

INTERACTIVE CONTROL ALGORITHM BASED ON REAL-TIME
SOLAR IRRADIANCE FORECASTING MODEL FOR STANDALONE
PHOTOVOLTAIC SYSTEM



AHMAD SYAHIMAN BIN MOHD SHAH

AZRI BIN IDRIS

MOHD SHAWAL BIN JADIN

MUHAMMAD IKRAM BIN MOHD RASHID

MOHD SAIFIZI BIN SAIDON

RESEARCH VOTE NO:

RDU170367

Faculty of Electrical and Electronics Engineering Technology

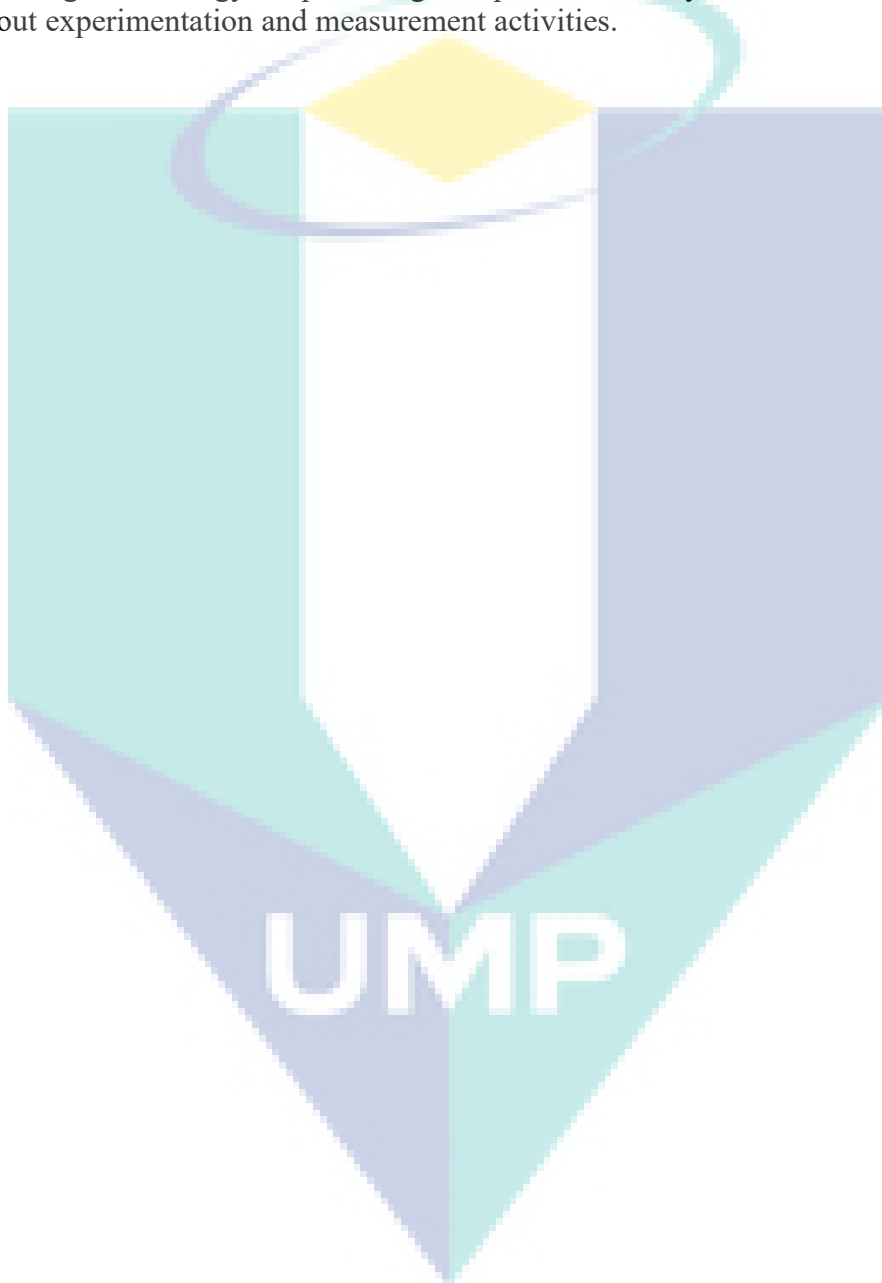
UNIVERSITI MALAYSIA PAHANG

2019

ACKNOWLEDGEMENTS

We would like to thank Universiti Malaysia Pahang for providing this research grant to enable us to conduct this study.

Also, we would like to acknowledge the Faculty of Electrical and Electronics Engineering Technology in providing adequate laboratory facilities for our team to carry out experimentation and measurement activities.



ABSTRACT

Standalone photovoltaic (PV) system is practical and beneficial for the place where the physical power transmission line is not feasible. Nevertheless, for miniature scale standalone PV system, efficient and interactive energy management is extremely necessary to ensure that the battery is capable of supplying energy to the load uninterruptedly without any failure as its condition is being monitored, time by time. In this paper, a real-time energy management system equipped with wireless monitoring features has been developed and tested. All energy information such as battery voltage, generating current, discharging current, etc. are well displayed and extracted directly from the developed system. The high-power switching system is able to be controlled remotely as several MOSFETs attached to the main circuit are feasible to be flagged on or off via Blynk application instantaneously without any time lags. Therefore, the proposed system may become a good model for better small-storage-capacity based real-time energy management system in the future.



UMP

TABLE OF CONTENT

ACKNOWLEDGEMENTS	ii
ABSTRACT	iii
TABLE OF CONTENT	iv
CHAPTER 1 INTRODUCTION	1
1.1 Project Background	1
1.2 Problem Statement	2
1.3 Objective	3
1.4 Project Scope	3
CHAPTER 2 METHODOLOGY	4
2.1 Introduction	4
2.2 System Design and Configuration	4
2.3 Software	5
2.3.1 Arduino IDE	5
2.3.2 Proteus	6
2.3.3 Blynk	7
2.4 Hardware Development	8
2.4.1 PV Panel	8
2.4.2 Battery	9
2.4.3 Inverter	10
2.4.4 Charge Controller (MPPT)	11
2.4.5 Arduino Mega	12
2.4.6 Wi-Fi Serial Transceiver Module ESP8266	13
2.4.7 TFT LCD Screen	14

2.4.8	Voltage Sensor	14
2.4.9	Current Sensor	15
2.4.10	Power MOSFET	16
2.5	Algorithm of Load Scheduling	18
2.6	Block Diagram	20
CHAPTER 3 RESULTS AND ANALYSIS		21
3.1	Introduction	21
3.2	Result and Discussion	21
3.2.1	State of Charge (SOC)	21
3.2.2	Full Assemble System	23
3.2.2.1	Discharging Process	24
3.2.2.2	Charging Process	29
CHAPTER 4 CONCLUSION		35
4.1	Introduction	35
4.2	Conclusion	35
4.3	Recommendation	35
CHAPTER 5 JOURNAL PAPERS		
5.1	Efficient Operation of Lithium-Ion Batteries Based on Forecasted PV Output	35
5.2	Real-Time Wireless Energy Management System of Miniature Standalone Photovoltaic Application	35
5.3	A Review on Factors Affecting Heat Transfer Efficiency of Nanofluids for Application in Plate Heat Exchanger	35

CHAPTER 1

INTRODUCTION

1.1 Project Background

Solar energy is a renewable energy that has many application and a lot of usage to humans nowadays, and considered to be one of the most effective resources because it is very common and its sustainability. Solar energy is a free source of energy that everyone can gain a lot of benefits if they know the right method to gain and manage that energy. Actually there are several application that has been developed such as solar power generations, satellite power systems and solar vehicles. Example of advantages that people can gain from this energy is by building a stand-alone PV system. Power generation through PV solar power is very popular as it can generate power in from kilowatts to hundreds of megawatts. However, there is some reason people not used this kind of energy, it is because usually the price in order to setup for the first time using this energy is quite expensive throughout the incoming years.

There is a lot of ways people can build their own stand-alone PV system such as by installing it on rooftop of the house, vehicles and others. However, in this project, the stand-alone PV system was built on a normal board with the aim to gain electricity power supply when there are some problems occur. For example, an emergency use during sudden blackout or at remote places where physical electricity power supply is not feasible such as mountain, jungle and others, this system is able to supply electricity to user. This project will be focused on management system for the usage of stand-alone PV system. The storage and usage of this system depend on updated forecasted data. When forecasted data is updated, state of charge (SOC) will be calculated and further processed, time by time. The battery capacity depends on this SOC's estimated result.

The unit of SOC for empty and fully battery charged are 0% and 100%, respectively. The SOC in a battery management system must be accurately estimated because the system controls the performance of the battery to continue its lifetime. Many methods can be applied to estimate the state of charge of the battery. These methods can possibly improve the performance and reliability of the battery. This paper implements ampere-hour (Ah) counting, discharge test and open circuit voltage (OCV) methods since these methods are easy to calculate and can be monitored in real-time under unstable consumption condition. Thus, the usage of the load will be set depending on the estimated result of the SOC. Based on this, load usage such as total energy to be discharged and its time duration will be determined automatically by using Arduino Mega as main microcontroller. If the value of SOC is low due to bad weather condition on that particular day, the power usage limit will be set to low and its time duration also should be shortened than the normal days. Eventually, the result of the SOC and other energy information such as voltage and current values of PV panel, battery, DC load, AC load and total load will be displayed and monitored in real-time through Arduino's serial monitor, TFT LCD screen and smartphone apps.

1.2 Problem Statement

There are several reasons why the main focus is on interactive energy management system that includes remote real-time monitoring control system. It can be expressed as follows.

- When the battery storage is low or does not have enough power to supply to the system, the system will automatically shut down. Consumers do not know how much energy can be used and how long the system can be run.
- Consumers tend to use the system without knowing the details information about the currents flow, total energy usage, remaining battery, etc. In simple words, they are unable to monitor the system while it is running. Conventionally, they just use it until the system is automatically shut down.
- Consumers need to stay close to the system if they want to control the system such as AC load and DC load (switch on or off the load).

1.3 Objective

There are several objectives need to be achieved at the end of this project such as follows:

- To construct an interactive management system for usage of the load based on battery capacity and forecasted data of standalone PV system.
- To develop a real-time monitoring scheme for the result of the usage of some components such as voltage and current of every measureable parameters.
- To setup an online wireless control of the system by using smartphone apps (Blynk) based on ESP8266 Wi-Fi Module.

1.4 Project Scope

The main scope of this project is actually focusing on interactive management system in order to manage the usage of the DC and AC load based on the forecasted data and battery capacity. Based on forecasted data, the value of SOC will be calculated and then processed by the Arduino Mega. High SOC value will results higher charging of battery capacity and influenced the change of DC and AC load usage at night, where there is no exposure of sunlight.

The usage of the DC and AC load can be monitored as the result of total usage that will be displayed at serial monitor, TFT LCD screen and on smartphone apps (Blynk). Therefore, user can monitor the values such as PV panel, battery, DC and AC load current or voltage in real-time. If there is some problems occurs, it is easier for user to detect and fix them since the result of energy usage and SOC is always updated and displayed. Furthermore, the system is upgraded to be wirelessly controlled by using ESP8266 module. This ESP8266 module just needs to be connected to the Wi-Fi connection and synchronise to the smartphone using Blynk software that can be downloaded from Appstore or Google Playstore. Thus, the proposed system will provide wireless remote control and real-time monitoring system.

CHAPTER 2

METHODOLOGY

2.1 Introduction

This chapter describes the method used in this project such as software and hardware development. This chapter also will describe how the project will run with the whole system. Literally, study requires a proper management in order to make sure the whole proposed system works properly. Thus, in order to make sure the system can be used efficiently, the energy storage system is introduced by using load forecasting method.

2.2 System Design and Configuration

In designing the system, the list of hardware and components must be chosen properly. The current values across some point of the circuit on the system can be measured using current sensor. So in this project, ACS712 current sensor has been selected in order to measure the current values from PV panel, batteries and the load of DC and AC. The whole system design of this project can be refer to the Figure 2.1 shown below.

