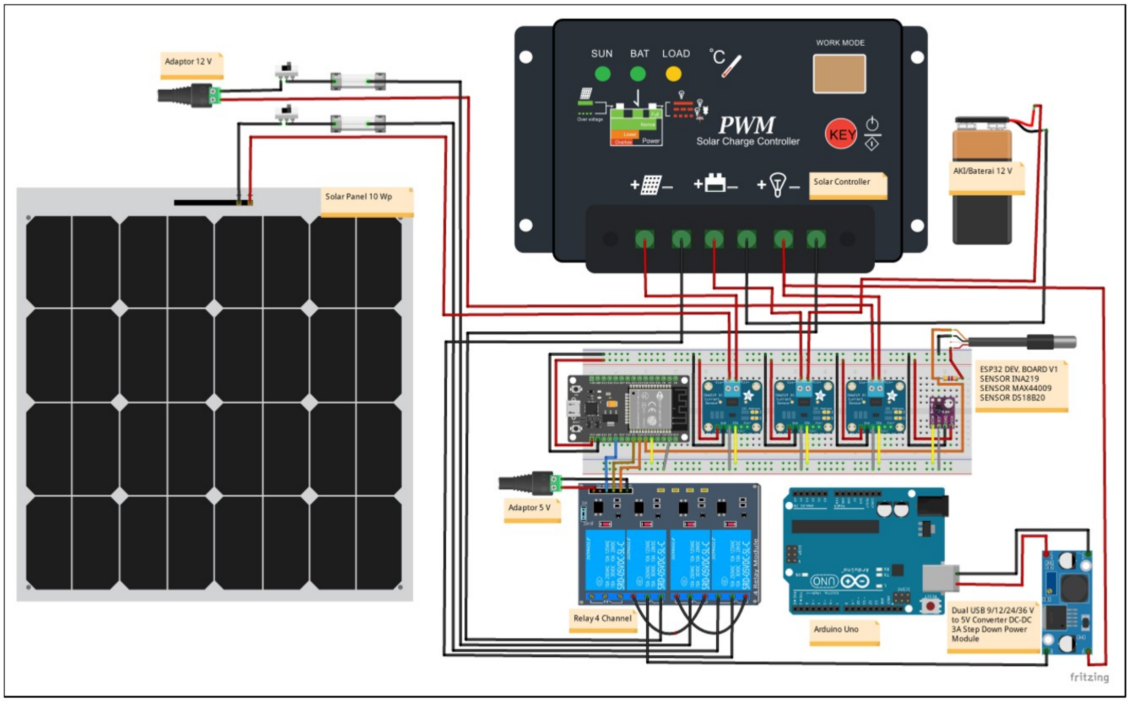


Figure 15. System Design Series

3.5. Testing

Testing is an important part to do because it can be a benchmark for how the system can work and the shortcomings of the system that needs to be further improved. Tests carried out are:

3.5.1. Battery Charging Testing

The battery charging test uses a 10 Wp solar panel and a 12 volt battery. The test is carried out to determine the battery in charging conditions. Charging is done when the condition of the battery is under 12 volts, by automatic and manual. The filling test is automatically done to find out that the charging is going according to the reading of the sensor value and charging manually can be seen by pressing the button on the web monitoring.

a. Automatic Battery Charging

The auto-fill condition with Auto Relay Set and run the *handleAutomatic()* function. If the value of *t_state == 3* then *relay 1*, *relay 2* and *relay 3* is *off* and displays the value of the *valueray* and *valuecharger*. If the value of *t_state == 4*, enter *auto-running* options when the parameter values meet the requirements. The following are the parameters for charging the battery automatically:

1) If the *valueLux* value is above *1000 lux* then *relay 1* is *on*. *Relay 2 and relay 3* are *off* and display the value of the *relay value* and *valuecharger*.
2) If the *valueLux* value is below *1000 lux* and the value of the battery is below 12.00 volts then *relay 2* is *on*. *Relay 1 and relay 3* are *off* and display the value of the *relay value* and *valuecharger*.
3) If the *valueLux* value is below *1000 lux* and the value of the battery is below 11.89 volts then the *relay* is *3 on*. *Relay 1 and relay 2* are *off* and display the value of the *relay value* and *valuecharger*. The condition is that there is no battery charging and the battery supply for the device is disconnected to avoid overdischarge the battery so that the device is supplied directly by electricity.
4) If the *valueLux* value is above *1000 lux* and the value of the battery is above 14.40 volts, then *relay 1, relay 2 and relay 3* are *off*. Displays the *relay value* and *valuecharger*. The condition of the battery is full, charging is cut off to avoid battery overcharge so the device is supplied by the battery.

Automatic battery charging flowchart can be seen in Figure 16.

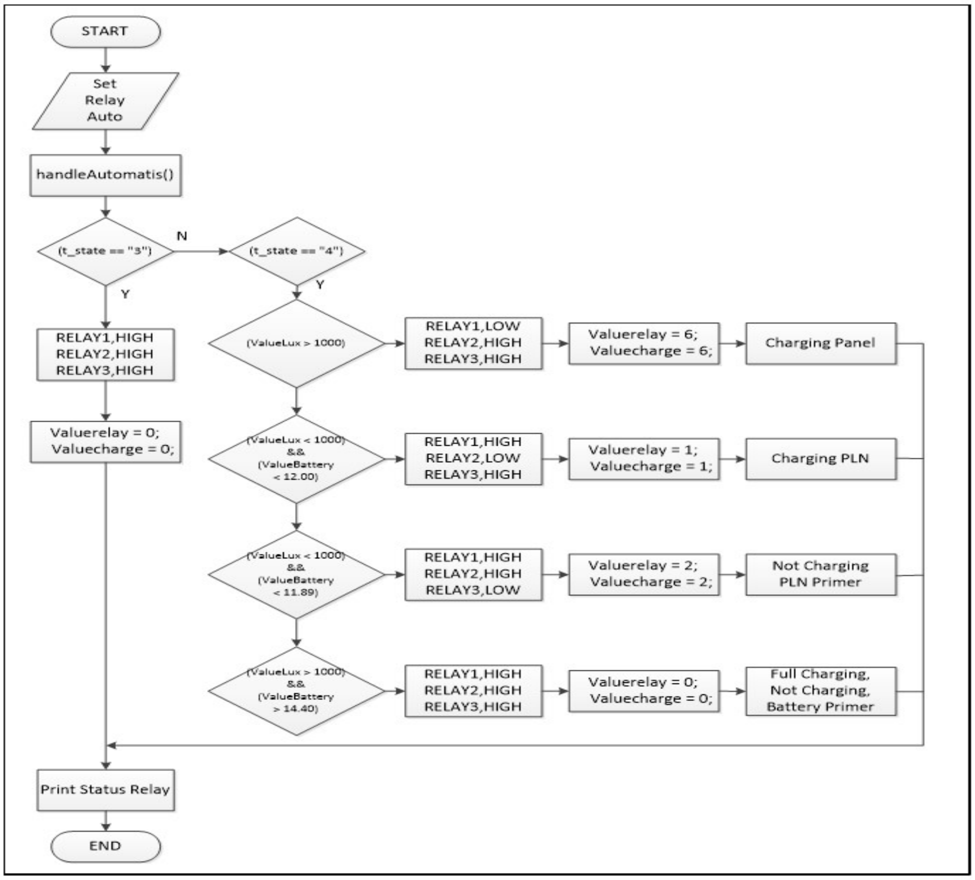


Figure 16. Automatic Battery Charging Flowchart

b. Manual Battery Charging

This test is to switch the battery charging automatically to charging the battery manually.