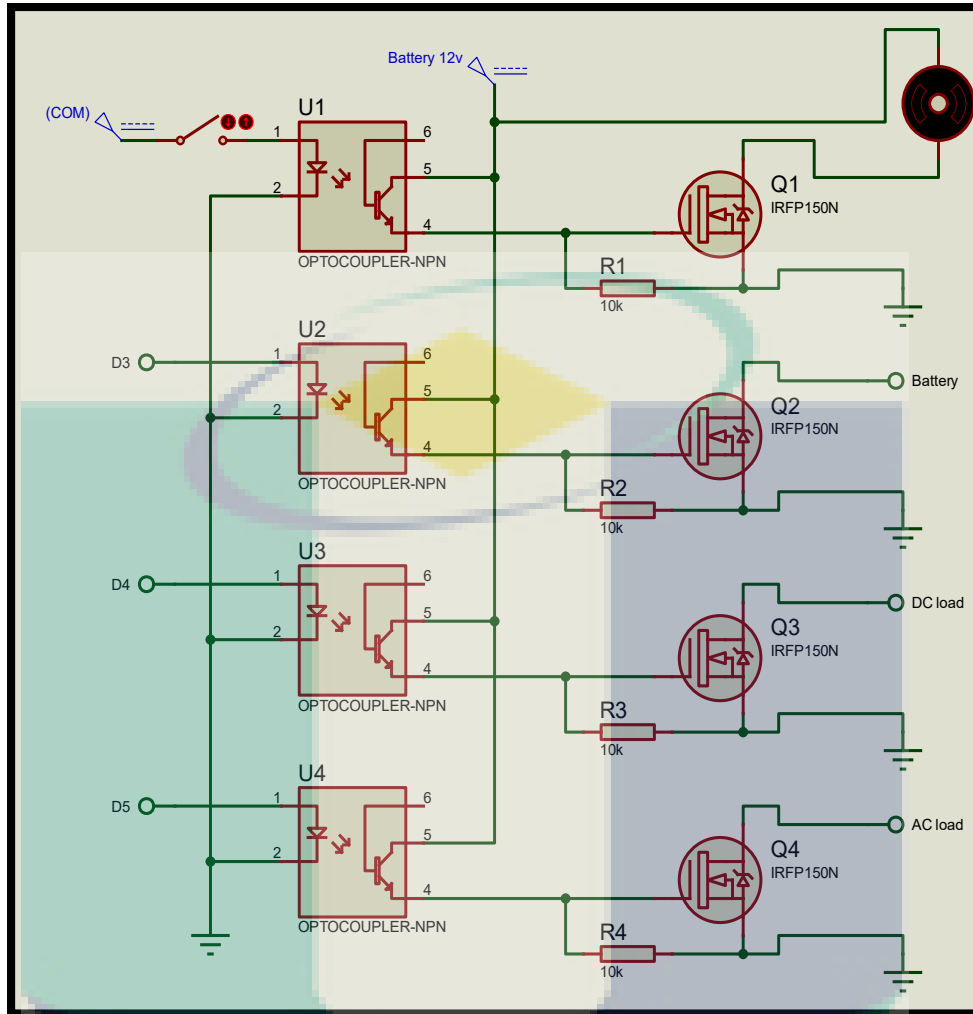


Figure 2.1 The whole design of the system

2.3 Software

2.3.1 Arduino IDE

Arduino IDE is the main software used in this project. This software has been used in order to make some coding to manage the load storage interactively. Using this software, all controllable variable and component can be controlled automatically such as current, voltage, power values, load usage and others. Next, by using this software also the users can decide what values or result will be displayed so it will be easier for users to monitor the system usage or other things. Example of Arduino IDE program shown in Figure 2.2

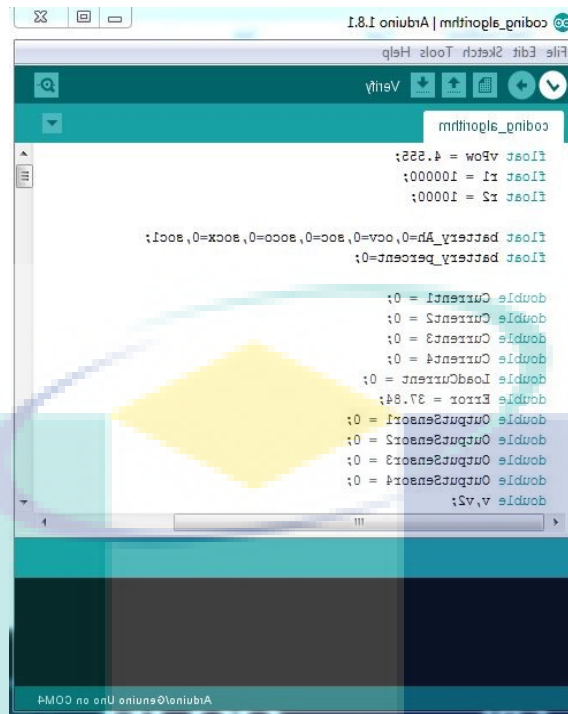


Figure 2.2 Example of Arduino.IDE program

2.3.2 Proteus

Proteus software has been used in this project in order to design the circuit systems of this whole project. Component by component need to be inserted properly in Proteus software in order to test the circuit whether it can run clearly without a single problem that can affect the system. Figure 2.3 below is the example of system design using Proteus software.

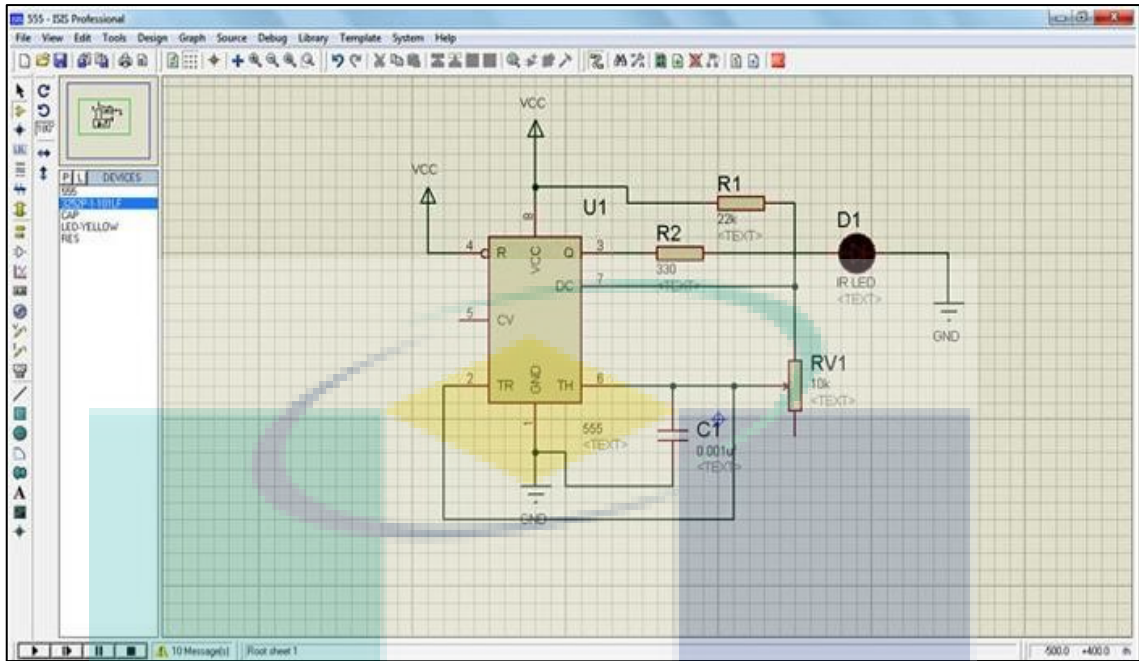


Figure 2.3 Example of system design using Proteus software

2.3.3 Blynk



Figure 2.4 Example of Blynk application

When used ESP8266 for this project to control the Arduino wirelessly and for far distance, Blynk software is the perfect combination with ESP8266 because it can send and receive any signal from and to the Arduino board by using a Wi-Fi connection. Just download Blynk software in the phone at Appstore or google play store and link it to the ESP8266 by using auth token provided by Blynk software. Figure 2.4 above is the example of Blynk used to control the Arduino board wirelessly.

2.4 Hardware Development

2.4.1 PV Panel

PV panel is the main and most important hardware when the project is related to the PV system. Photovoltaic is a term which covers the conversion of light into electricity using semiconducting materials. Same thing here, PV panel is the main and most important hardware in this project in order to make sure the batteries accumulate excess energy created by PV system and store it to be used at night or when there is no other energy input. Thus, this stand-alone system project can work as planned.

In this system, after all calculation considered, 100W solar panel with 18V maximum will be used. This solar module will be exposed to sunlight generates heat as well as electricity. Full specifications of the PV module used in this project shown in Figure 2.5 below and PV module 100W 18V is in Table 2.1

Table 2.1 Full specification of 100W PV Module

Content	Value
Maximum Power	100W
Tolerance	± 3%
Open Circuit Voltage	22V
Short Circuit Current	6,06A
Maximum Power Voltage	18V
Maximum Power Current	5,56A
Module Efficiency	14,9%
Solar Cell Efficiency	17,2%
Series Fuse Rating	15A
Terminal Box	IP65
Maximum system voltage	1000V DC
Dimensions	-40°C - 85°C
Weight	1005mm x 670mm x 30mm
	8kg

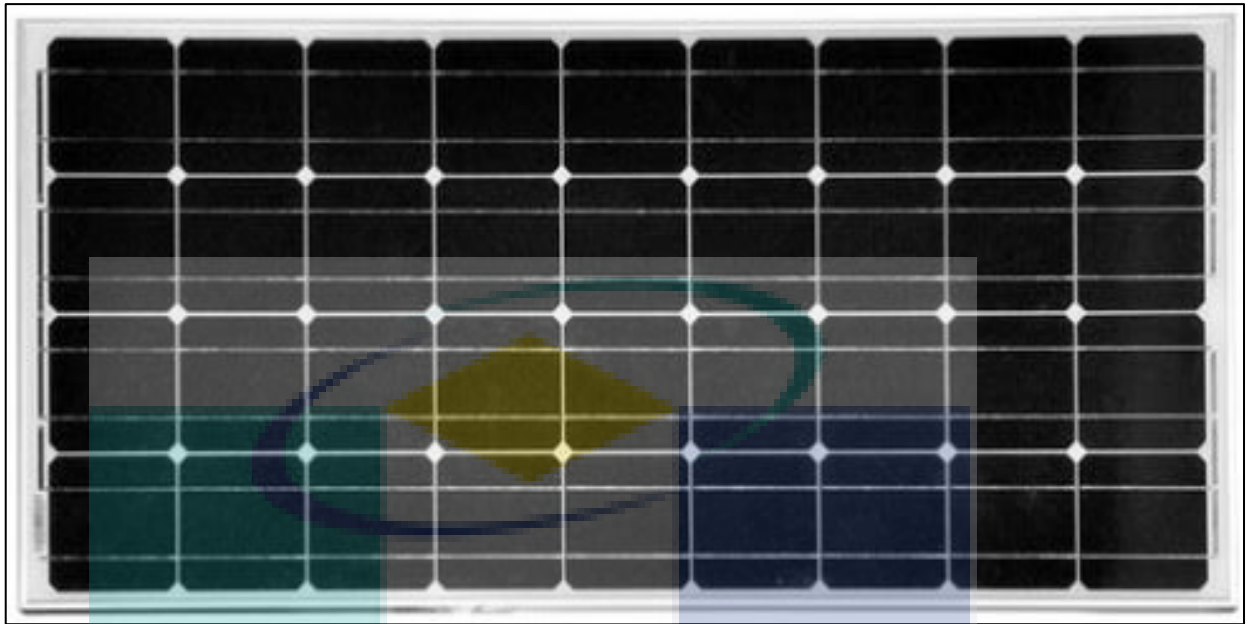


Figure 2.5 PV Module 18V 100W

2.4.2 Battery



Figure 2.6 GP 12400 40Ah lead acid battery

In stand-alone PV systems, electrical energy that was produced by the PV panels cannot always be used directly. Since the demand from the load is not always equal with the solar panel capacity, that is why battery bank is needed. By using battery, excess energy from solar panel can be stored and then it can provide excess energy when required such as there is no electricity, in nights and so on. In this project, lead acid - GP 12400 40Ah battery type has been used as battery bank. GP 12400 40Ah battery shown in Figure 2.6 and its full specification provided in Table 3.2.

Table 2.2 GP 124000 40Ah Battery

Specification	Value
Cells Per Unit	6
Voltage Per Unit	12V
Capacity	40Ah
Maximum Discharge Current	400A (5sec)
Internal Resistance	8.7 mΩ
Nominal Operating Temperature Range	25°C ± 3°C
Float Charging Voltage	13.5V to 13.8V
Max Charging Current	12A

2.4.3 Inverter

Inverter is an important component that need to be used in any PV system where AC power output is needed when there is AC load. Inverter will convert DC power from solar panel into clean AC power for AC load/appliances. In stand-alone PV system, stand-alone inverter is designed for remote stand-alone application with battery backup where the inverter will draw DC power from the batteries that is charged by solar panel and convert it to AC power.

In this project, SUOER SAA-1500A 1500W DC 12V to AC 220V inverter as shown in Figure 2.7, has been used as this inverter can produce small scale output power that is suitable for small scale appliances, around 500W. Full specifications of this inverter is provided in Table 3.3.