1. **Charging the Battery with a Solar Panel**
   The condition of solar panel charging with *Set Relay Panel* and running *handleRELAY1()* function. If the value of *t_state == 1*, *relay 1* is *on* and *relay 2* is *off* and displays the value of *relay value* and *valuecharger*. If the value of *t_state == 0* then *relay 1* is *off* and after that displays the value of the *value relay* and *value charger*. Battery charging flowchart with solar panels can be seen in Figure 17(a).
2. **Electric Battery Charging**
   The condition of charging with the *Electric Relay Set* and running *handleRELAY2()* function. If the value of *t_state == 1*, *relay 2* is *on* and *relay 1* is *off* and displays the value of *relay value* and *valuecharger*. If the value of *t_state == 0* then *relay 2* is *off* and after that displays the value of the *relay value* and *valuecharger*. The flowchart of charging the battery with electricity can be seen in Figure 17(b).
3. **No Battery Charging**
   Conditions that there is no battery charging with the *Set Relay Battery* and running the *handleRELAY3()* function. If the value of *t_state == 1* then *relay 3* is *on* and displays the value of the *relay value* and *valuecharger*. If the value of *t_state == 0* then *relay 3* is *off* and after that the *valuerelay* and *valuecharger* display appears. Flowchart no battery charging can be seen in Figure 17(c).

3.5.2. Testing the Transfer of Electric Energy Sources

Tests carried out to determine the transfer of electrical energy sources used to supply devices. Testing the transfer of electrical energy sources using a test scenario. The test scenario was made referring to research from Situmorang and Jatmiko [21] who tested the transfer of electric energy sources using manual mode testing and automated testing.

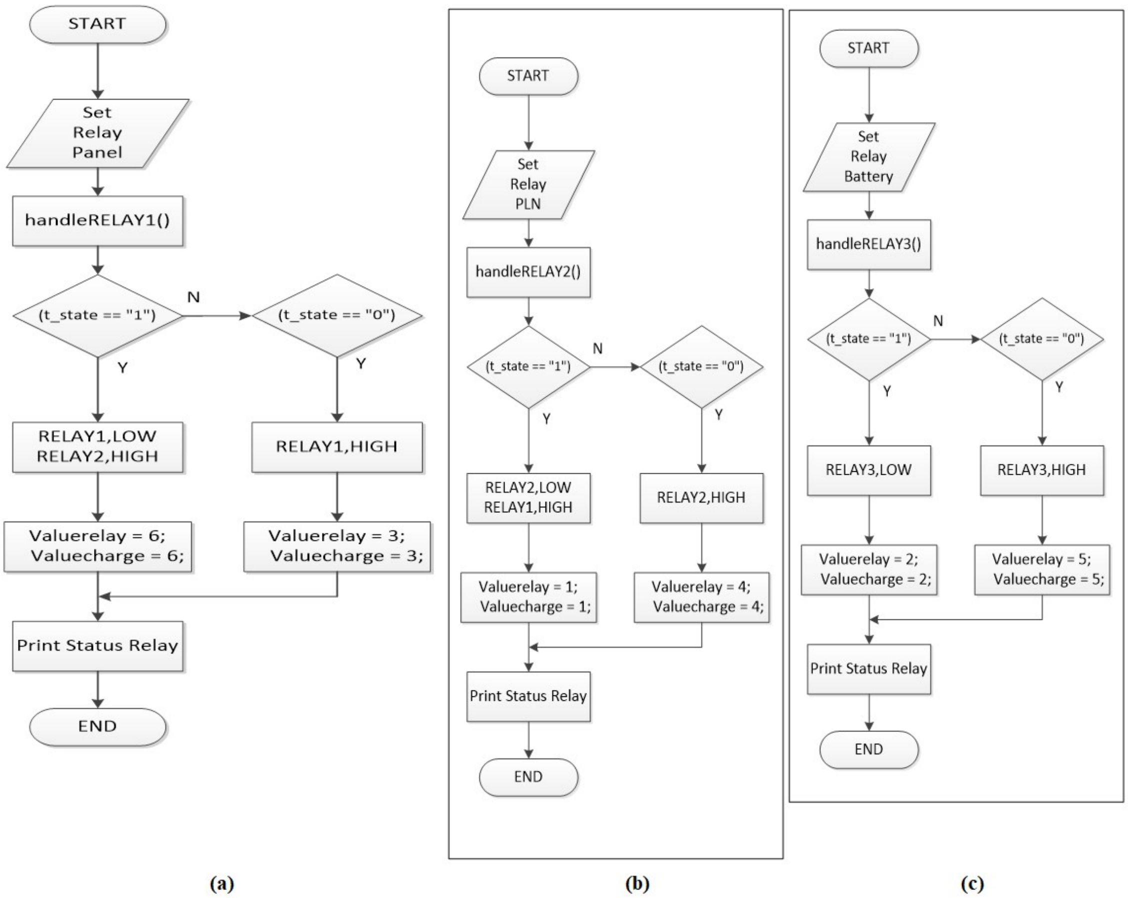


Figure 17. Flowchart for Testing of Manual Battery Charging

This research consists of two different scenarios, according to the parameters that have been set. The two scenarios include:

Scenario 1

This test is to find out the system is running normally. This test is carried out by operating the monitoring and control system in normal mode by taking the value of the battery voltage sensor parameter and the value of the sunlight intensity sensor. The parameter values of normal electric energy source transfer can be seen in Table 2.

Table 2. Normal Electric Energy Source Parameter Parameters

Solar Panel Relays	Electric Relay	Battery Relay	No Charging
The value of sunlight intensity is greater than the standard value (1000 Lux)	The value of sunlight intensity is smaller than the standard value (1000 Lux) and the value of the battery voltage is smaller than the standard value (12.00 Volts)	The value of sunlight intensity is smaller than the standard value (1000 Lux) and the value of the battery voltage is smaller than the minimum value (11.89 Volts)	The value of sunlight intensity is greater than the standard value (1000 Lux) and the value of battery voltage is greater than the maximum value (14.40 Volts)

Scenario 2

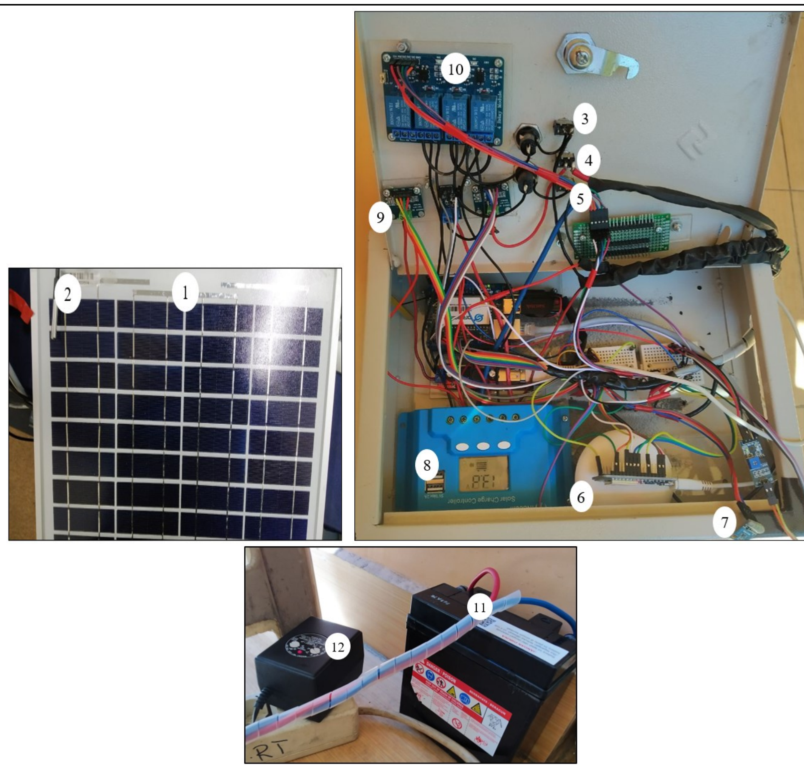
This test is done by manually operating the remote monitoring and control system by pressing the buttons on the web interface. This test is for forced displacement when normal conditions are active. Examples of manual displacement are performed when night conditions and battery capacity are decreasing so that it is not possible to supply the device and cannot charge. The following conditions of electric energy transfer manually can be seen in Table 3.

Table 3. Manually Transferring Electric Energy

Solar Panel Relays	Electric Relay	Battery Relay	*Output*
ON	OFF	ON	ON
ON	OFF	OFF	ON
OFF	OFF	ON	ON
OFF	ON	OFF	ON

3.6. Analysis and Conclusions

At this stage an analysis of the measurement and testing results of each parameter by looking at the reference, then used as the final product document in this study. Problems found in the research process are also used as research data in developing further research.



1) 10 Wp solar panel.
2) Temperature sensor (DS18B20).
3) Energy source from solar panels.
4) Battery battery connection.
5) Source of energy from electricity.
6) ESP32 Microcontroller.
7) Light intensity sensor (MAX44009).
8) Charger Controller.
9) Voltage, current and power sensors (INA219).
10) 4 Channel Relay.
11) A adapter 12 Volt as a backup power source if the battery voltage is insufficient to supply the device.
12) Batteries for supplying electrical energy.

Figure 18. System Prototype

4. Results and Discussion

4.1. Implementation

4.1.1. Hardware

Hardware implementation includes the use of devices used. Knowing the workflow of the device from the microcontroller to read sensors, control relays and send data to the server. The prototype system that has been made can be seen in Figure 18.

4.1.2. Software

Implementation of the software aims to implement and use applications into the system.

Software Configuration

a. Arduino Program

The use of libraries, initialization of sensor variables and initialization of data delivery destinations in the Arduino program can be seen in Figure 19 and Figure 20.

DHCPRevisi17 § | index.h

```
#include <Wire.h>
#include <Adafruit_INA219.h>
#include <OneWire.h>
#include <DallasTemperature.h>
#include <BH1750.h>
#include <WiFi.h>
#include <PubSubClient.h>
#include <WebServer.h>
#include "index.h" // File web interface
#include <HTTPClient.h>

// Topic MQTT configuration
#define MQTT_TOPIC_CELCIUS "TEMPERATUR/celcius"
#define MQTT_TOPIC_BUSVOLTAGE_C "INA219/busvoltage_C"
#define MQTT_TOPIC_SHUNTVOLTAGE_C "INA219/shuntvoltage_C"
#define MQTT_TOPIC_CURRENT_MA_C "INA219/current_mA_C"
#define MQTT_TOPIC_POWER_MW_C "INA219/power_mW_C"
#define MQTT_TOPIC_LOADVOLTAGE_C "INA219/loadvoltage_C"
#define MQTT_TOPIC_VOLTAGE "Voltage/Volt"
#define MQTT_TOPIC_BUSVOLTAGE_A "INA219/busvoltage_A"
#define MQTT_TOPIC_SHUNTVOLTAGE_A "INA219/shuntvoltage_A"
#define MQTT_TOPIC_CURRENT_MA_A "INA219/current_mA_A"
#define MQTT_TOPIC_POWER_MW_A "INA219/power_mW_A"
#define MQTT_TOPIC_LOADVOLTAGE_A "INA219/loadvoltage_A"
#define ARRAYSIZE 3
#define MQTT_TOPIC_Counter "Counter/counter"
#define MQTT_TOPIC_Relay "Value/relay"
#define MQTT_TOPIC_Charge "Value/Charge"
#define MQTT_TOPIC_Capacity_Bateray "Cap/Bateray"
#define MQTT_TOPIC_BH1750 "BH1750/Light"
#define MQTT_TOPIC_STATE "STATUS"
#define MQTT_PUBLISH_DELAY 60000
#define MQTT_CLIENT_ID "root"
#define RELAY1 18 //Relay 1
#define RELAY2 5 //Relay 2
#define RELAY3 4 //Relay 3
#define DS18B20 19

float valueLux = 0.00;
float volta = 0.00;
int Relay1 = 0;
int Relay2 = 0;
int Relay3 = 0;
int Relay4 = 0;
```