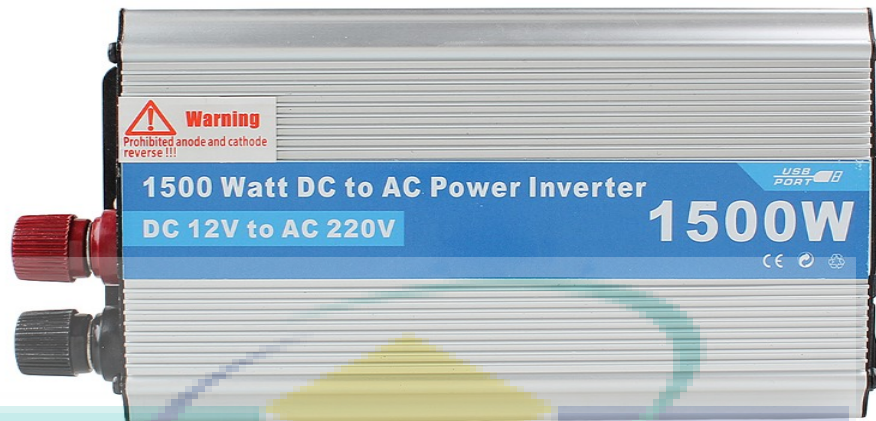


Figure 2.7 1500W DC 12V to AC 220V inverter

Table 2.3 SUOER SAA-1500A 1500W DC 12V to AC 220V Power Inverter

Specification	Value
Input Voltage	12 V
Output Voltage	230 V
Output Current	3500~4000 mA
Output Power	600~900W
Peak Power	1500W
Waveform Type	Modified Sine Wave
Output Socket	Universal
Conversion Efficiency	98%
Output Frequency	50 +/- 2Hz
Overvoltage Protection	14.5~15.5V
Low-voltage Protection	10.4~11.0V
Over temperature Protection	50'C

2.4.4 Charge Controller (MPPT)

Another type of tracker, called electrical Maximum Power Point Tracker (MPPT), is based on moving the operating PV voltage, or current, in order to get the maximum power. MPPT is an electronic DC to DC converter that optimizes the match between the solar panel and battery bank. MPPT convert a higher voltage DC power from solar panels down to the lower voltage needed to charge the batteries.

Y-Solar 12V/24V 30A MPPT solar charge controller as shown in Figure 2.8 has been used as charge controller in this whole project. This type of MPPT is very compatible MPPT charge controller because it has very efficient controller charging function that

can track the maximum power point automatically, and it is higher than the ordinary MPPT. Full specifications of this type of MPPT is provided in Table 2.4 below.

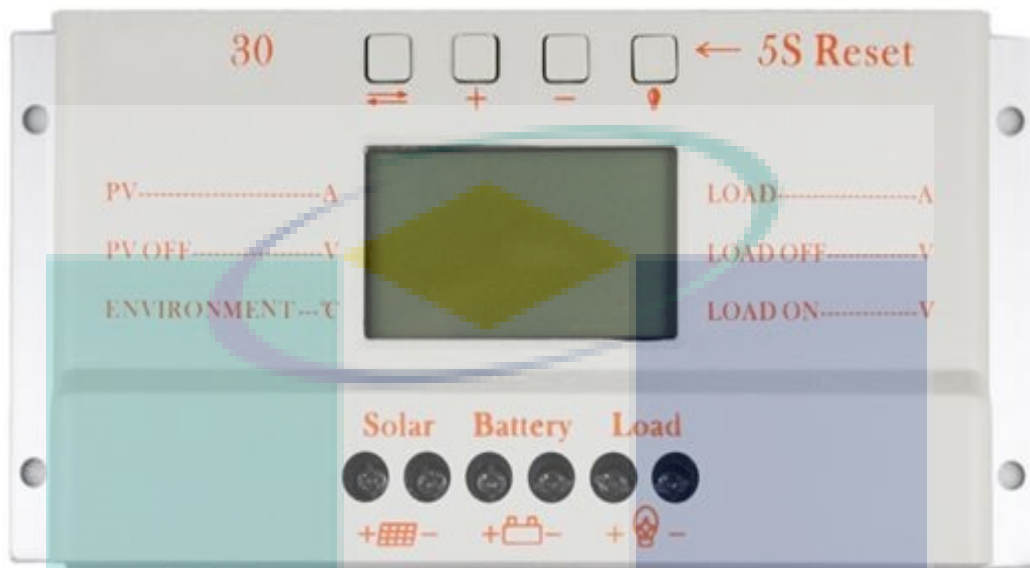


Figure 2.8 Y-Solar 12V/24V 30A MPPT solar charge controller.

Table 2.4 Y-Solar 12V/24V 30A MPPT Solar Charge Controller

Specification	Value
Maximum power current	30A
Battery float voltage	13.8V
Battery under voltage protection	10.6V
Battery under voltage recovery voltage	12.6V
Charge mode	MPPT+PWM mode
Operating temperature	-10°C~60°C
Storage temperature	-30°C~70°C

2.4.5 Arduino Mega

In order to make some coding that used a lot of component attach to Arduino board, Arduino Mega is needed as it has extra pins compared to Arduino Uno. Some component that need to be attached with Arduino Mega board are ESP8266, TFT LCD, current sensors and so on.

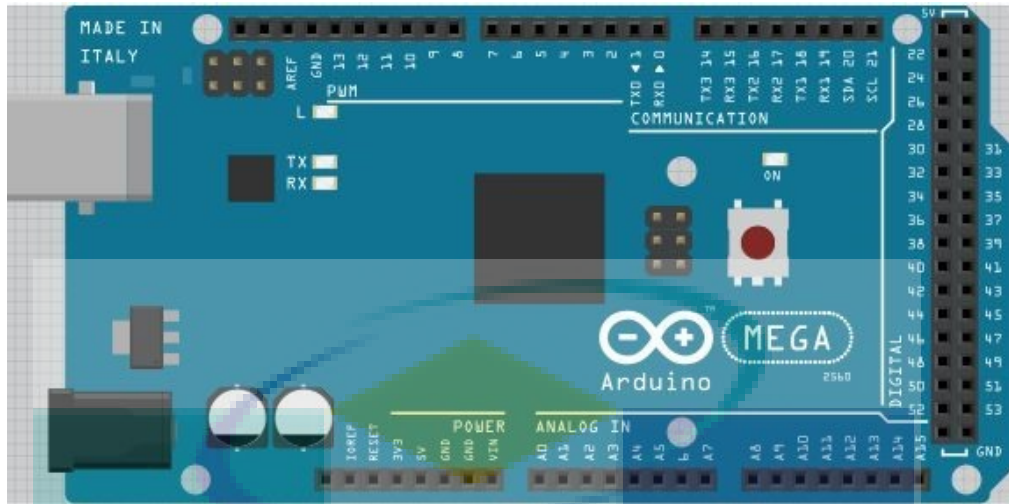


Figure 2.9 Arduino Mega 2560

2.4.6 Wi-Fi Serial Transceiver Module ESP8266

This project actually planned to have interactive management system such as controllable wirelessly and can used at far distance. Thus, ESP8266 is the solution to this problem as it can provide Wi-Fi connection. It is easy to use this component, just connect ESP8266 with a network by using Arduino IDE coding, a computer or phone using Blynk software. Figure 2.10 shows the example of ESP8266 used in this project in order to get Wi-Fi connection.

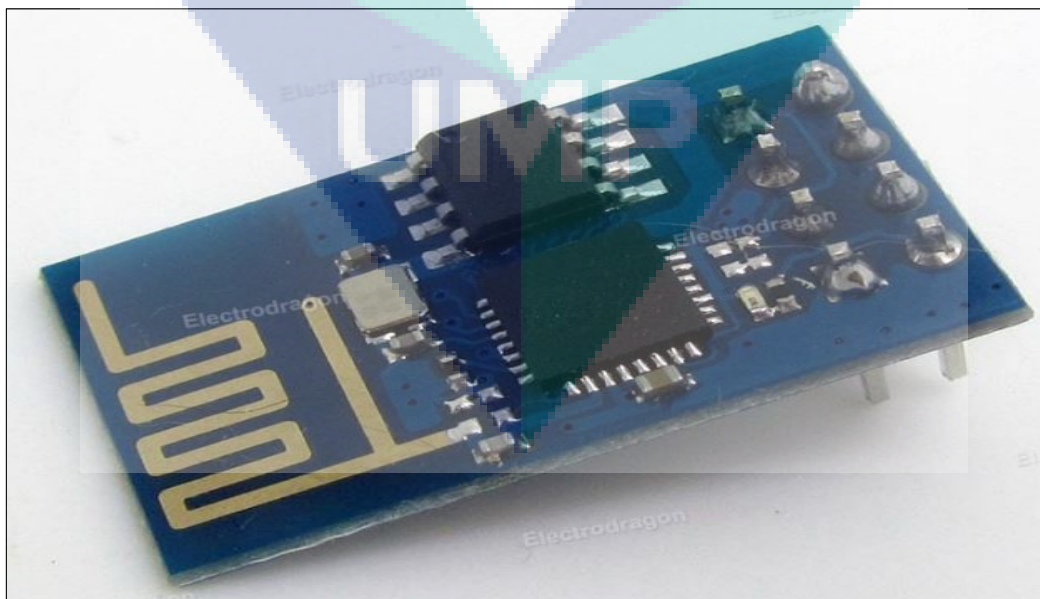


Figure 2.10 Wi-Fi Serial Transceiver Module ESP8266.

2.4.7 TFT LCD Screen

In case user want to monitor the results of this system every time easily, TFT LCD can be used as it can display everything that has been set by Arduino IDE coding. Thus in this project, TFT LCD has been used in order to display the result value of PV panel current, battery current, AC load current, DC load current, total load current and others important results to be monitored. Figure 2.11 is the example of TFT LCD used in this project.

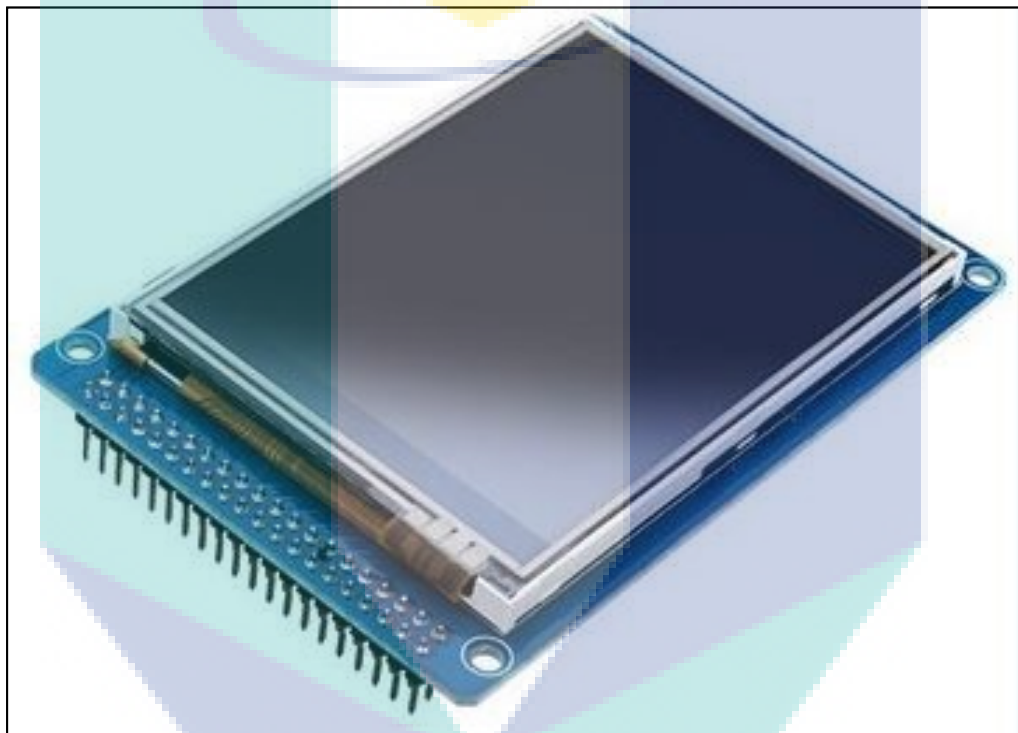


Figure 2.11 TFT LCD

2.4.8 Voltage Sensor

In order to measure the value of voltage, voltage divider has been constructed properly and act as voltage sensor now. Voltage divider is a simple circuit that transform the value of voltage from large to smaller value. By using an input voltage and two different resistor that is $100\text{k}\Omega$ and $10\text{k}\Omega$, the output of the voltage can be created. In this system, voltage divider is connected to two incoming voltages that is from solar module and solar charge controller. Based on Equation 2.1 below, the maximum output voltage that can be measured is 50V.

$$V_{out} = \frac{R_2}{R_1 + R_2} * V_{in}$$

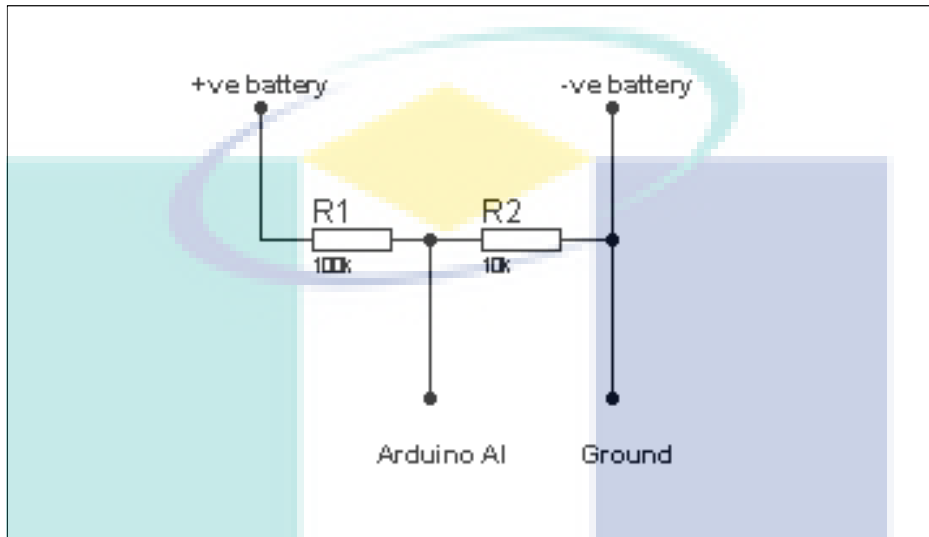


Figure 2.12 Voltage Divider in the system.