Figure 19. Use of Library and Sensor Data Variable Initialization

```
const char *MQTT_SERVER = "10.0.0.207";
const char *MQTT_SERVER_2 = "10.0.0.205";
const long MQTT_PORT = 1883;
const char *MQTT_USER = "cuaca";
const char *MQTT_PASSWORD = "123456";
const char* deviceName = "mws";
```

```
WiFiClient espClient_1;
WiFiClient espClient_2;
PubSubClient mqttClient_1(espClient_1);
PubSubClient mqttClient_2(espClient_2);
```

Figure 20. Initializing the Purpose of Sending Data to the Server

b. Lumen Microframework Program.
Lumen Microframework Program can be seen in Figure 21(a) and Figure 21(b).

```
APP_NAME=Lumen
APP_ENV=local
APP_KEY=
APP_DEBUG=true
APP_URL=http://10.0.0.207
APP_TIMEZONE='Asia/Makassar'
DB_TIMEZONE= '+08:00'

LOG_CHANNEL=stack
LOG_SLACK_WEBHOOK_URL=

DB_CONNECTION=influxdb
DB_HOST=10.0.0.207
DB_PORT=8086
DB_DATABASE=mydb
DB_USERNAME=root
DB_PASSWORD=123456


CACHE_DRIVER=file
QUEUE_CONNECTION=sync
```

```
GNU nano 2.2.6     File: /var/www/lumen/composer.json

{
    "name": "laravel/lumen",
    "description": "The Laravel Lumen Framework.",
    "keywords": ["framework", "laravel", "lumen"],
    "license": "MIT",
    "type": "project",
    "require": {
        "php": ">=7.1.3",
        "guzzlehttp/guzzle": "~6.0",
        "influxdb/influxdb-php": "^1.14",
        "laravel/lumen-framework": "5.8.*",
        "oanhnn/laravel-influxdb": "^0.1.0",
        "orumad/lumen-config-cache": "^1.0",
        "vlucas/phpdotenv": "^3.3"
    },
    "require-dev": {
        "fzaninotto/faker": "^1.4",
        "phpunit/phpunit": "^7.0",
        "mockery/mockery": "^1.0"
    },
    "autoload": {
        "classmap": [
            "database/seeds",
            "database/factories"
```

(a) **(b)**

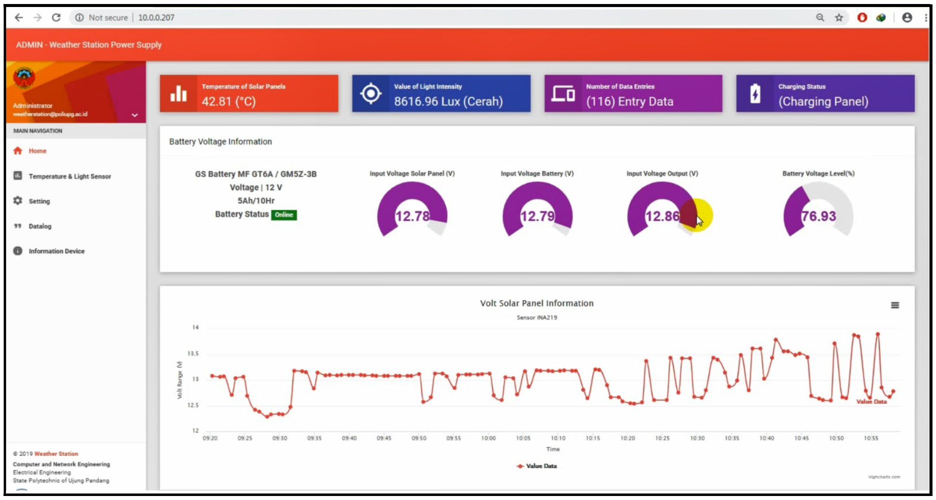
Figure 21. Lumen Microframework Program

c. Data Visualization

Home Menu
The Home menu displays voltage, current and power information data. Besides displaying status such as panel surface temperature, light intensity value, the amount of data entering and charging status information as shown in Figure 22.

Temperature and Light Sensor Menu
The Temperature and Light Sensor menu displays information about the temperature of the solar panel surface and information on the intensity of sunlight. The temperature and light sensor menu display can be seen in Figure 23.

Settings Menu
The Settings menu displays information about the settings for using electric energy sources. Display Settings menu can be seen in Figure 24.



Gambar 22. Home Menu Display

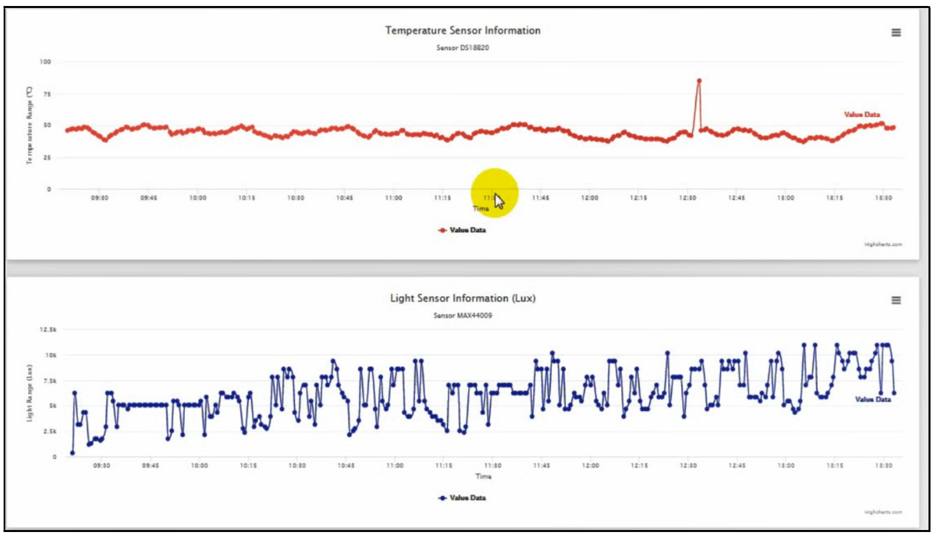


Figure 23. Temperature and Light Display

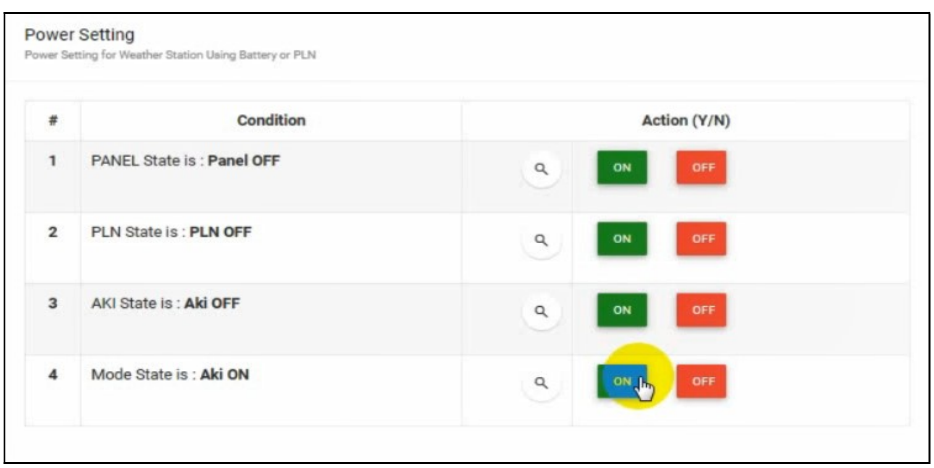


Figure 24. Display the Settings Menu

Data Log Menu

Data Log Menu to display all data that has been stored in the database in tabular form. Display data log menu can be seen in Figure 25.