2.4.9 Current Sensor

A current sensor is a device that detects electric current in a wire, and generates a signal proportional to that current. The generated signal could be analog voltage or current or even a digital output. Current values across some point of the circuit on the system can be measured by using current sensor. In this project, ACS712 current sensor as in Figure 2.13 has been selected as it can provide economical and precise solutions for AC and DC current sensing in industrial, commercial, and communications systems.

Below in the Figure 2.14 is the design of connection from current sensor pin to the Arduino mega board. First, A0 Arduino pin has been connected to pin 7 of current sensor and linked to the solar panel to get the solar panel current value. A1 Arduino pin then connected to pin 7 of current sensor and linked with the battery to measure the battery current. Next, to measure the DC load current, A2 Arduino pin is connected to pin 7 of current sensor and linked to the DC load. Finally for AC load, A3 Arduino pin

has been connected to pin 7 of current sensor and linked to the AC load to identify the AC load current.

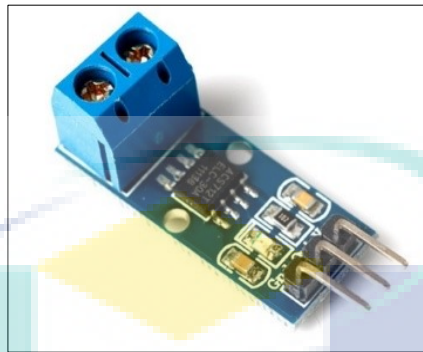


Figure 2.13 ACS712 Current Sensor

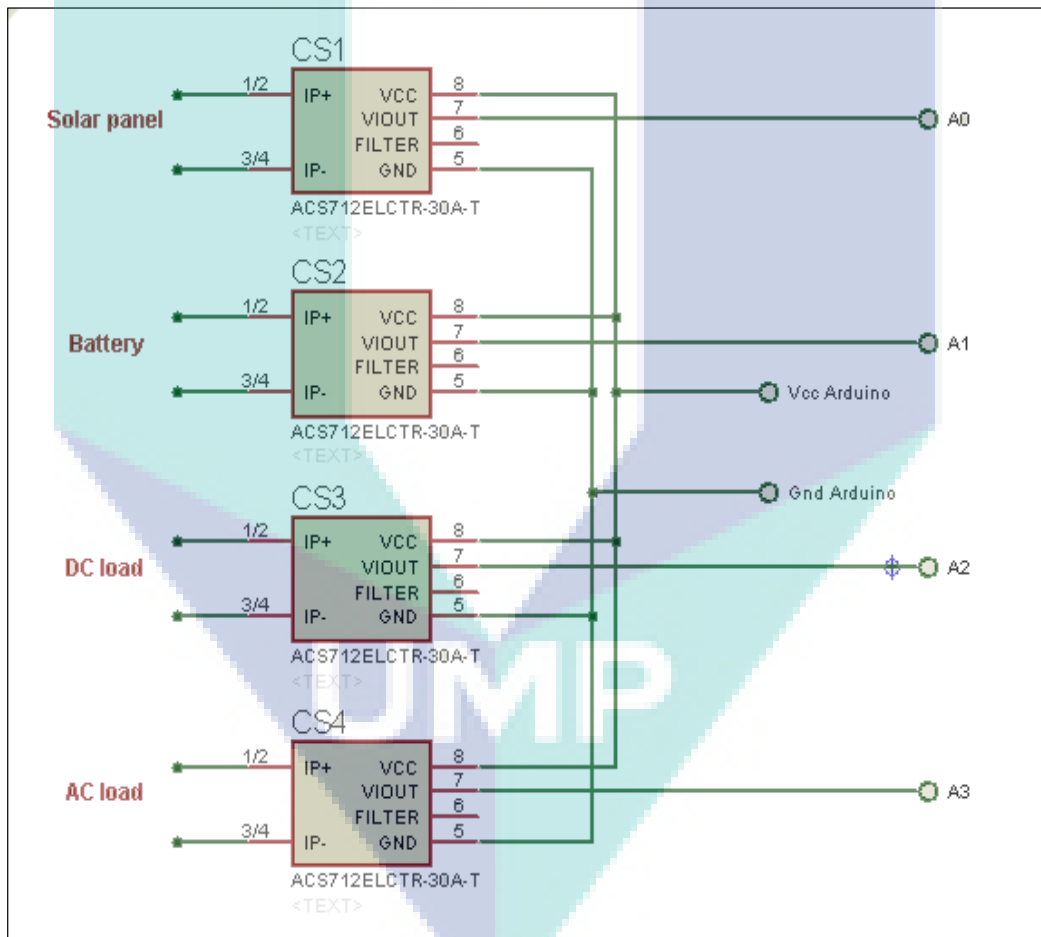


Figure 2.14 Connection of ACS712 in the system.

2.4.10 Power MOSFET

Most of power MOSFET actually used low voltage switch, which is less than 200V. Usually it can be found in power supply, DC to DC converter and low voltage motor

controller. In this system, IRFP150 Power MOSFET has been the choice to be used as it can provide the designer with the best combination of fast switching, ruggedized device design, low on-resistance and cost-effectiveness. Figure 2.15 below is the power MOSFET (IRFP150) used in this project and its specifications is show in Table 2.5 below.

Table 2.5 IRFP150 Power MOSFET

Specification	Value
Continuous drain current, V_{gs} ($T_c=25^\circ\text{C}$)	41A
Gate to source Voltage	$\pm 20\text{V}$
Pulsed Drain Current, I_{DM}	160A
Avalanche current, I_{AR}	41A
Peak diode recovery dv/dt	5.5V/ns

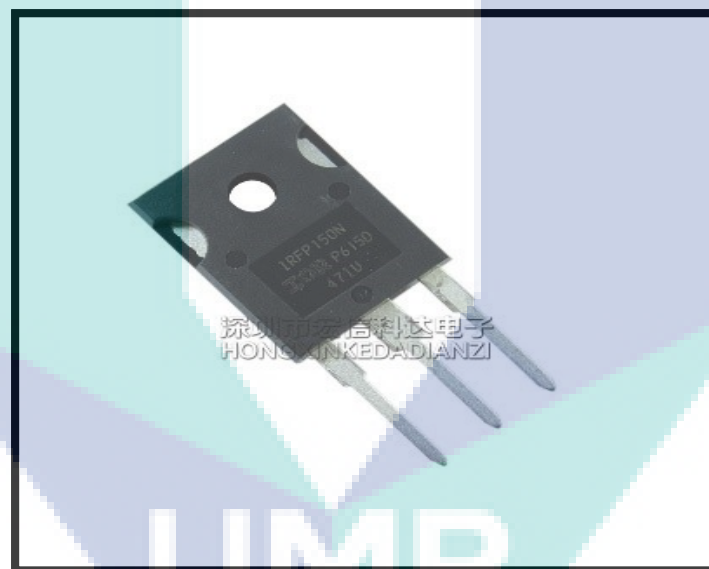


Figure 2.15 IRFP150 Power MOSFET

In this project, to use a MOSFET as a switch, you have to have its gate voltage some voltage (V_{gs}) higher than the source. If you connect the gate to the source you are ensuring the MOSFET is off ($V_{gs}=0$). Thus, in order to get value of gate voltage equal to zero and still using Arduino to control the MOSFET, an optocoupler has been paired with the MOSFET. Figure 2.16 below show the connection of optocoupler with MOSFET.

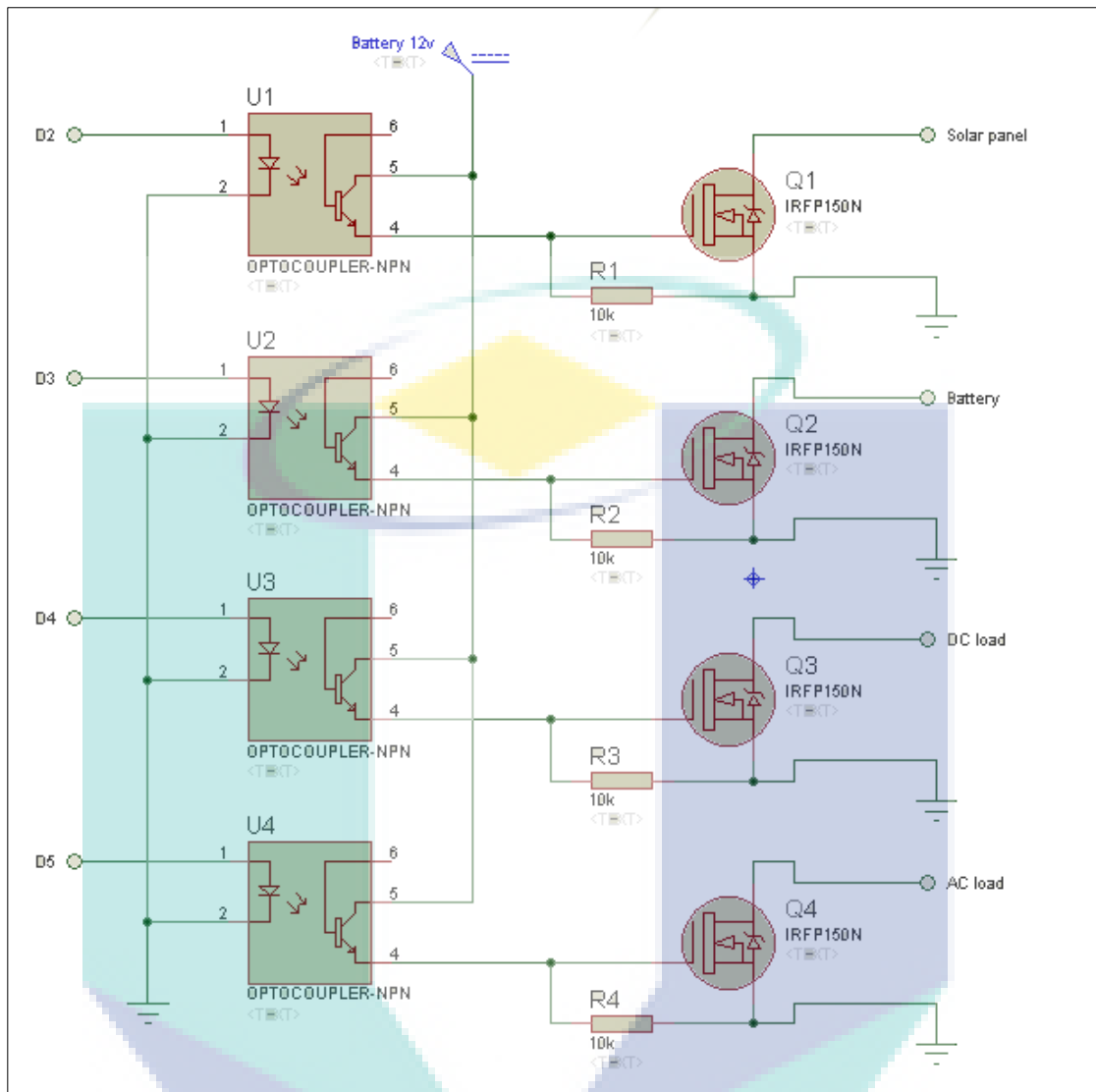


Figure 2.16 Circuit of optocoupler plus MOSFET

2.5 Algorithm of Load Scheduling

When related to the PV system, interactive energy management is the most important in case the consumer want to use the electrical energy efficiently. By applying interactive energy management, the consumer can gain a lot of benefits. However, an algorithm of load scheduling must be constructed clearly so that the consumer can identify the power flow in and out of the system and storage devices. Figure 2.17 represents the flowchart of the algorithm for the whole system in this project.