Battery Voltage Sensor Data Tabel

Copy CSV Excel PDF Print

Search:

No	Date	Loadvoltage (V)	Busvoltage (V)	Shuntvoltage (mV)	Current (mA)	Power (mW)
1	2019-07-29T17:29:20Z	13.62	13.46	159.06	1629	22090
2	2019-07-29T17:29:42Z	13.67	13.5	164.19	1630.1	22018
3	2019-07-29T17:30:26Z	13.69	13.61	81.91	-56.3	810
4	2019-07-29T17:30:47Z	13.55	13.55	-6.18	-62.2	862
5	2019-07-29T17:31:31Z	13.52	13.52	-6.3	-61	848
6	2019-07-29T17:31:53Z	13.51	13.52	-6.29	-61.7	846
7	2019-07-29T17:32:36Z	13.46	13.46	-6.31	-64.4	878
8	2019-07-29T17:32:58Z	13.44	13.45	-6.25	-64	856
9	2019-07-29T17:33:42Z	13.43	13.44	-6.38	-61.8	882
10	2019-07-29T17:34:03Z	13.43	13.44	-6.48	-61.5	878
No	Date	Loadvoltage (V)	Busvoltage (V)	Shuntvoltage (mV)	Current (mA)	Power (mW)

Showing 1 to 10 of 11 entries

Previous 1 2 Next

Figure 25. Display Data Log Menu

Device Information Menu

Device Information menu to display all devices starting with solar panels, actuator sensors etc. used in this study. Information device menu display can be seen in Figure 26.

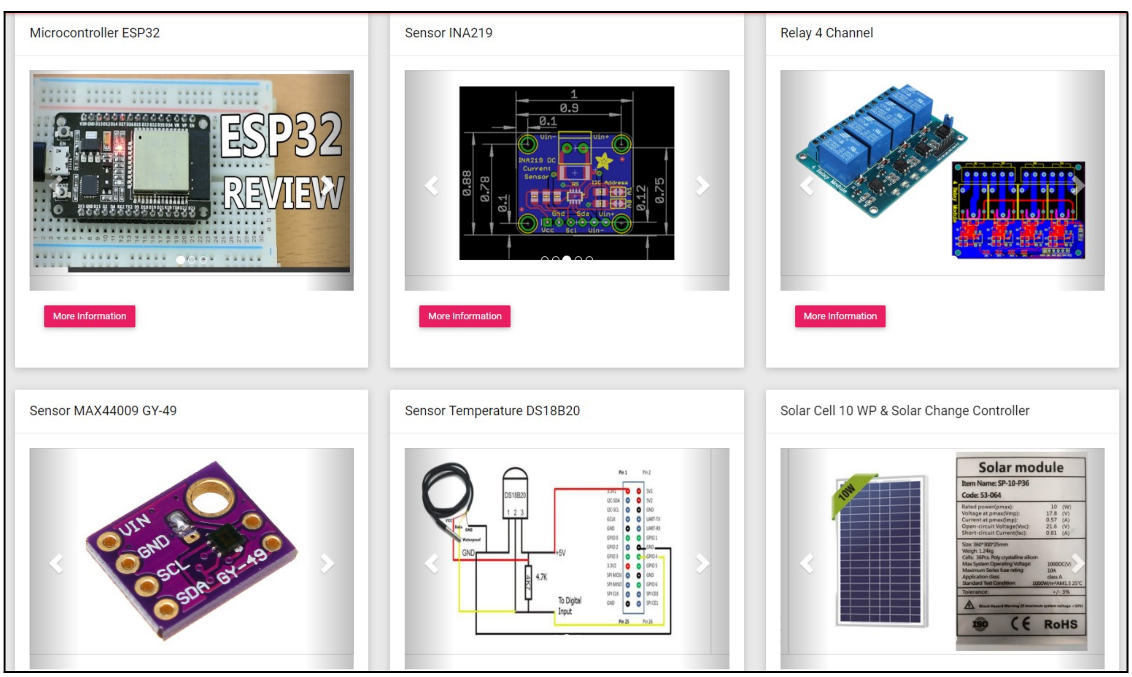


Figure 26. Display Information Device Menu

4.2. Testing

4.2.1. Battery Charging Testing

Automatic Battery Charging Test

Automatic battery charging test to see the charging run automatically according to the sensor value read. The filling test is carried out in clear weather conditions and allows for charging. The test is carried out for 12 hours on 16 August 2019 starting at 08:30 WITA until 20:00 WITA and the data collection time is every 30 minutes. The following results of battery charging tests can be seen in Table 4. In Table 5, the automatic mode runs by using several parameters to run the battery charging switching process. Displacement parameters as described in section 3.5. The current value is negative because the reading of the current value on the INA219 sensor works both ways where it is negative if there is an electric load and is positive if there is no electricity load.

Table 4. Table Testing Automatic Battery Charging

Time (Month / Date / Year Hours)	Solar Panel Voltage (V)	Battery Voltage (V)	Battery Ampere (mA)	Battery Power (mW)	Electric Voltage (V)	Ampere Electricity (mA)	Electric Power (mW)	Light (lux)	Temperature (°C)	Relay	*Output* or Supply	Mode
8/16/2019 8:30	14.72	13.21	222.6	2896	13.19	-62.9	836	9180	39.25	6	2	Otomatis
8/16/2019 9:00	14.73	13.28	287.6	4234	13.26	-90	1236	155725	44.63	6	2	Otomatis
8/16/2019 9:30	14.84	12.64	-74.7	950	12.62	-95.2	1242	546125	50.81	6	2	Otomatis
8/16/2019 10:00	14.71	12.59	-71.6	944	12.55	-98.5	1242	546125	51.69	6	2	Otomatis
8/16/2019 10:30	14.74	13.45	-73.6	944	12.53	-62.9	800	546125	54	6	2	Otomatis
8/16/2019 11:00	15.74	13.49	485.9	6764	13.44	-62.1	826	546125	54.06	6	2	Otomatis
8/16/2019 11:30	15.91	13.6	539.5	7236	13.49	-58.9	802	546125	47.44	6	2	Otomatis
8/16/2019 12:00	15.02	13.75	532.9	7186	13.59	-60	810	546125	52.56	6	2	Otomatis
8/16/2019 12:30	16.22	14.02	523.1	7190	13.75	-56.2	810	546125	52.19	6	2	Otomatis
8/16/2019 13:00	17.51	14.09	478	6662	14.03	-57.6	820	546125	52.75	6	2	Otomatis
8/16/2019 13:30	17.8	14.78	420.2	6288	14.06	-56.9	874	546125	53.25	6	2	Otomatis
8/16/2019 14:00	17.72	13.95	341.2	5374	14.72	-53.2	872	546125	52.69	0	2	Otomatis
8/17/2019 14:30	17.78	13.65	310.4	4964	14.31	-49.5	750	546125	51.63	0	2	Otomatis
8/18/2019 15:01	16.5	13.41	-20.9	330	14.4	-45.8	628	31750	50.12	0	2	Otomatis
8/19/2019 15:31	15.65	13.5	-15.9	250	14.49	-42.1	506	17500	48.61	0	2	Otomatis
8/20/2019 16:01	14.55	13.6	-11.9	223	14.08	-38.4	584	8500	47.1	0	2	Otomatis
8/21/2019 16:31	14.4	13.5	-13.9	200	13.5	-34.7	462	610	45.59	0	2	Otomatis
8/22/2019 17:02	13.3	13.3	-12.9	223	13.26	-31	440	321	44.08	0	2	Otomatis
8/23/2019 17:32	12.5	12.0	-19.9	392	12.0	-27.3	310	140	42.57	0	2	Otomatis
8/16/2019 18:00	13.1	13.09	-19.9	266	13.1	-6.8	88	33.33	27.19	2	2	Otomatis
8/16/2019 18:30	12.08	12.05	-11.5	140	12.06	-31.5	380	27.5	27.13	2	2	Otomatis
8/16/2019 19:00	12.05	12.05	-11.6	140	12.06	-32.4	390	28.33	27.13	2	2	Otomatis
8/16/2019 19:30	12.05	12	-12	142	12	-32.4	390	28.33	27	2	2	Otomatis
8/16/2019 20:00	12.08	12.1	-19.5	262	13.03	-6.6	88	28.33	25.12	2	2	Otomatis

Relays and Output Descriptions or supplies:

1: Electricity ON　　3: Panel OFF　　5: Battery OFF
2: Battery ON　　4: Power OFF　　6: Panel ON
0: There is no charging

Manually Charging Battery Testing

Test the battery charging manually to see the battery charging running by pressing the button on the web monitoring. The charging test is carried out at night when the battery capacity decreases and it is not possible to charge the battery with solar panels. The test is carried out for 12 hours on August 16, 2019 starting at 20:30 WITA until August 17, 2019 at 08:00 WITA and the time of data collection every 30 minutes. The following results of manually charging the battery can be seen in Table 5.

In Table 5, the battery charging process with manual mode is done by pressing the button on the web monitoring. In this test, the battery is maintained so as not to reach the minimum voltage level of

11.89 volts. This is done so that if the battery reaches an empty condition too often will cause battery sulfation so that the battery will be damaged quickly.

Table 5. Table Testing Battery Charging Manually

Time (Month / Date / Year Hours)	Solar Panel Voltage (V)	Battery Voltage (V)	Battery Ampere (mA)	Battery Power (mW)	Electric Voltage (V)	Ampere Electricity (mA)	Electric Power (mW)	Light (lux)	Temperature (°C)	Relay	*Output* or Supply	Mode
8/16/201920:30	12.15	12.5	-11.4	138	12.06	-31.9	390	0.83	24.81	2	2	Manual
8/16/201921:00	12.13	12.5	-11.6	140	12.05	-32.4	400	3.33	24.87	2	2	Manual
8/16/201921:30	12.11	13	-18.8	256	13	-6.8	86	3.33	24.87	2	2	Manual
8/16/201922:00	12.15	12.05	-11.3	134	12.05	-31.5	390	3.33	24.87	0	1	Manual
8/16/201922:30	12.13	12.05	-11.6	138	12.06	-32.2	394	3.33	25	2	0	Manual
8/16/201923:00	12.11	12.98	-19.8	262	12.98	-6.6	88	3.33	24.69	0	1	Manual
8/16/201923:30	12.09	12.98	-20.6	252	12.98	-6.6	86	3.33	24.94	0	1	Manual
8/17/20190:00	12.09	12.97	-20.1	250	12.98	-6.7	88	3.33	25.5	2	2	Manual
8/17/20190:30	12.15	12.98	-11.3	138	12.05	-31.9	390	2.5	26.12	0	1	Manual
8/17/20191:00	12.09	12.05	-18.4	246	12.98	-6.7	88	2.5	26.44	2	2	Manual
8/17/20191:30	12.09	12.97	-19.7	258	12.98	-6.7	88	2.5	26.62	0	1	Manual
8/17/20192:00	12.09	12.97	-18.7	252	12.97	-6.4	88	2.5	26.75	2	2	Manual
8/17/20192:30	12.13	12.97	-11.2	134	12.04	-32.3	386	3.33	26.81	2	2	Manual
8/17/20193:00	12.11	12.02	-11.5	138	12.05	-32.2	390	3.33	26.87	2	2	Manual
8/17/20193:30	12.16	12.01	-11.4	140	12.01	-64.5	780	3.33	26.87	2	2	Manual
8/17/20194:00	12.22	11.96	-11.3	138	12.01	-65.7	802	3.33	26.94	2	2	Manual
8/17/20194:30	12.27	12.01	-11.3	134	12.01	-66.3	792	3.33	27	2	2	Manual
8/17/20195:00	12.3	12.06	-11.3	139	12.2	-66.9	850	3.8	27.1	2	2	Manual
8/17/20195:30	12.33	12.1	-11	130	12.39	-67.5	825	4.27	27.2	2	2	Manual
8/17/20196:00	12.36	12.16	-11.2	135	12.58	-68.1	850	4.74	27.3	2	2	Manual
8/17/20196:30	12.39	12.21	-11.22	137	12.77	-68.7	860	718.21	27.4	2	2	Manual
8/17/20197:00	12.42	12.26	-11.31	138	12.96	-69.3	881	1536	27.5	2	2	Manual
8/17/20197:30	12.45	12.3	-11.35	140	12.15	-69.9	911	2304.15	27.6	2	2	Manual
8/17/20198:00	12.48	12.36	-11.3	140	12.15	-70.5	910	5826	27.7	2	2	Manual

Relays and Output Descriptions or supplies:

1: Electricity ON — 3: Panel OFF — 5: Battery OFF
2: Battery ON — 4: Power OFF — 6: Panel ON
0: There is no charging

4.2.2. Testing of Displacement of Electric Energy Sources

The results of the transfer of electrical energy sources as described in Section 3.5 consist of two scenarios.