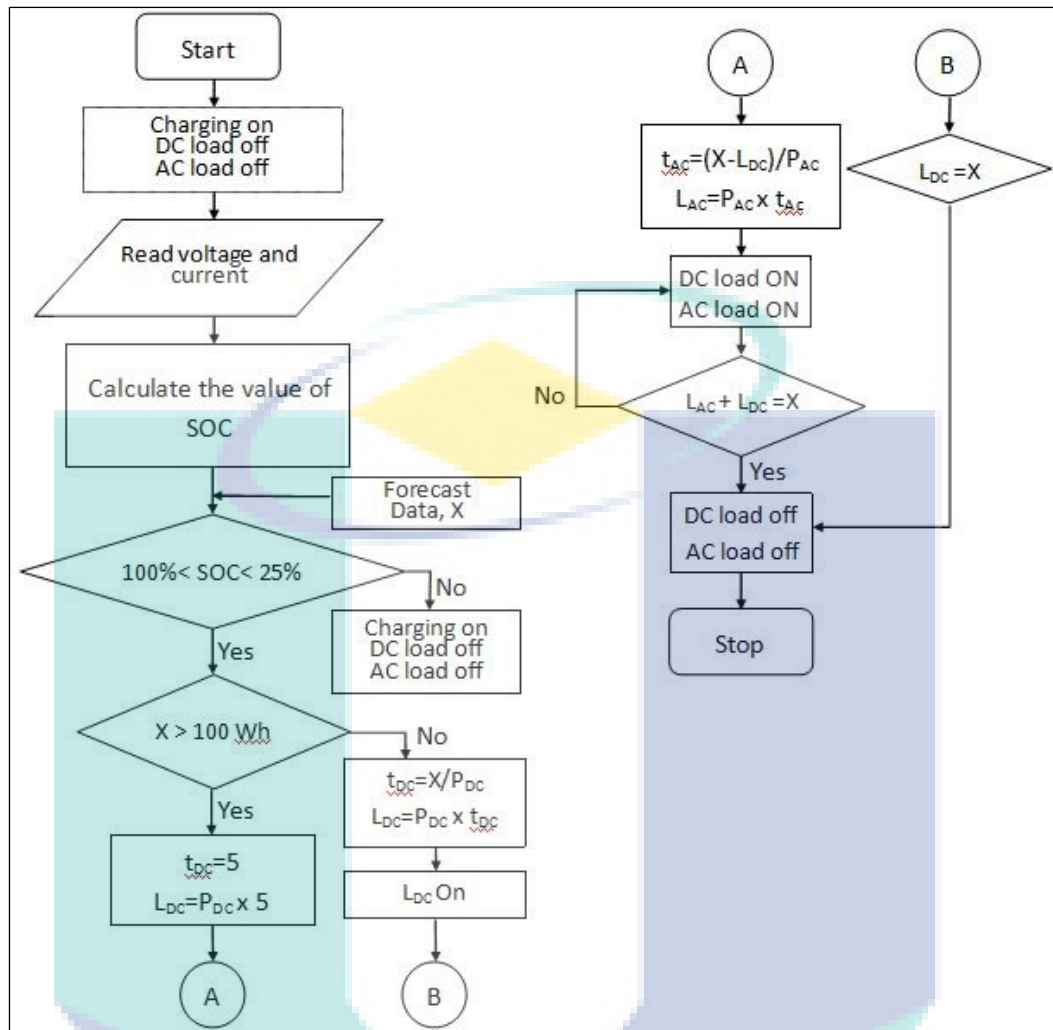


Figure 2.17 Flowchart of load scheduling algorithm

First of all, when the system is on, PV panel will begin to charge the battery while both DC and AC load were off. At the same time, the value of battery voltage and current will be measured. The value of state of charge (SOC) of the battery will be calculated and identified. If the value of SOC is higher than 25%, the system will continue to next step in order to operate. However, if the value of SOC is below than 25%, PV panel will continue to charge the battery continuously until it reaches 25% or more. Simultaneously, the forecasted data will be interrupted to the system which acts as the reference on how much energy can be used that day.

Then, if the value of SOC is greater than 25% and example for forecasted data is 10Ah, so users now can proceed to set the duration of DC load to be turned on. User can use the Blynk application to set the DC load duration. However for the time being, user

cannot set the duration of AC load for now because load management for AC is not ready yet. Therefore, AC load can be used normally in this system but cannot be managed properly yet.

Next, the load will begin to operate automatically based on the Blynk application that has been set by the user. When load is on, total load usage will be calculated. If the total load usage reach the value of forecasted data that has been interrupted early in this system, all loads will be turned off and the system will stop automatically. However, if the total load usage still below the value of forecasted data, all load will continue to operate again until it reaches the value of forecasted data.

2.6 Block Diagram

The block diagram for the whole system of this project is shown in Figure 2.18. Based on the block diagram shown in this figure, solar panel and battery are required as the power supply. 4 MOSFETs and 4 MOSFET drivers, which are optocouplers are used in this system with the aim to do the switching process such as to turn on and turn off the load, battery and solar panel. Then, current sensors and voltage divider that act as voltage sensor are required to measure the value of current at certain components and voltage of the battery, respectively. Next, this system need an inverter in order to invert direct current (DC) to alternating current (AC) as this system provide AC load slot too.

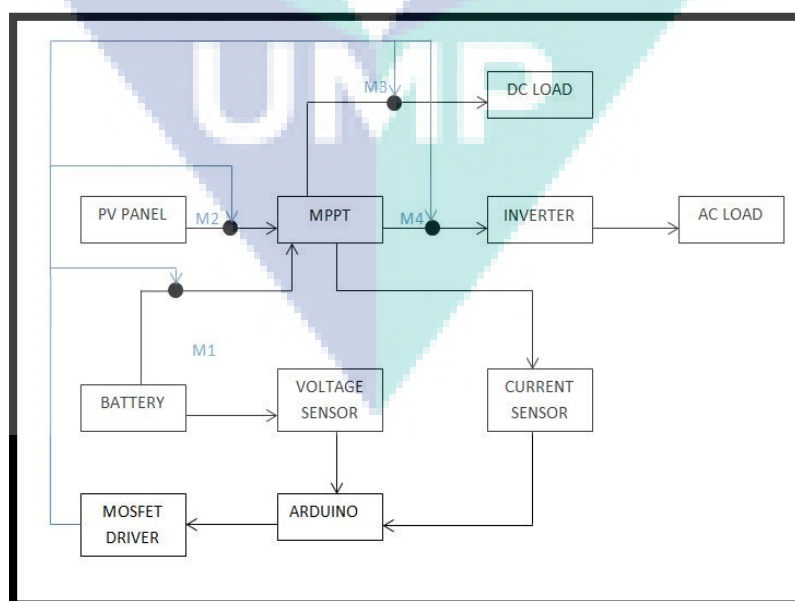


Figure 2.18 Block diagram for the whole system.

CHAPTER 3

RESULTS AND ANALYSIS

3.1 Introduction

In this chapter, the result of state of charge (SOC) of GP12400 Lead-Acid battery have been obtained based on some experiment conducted. Then, the result for load scheduling when the system is running also has been recorded based on the SOC obtained.

3.2 Result and Discussion

3.2.1 State of Charge (SOC)

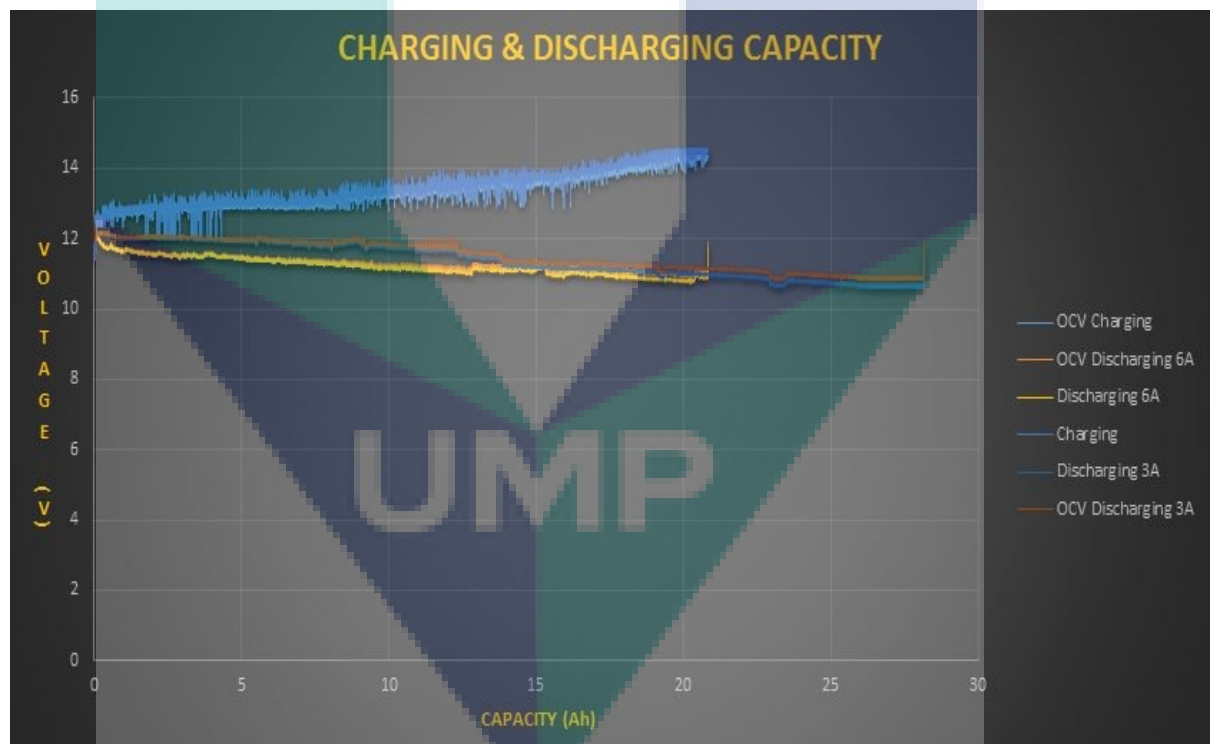


Figure 3.1 Result for discharging test of GP12400 Lead-Acid Battery.

The most critical part of this project is to determine the state of charge (SOC) of the battery in order to use and apply the algorithm of load scheduling of the system. Two

important on-line parameters for modelling the operation of a SOC are discharging or charging current and discharged capacity. As shown in Figure 3.1 above, it can be seen that the maximum charged capacity that was reached by this battery was about 21Ah. However, the battery that had been tested was GP12400 40Ah battery, which supposedly achieved 40Ah of nominal capacity based on its specification. Thus, it can be suggested that this problem might be caused by ageing factor of this battery or due to defect of the battery itself.

In order to determine the SOC of the battery, discharging of the battery have been conducted using 3 types of load with different load currents of 10A, 6A and 3A. When 10A of load was used, the battery voltage decreased sharply after the process began. This problem caused the discharging period to be very short which affected the discharged capacity to become very low. Since the result was not clear enough, it cannot be feasibly used as SOC database. Next, when 3A of load was used to discharge the battery, the discharged capacity obtained was almost 30Ah, which exceeded the charged capacity, 21Ah. This is because when the experiment began, the voltage just decreases slightly which led to higher total discharged capacity. Then, when 6A of load was used, the obtained results were stable as expected. The discharged capacity was about 20.9Ah and it almost reached the value of charged capacity which was 21Ah. Here, the discharging of the battery using 6A load was chosen as our database in order to identify the SOC of the battery. Below is the integral equation used in order to determine the discharged capacity.

$$Discharging_Capacity = \frac{I_{load}}{3600} \quad 3.1$$

Then, based on the result of the discharged capacity of the battery, open circuit voltage (OCV) curve can be derived by using specific integral that eliminates internal resistance in the battery. Different types and capacities of batteries have different values of internal resistances, and their values can be found in the datasheets of the batteries purchased. In this case, the internal resistance of the battery used is stated in the datasheet as 8.1mΩ. Below is the integral equation used in order to derive the OCV curve.

$$OCV_{Discharging} = V - I_{discharging} \times Internal_Resistance \quad 3.2$$

Next, when the OCV curve is obtained, the SOC of the battery can be identified based on this voltage, as shown in Table 4.1.

Table 3.1 State Of Charge (SOC) of battery

Open Circuit Voltage (V)	SOC (%)
12.10V and above	100 %
12.099V – 11.60V	88 %
11.599V – 11.40V	75 %
11.399V – 11.25V	50 %
11.249V – 11.095V	25 %
11.094V – 11.067V	13 %
11.066V - 10.90V	5 %
10.89V and below	0 %

Moreover, based on Table 4.1 above, it has been identified that the battery is 100% when the voltage reaches 12.10 V and above. Then, when the voltage is in the range of 12.099 – 11.60 V, 11.59 – 11.40 V, 11.399 -11.25 V and 11.249 - 11.095 V, the battery percentage are reset to 88%, 75%, 50% and 25%, respectively. Meanwhile, the empty level of battery is underlined when the voltage drops to 10.89 V and below. Thus, the remaining battery percentage is feasibly revealed through this OCV that is originally derived from the discharging test method. The value of OCV after sufficient resting batteries can be considered since there is a correspondence between OCV and SOC and supporting little relation to battery life. It is an effective method in order to estimate SOC of the battery. Compared to Kalman Filter method, it is a recursive process and an effective method when is used to deal with measurement data containing noise either by the way of combining it with other sensor measurement data or the noise filter.

3.2.2 Full Assembled System

When the system is fully assembled, this full stand-alone photovoltaic system is now readily used by the user. User now can use any load they want such as lamp, fan, laptop, phone charger and any other loads.