Testing for Scenario 1

Retrieves the battery voltage sensor value and the sunlight intensity sensor value.

***Testing for Scenario 1:* Solar Panel Relays**

The solar panel relay is active when the light intensity value is above 1000 lux. Retrieval of data starting on August 18, 2019 at 07:30 WITA until 15:30 WITA. Display of active solar panel relays can be seen in Figure 27.

In Figure 29, the panel relay is active when the value of sunlight intensity is above 1000 lux. The above conditions can make the process of charging the battery. The condition of the solar panel relay does not charge the battery when the value of the light intensity is below 500 lux and dark conditions and at nightfall.

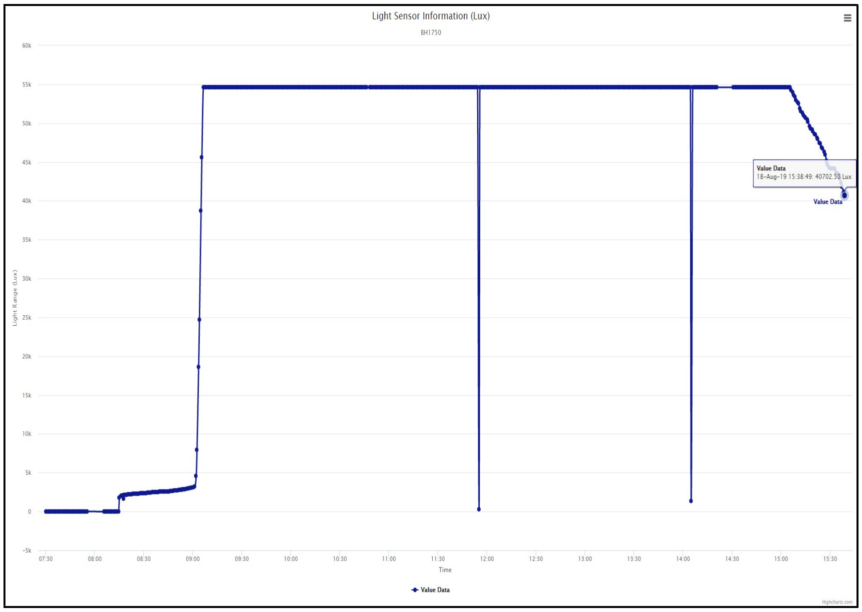


Figure 27. Active Panel Relay

Testing for Scenario 1: Electric Relay

Electric Relay is active when the light intensity value is below 1000 lux and the voltage is below 12 volts. Retrieval of data starting on August 23, 2019 at 00:00 WITA until 07:15 WITA. An active electric relay display can be seen in Figure 28.

In Figure 30, the electric relay is active when the battery voltage has reached 12 volts. This condition is active when charging a battery with solar panels cannot be done so it uses a power source from PLN. The use of PLN electricity sources does not increase the battery voltage level because the voltage source is only 12 volts.

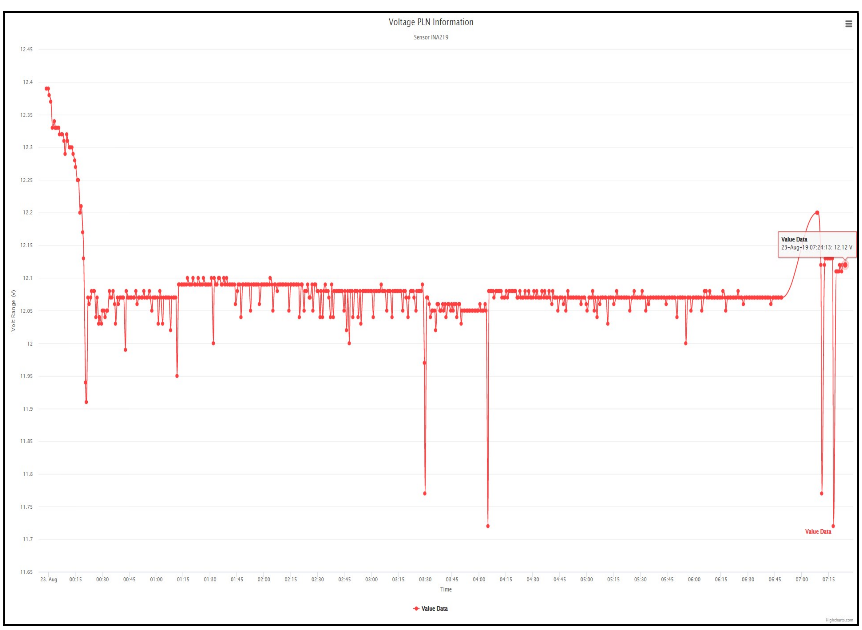


Figure 28. Active Electric Relays

Testing for Scenario 1: Battery Relay

The battery relay is active when the voltage value is below 11.89 volts. Retrieval of data starting on August 23, 2019 at 00:00 WITA until 07:15 WITA. The active battery relay display can be seen in Figure 29.

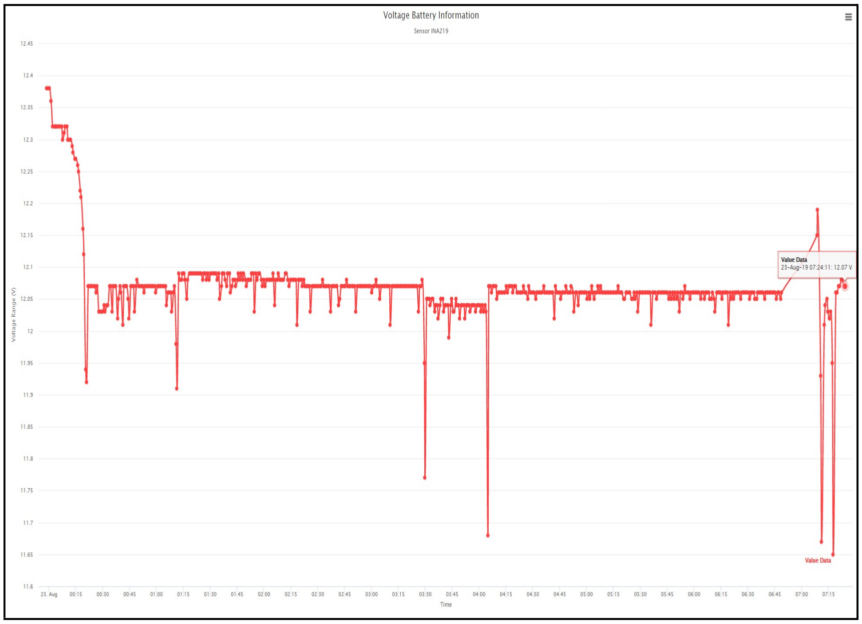


Figure 29. Active Battery Relay

In Figure 30, the battery relay is active when the battery reaches the minimum voltage level of 11.89 volts. This condition, the use of batteries to supply devices is disconnected and transferred to the PLN source with a 12 volt voltage.

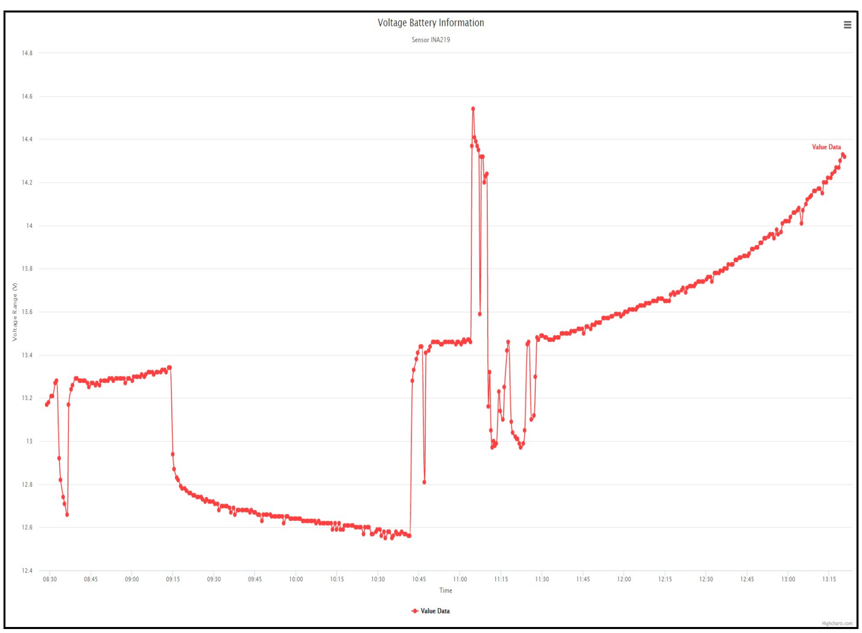


Figure 30. No Charging

Testing for Scenario 1: No Charging

The value of sunlight intensity is greater than the standard value (1000 lux) and the value of the battery voltage is greater than the value of the battery voltage above 14.40 volts. Retrieval of data starting on August 23, 2019 at 08:30 WITA until 13:15 WITA. Display no charging can be seen in Figure 32.

In figure 32, there is no charging when the battery voltage value is above 14.40 volts. So that the use of batteries is used to supply the device while preventing the battery from overcharging.

Testing for Scenario 2

Testing manually by pressing the button on the web monitoring. This test is carried out to move the energy source from normal mode to manual mode by pressing the button on the web monitoring. Retrieval of data by activating the battery relay when normal mode is active. Display the transfer of electric energy sources manually can be seen in Figure 31.

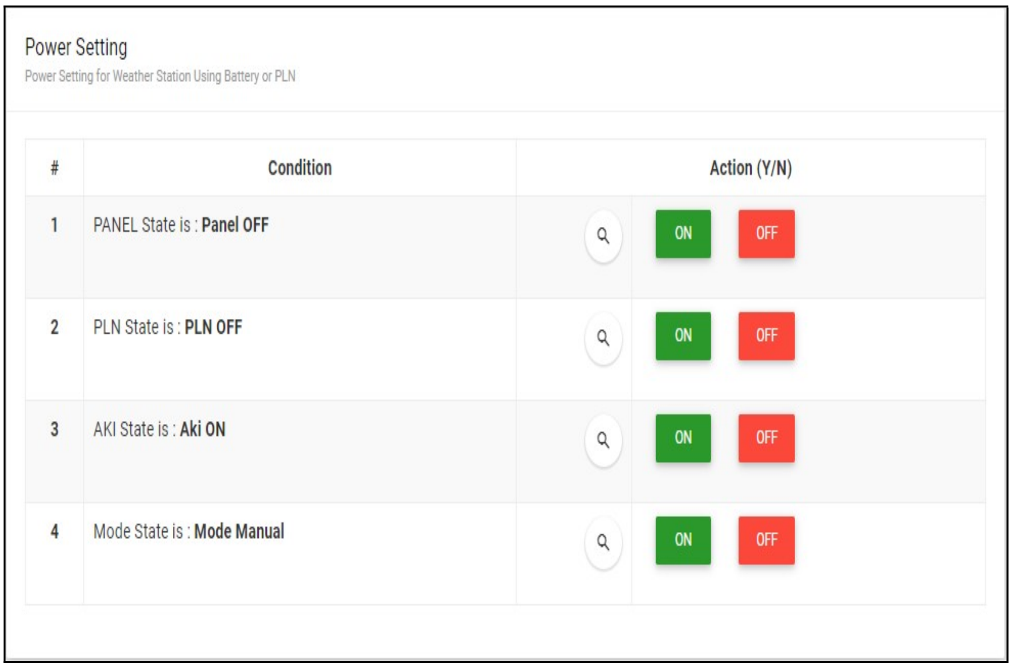


Figure 31. Manually Transferring Electric Energy Sources

In Figure 33, the transfer of electrical energy sources manually runs by pressing the button on the web monitoring. Web monitoring to regulate and control the transfer of electrical energy sources remotely.

5. Conclusions and Suggestions

From the process of design, implementation, and testing conclusions can be drawn as follows:

1) The use of two electrical energy sources to support the availability of a weather station electricity source through a web server has been successfully implemented to prevent sudden system outages due to power supply interruption.
2) This research produces a remote monitoring and control system that can automatically switch from the main energy source to the backup energy source. When the mains voltage goes out, the system is able to transfer the energy source to the main source again when the main source is restored. The system is also able to make changes manually using a web server that can be controlled remotely. When the battery reaches a voltage above 14.40 volts, the charging process stops and the system uses electrical energy from the battery. When the battery voltage reads 11.89 volts. then the battery charging process again.

3) The results of the electrical energy information system on a miniature weather station can display information about voltage, current, power, temperature and intensity of sunlight in the form of graphical visualization in real time.

In designing this system there are still shortcomings so that further improvements or developments can be made.

1) Use of a solar tracker to optimize the absorption of solar energy on solar panels.
2) Integrate the system with the Andriod / iOS smartphone application to make it more practical in controlling and monitoring the system.

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