3.2.2.1 Discharging Process

In this experiment, 11 pieces of DC lamps (most of them are LEDs) have been used as an experiment to check all the components function well or not such as MOSFETs in order to perform the switching process. Therefore, these lamps that act as load are set to be turned on 15 minutes soon after the system begins and all of them will be turned on for 2 hours before they are automatically turned off. Figure 3.2 shows the results obtained for battery voltage against time during the whole experiment was performed.

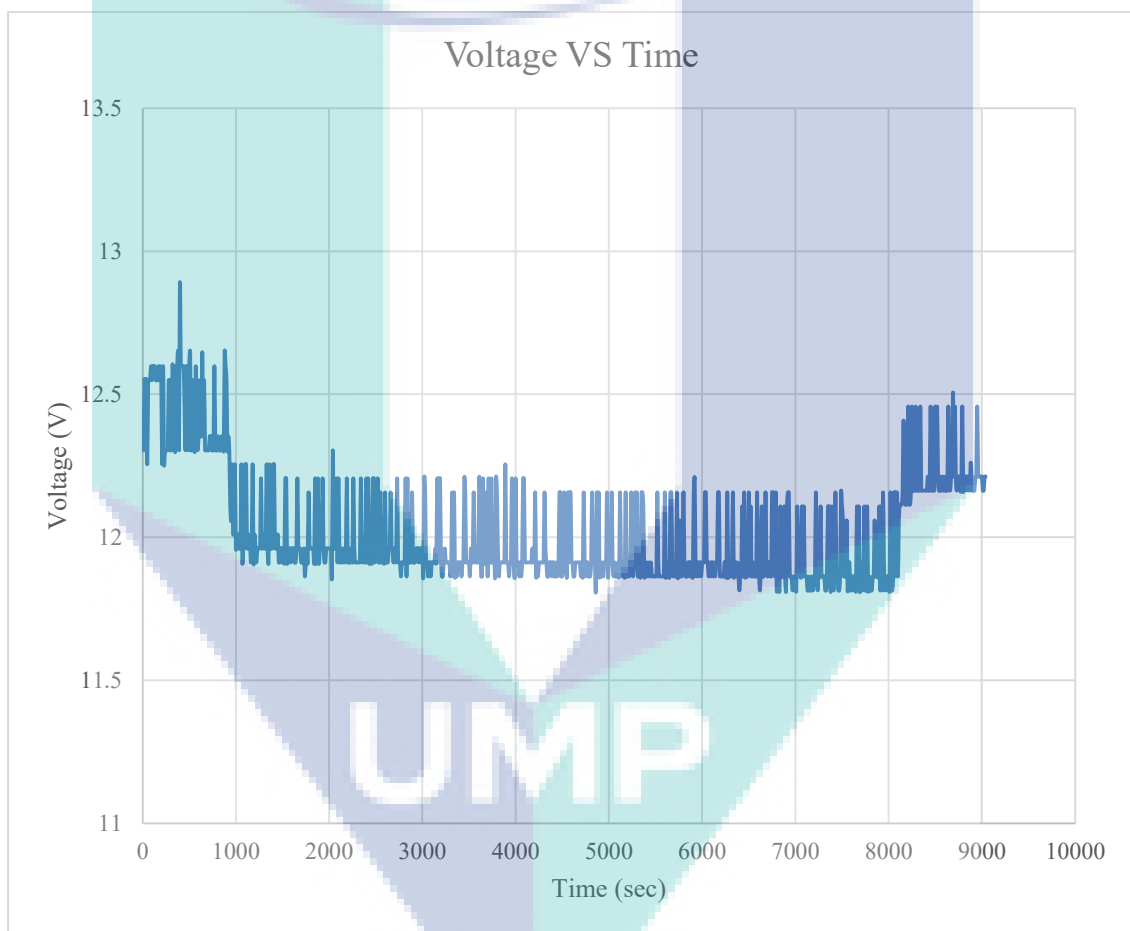


Figure 3.2 Voltage VS Time

Based on the figure above, the battery voltage was quietly high for the first 15 minutes (900s) which that value was around 12.3 V to 12.6 V. Then, the battery voltage immediately dropped to 11.8 V – 12.2 V soon after the load was turned on. The battery voltage just changed slightly throughout the 2-hour period while the load was still turning on. However, it seems that the battery voltage immediately rose up again to

12.2 V - 12.5 V soon after the load was turned off. Thus, it is proven that the switching process performed using MOSFET functions properly and user now can turn on and turn off the load anytime they want.

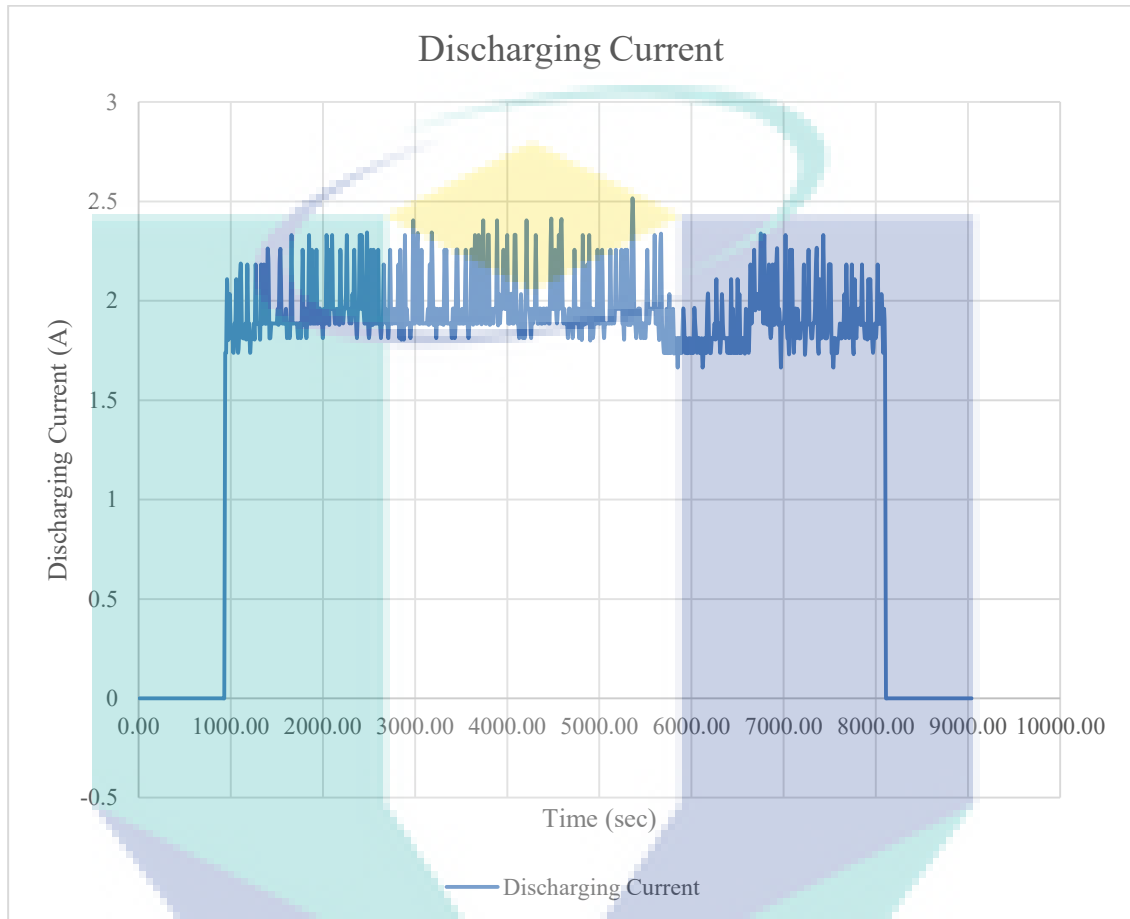


Figure 3.3 Discharging Current VS Time

Figure 3.3 above shows the discharging current against time. Based on the figure above, it shows that the discharging current when the load is not turned on yet is zero. However, when the load was automatically turned on, the value of the load current was between the range of 1.8 A to 2.2 A. Once again, when the load was immediately turned off after 2 hours the system was running, the value of the load current became zero. Therefore, it can be said that the MOSFETs installed in this system function successfully as expected, from different perspective.

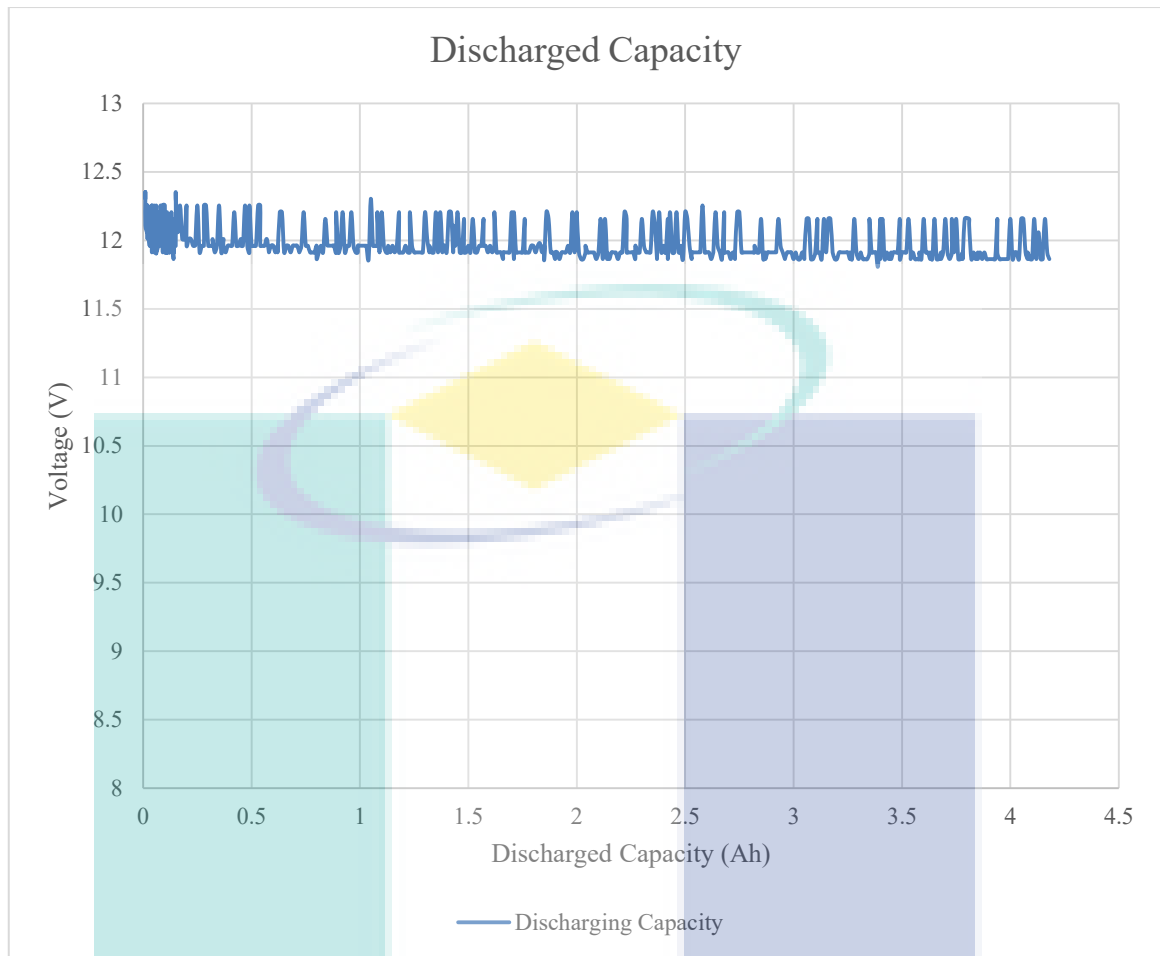


Figure 3.4 Voltage VS Discharging Capacity

Figure 3.4 above shows the voltage against discharged capacity. The load used in this experiment is 11 DC lamps which 1 lamp is filament (25W) and others 10 lamps are LEDs (12W). Thus, the total load did not consume much current (approximately 2 A) since LEDs consumed less current than the filament. On the other hand, the total discharged capacity obtained when this load was turning on for 2 hours was around 4.2Ah and here, it can be obviously seen that the voltage of the battery was dropping consistently from beginning to the end of the discharging process because the current discharged from the battery significantly affected the battery voltage. The charging graph is not available because no charging process performed during this experiment. Therefore, the charged capacity was zero for this experiment. In addition, Figure 3.5 and Figure 3.6 represent the result appeared in Blynk application and TFT module which can be classified as remote and monitoring system, respectively.



Figure 3.5 Discharging process result appeared in Blynk application.

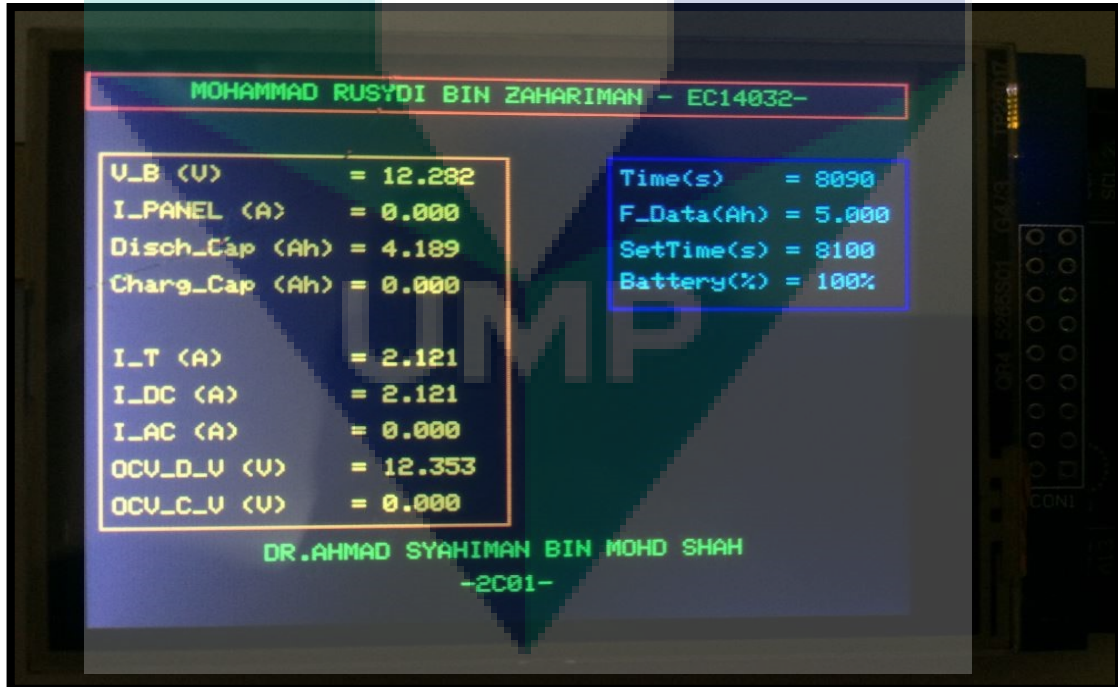


Figure 3.6 Discharging process result appeared in TFT module



Figure 3.7 Discharging process using 11 dc lamps.

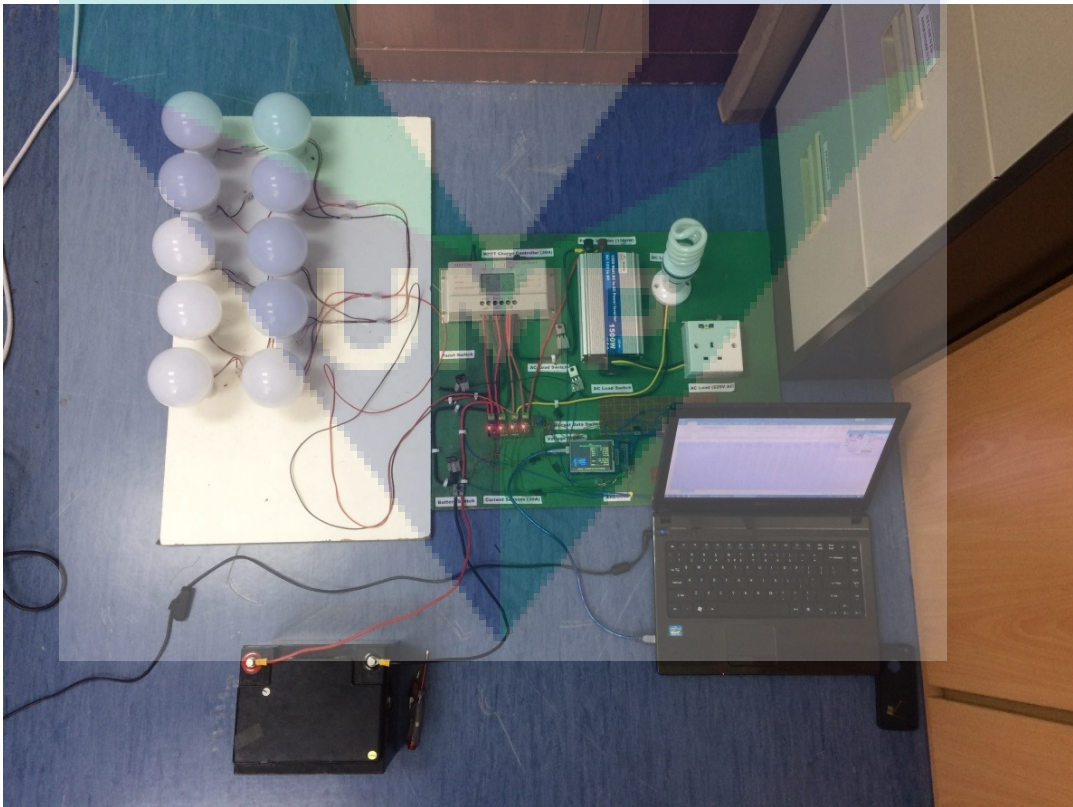


Figure 3.8 All dc lamps turned off.

Figure 3.7 above shows the whole system that has been fully assembled. All load was turned on so that the discharging process can be performed. All data during this process was recorded using laptop. Then, Figure 3.8 shows the load was automatically turned off when it reached the time that had been set using Blynk application.

3.2.2.2 Charging Process

In this experiment, PV panel was used as the main supply of the system in order to charge the battery that functioned as main supply at night or when there was no electricity. This experiment was performed on 23 May 2018 at 12 – 2 pm, which was the most suitable time in order to gain the higher current for charging process.

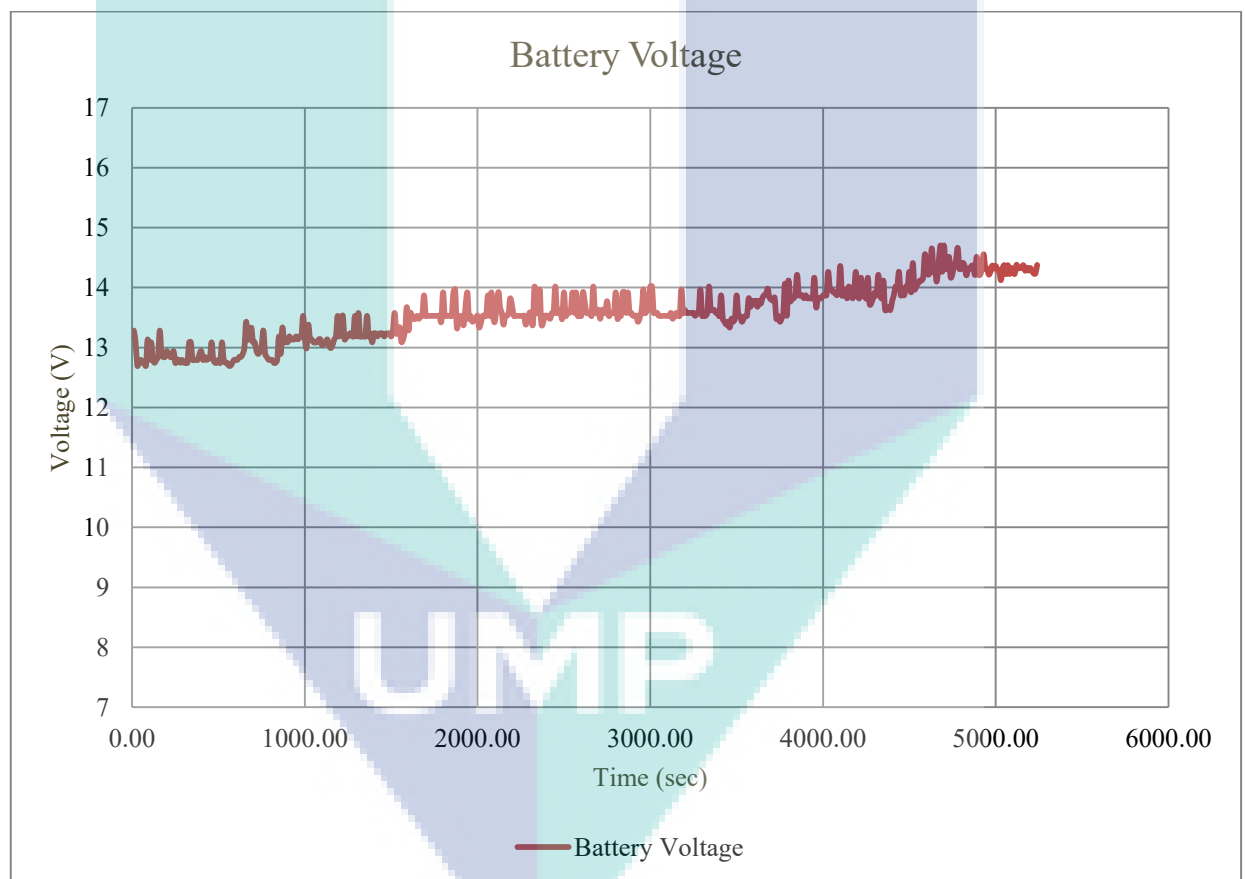


Figure 3.9 Voltage VS Time

Figure 3.9 above exhibits the graph obtained for the result of battery voltage against time. When the system was turned on, the charging process of the battery using PV panel began. The battery voltage at the beginning of the charging process was around 13 V and then, it increased slightly after 30 minutes of charging. This thing happened

because the current absorbed by the PV panel was not high enough, which was around 2A. Then, the battery voltage increased a lot due to the effect of the weather, which caused the current absorbed by the PV panel getting higher, which was around 4.8A to 5.7A. Finally, when the battery was fully charged, charge controller stopped the charging from the PV panel to the battery which made the battery voltage became constant for the last 10 minutes.

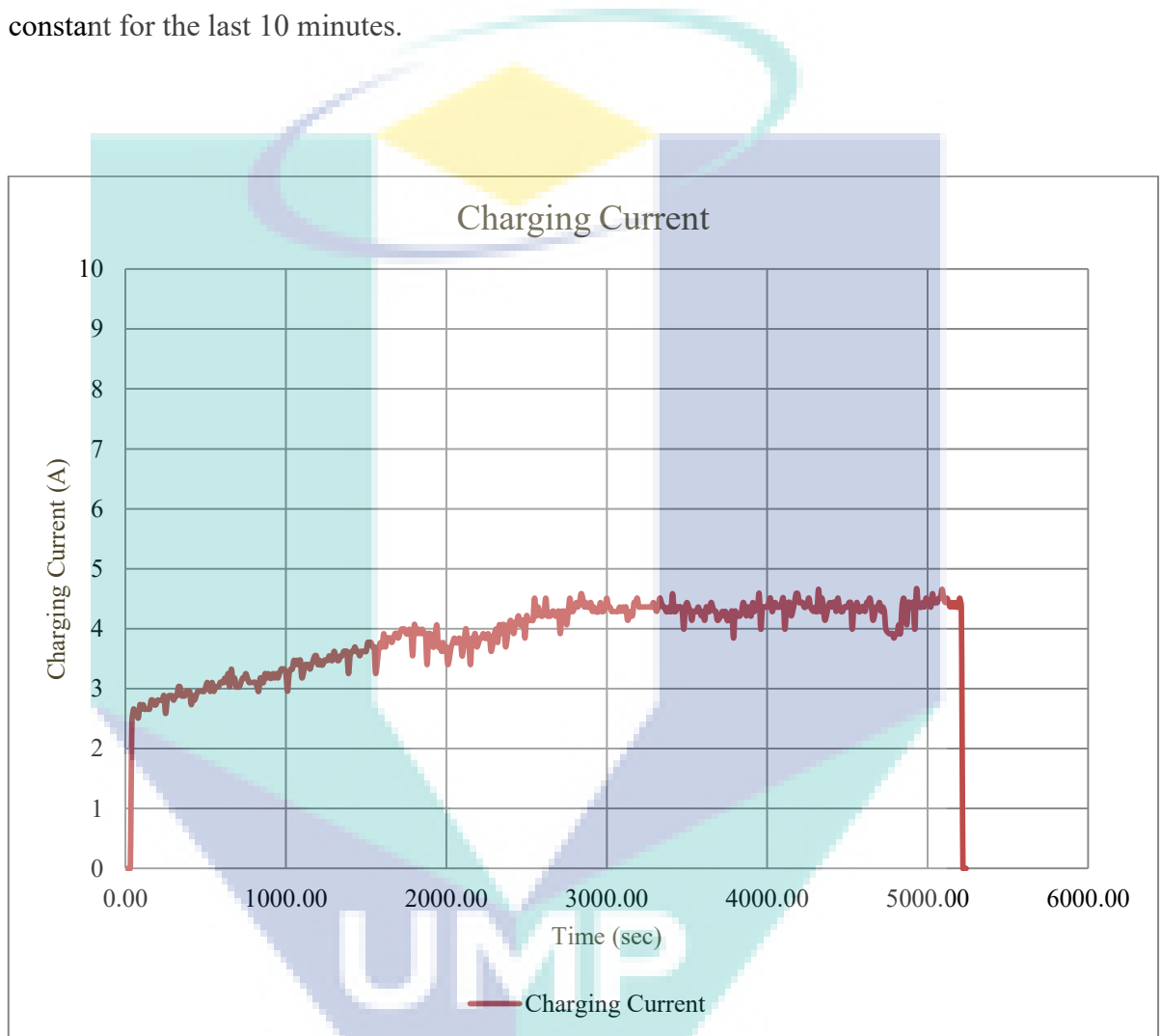


Figure 3.10 Charging Current VS Time

Figure 3.10 above exhibits the charging current against time. Before the charging process began, the curve shows the charging current was zero. After that, the charging current increased immediately to 2.4 A soon after the charging process began as the PV panel started to absorb the energy from the sunlight. The charging current reached the highest value between minutes 42 to 90 as the weather was very clear. Finally, the

charging current dropped to zero again as the battery was fully charged, which caused the PV panel to stop charging the battery.

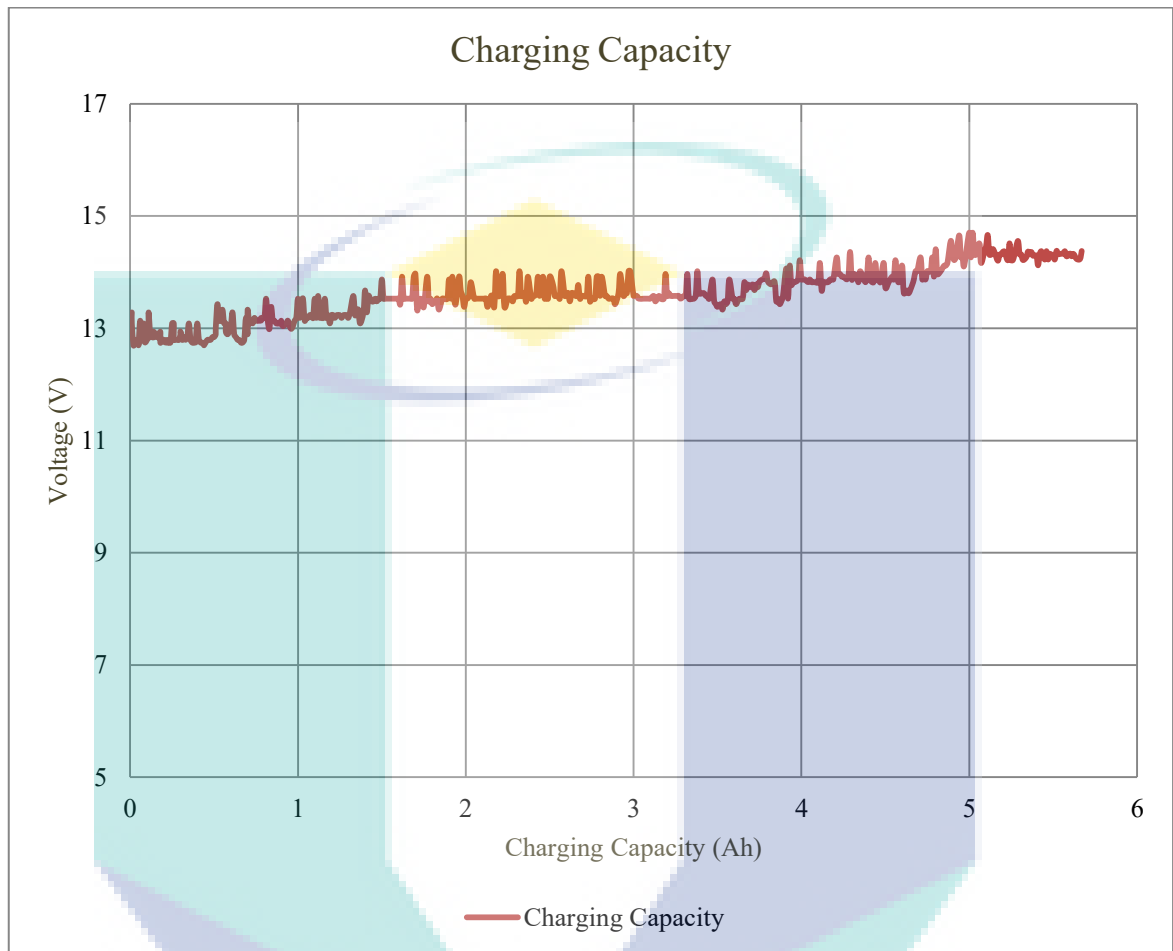


Figure 3.11 Voltage VS Charging Capacity

Figure 3.11 above represents the voltage against charging capacity for 90 minutes. Verily, this charging process took short time to fully charge because the battery capacity was already more than a half from its full capacity before the process began. By referring to the graph obtained above, it shows that the battery just need about 5.7 Ah of energy capacity to be fully charged. Furthermore, since this charging process used PV panel as power source, the current absorbed through it was not constant and totally depend on weather. This is the reason why the increase of the charging capacity every second is not constant.

Figure 3.12 shows the charging process of the whole project. PV panel was exposed to the sunlight to absorb the energy from sunlight as much as possible. The battery and the

whole stand-alone system was located under the shady area in order to prevent any problem that might be occurred if it was directly exposed to the sunlight too much. Moreover, Figure 3.13 shows the charge controller that can be used to monitor the value of charging current besides TFT modules and Blynk application. Based on this charge controller, it showed the value of charging current of 5.1A, which was very high.

Simultaneously, as appeared in Figure 3.14 below, Blynk application received the data from Arduino, which were exactly the same results from the system that were displayed in the charge controller. It was real-time, which meant that the data displayed in Blynk application were updated simultaneously with the charge controller. However, in this charging process, the value of the forecasted data and duration of the load to be turned on were not set as it was unnecessary in this charging process. Thus, in charging process, Blynk application just received and updated the data from Arduino. This time, it did not transmit any data to Arduino.

Eventually, based on Figure 3.15, it can be said that all the data obtained will be displayed in TFT module too. Same as Blynk application, it is real-time with the system. Therefore, user have a lot of choices in order to do the monitoring system and they may choose them based on their certain situation.



Figure 3.12 Charging Process Using PV Panel

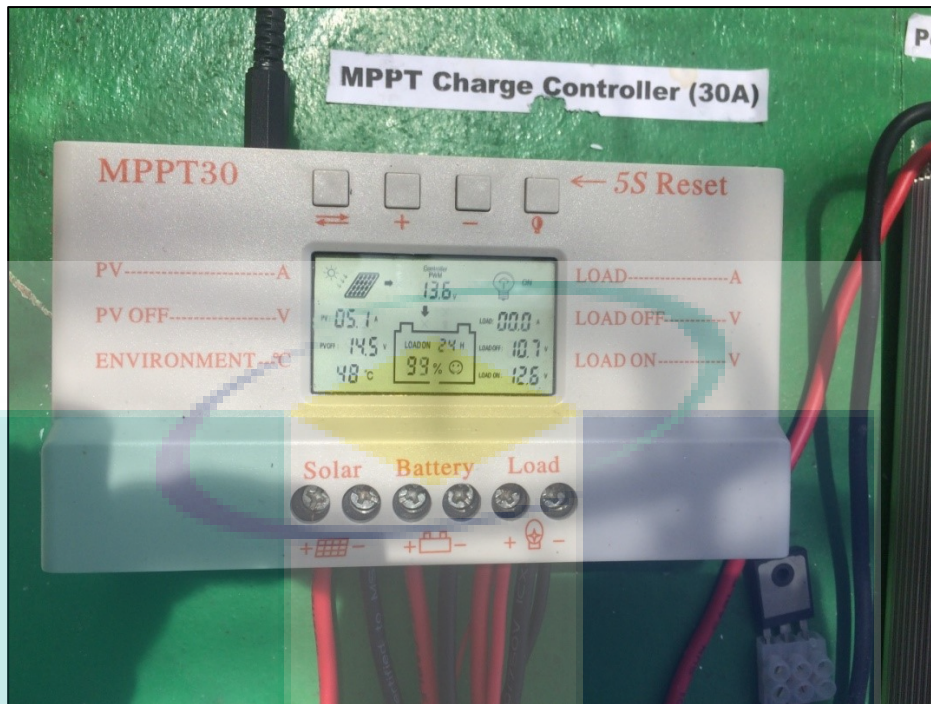


Figure 3.13 Charge controller shows the value of charging current

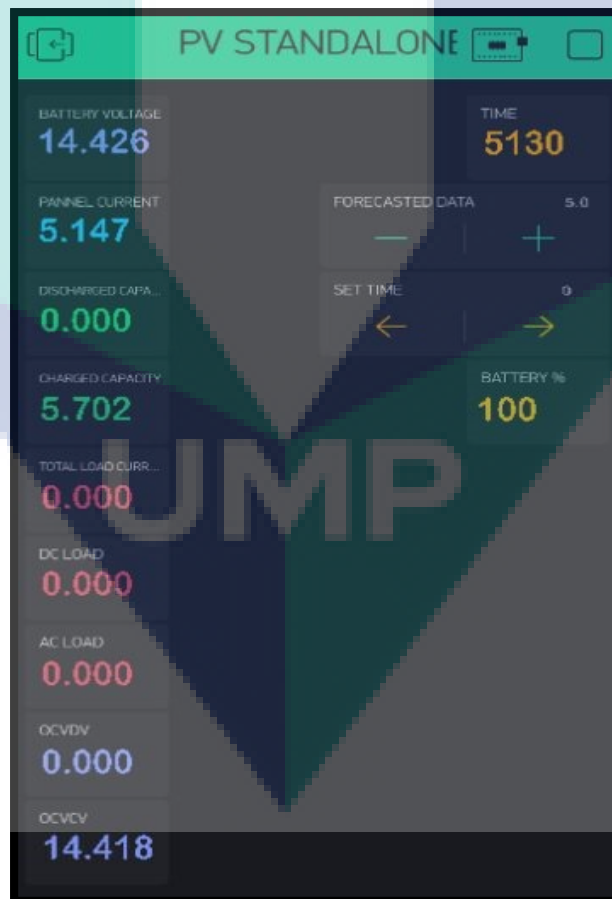


Figure 3.14 Charging process result appeared in Blynk application

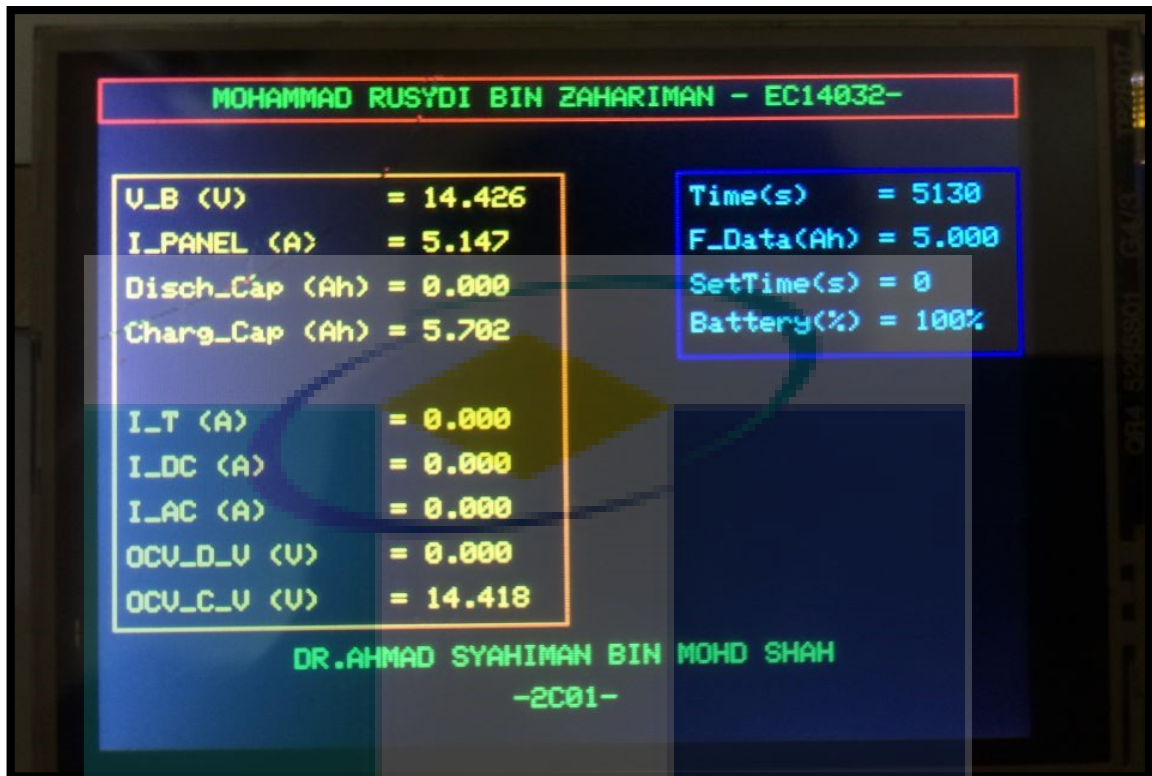


Figure 3.15 Charging process result appeared in TFT module.

UMP

CHAPTER 4

CONCLUSION

4.1 Introduction

In this chapter, it contains the conclusion of this project and also the future recommendation that can be implemented in this project so that it can improve the energy management system and make it more efficient in managing the energy stored in the battery.

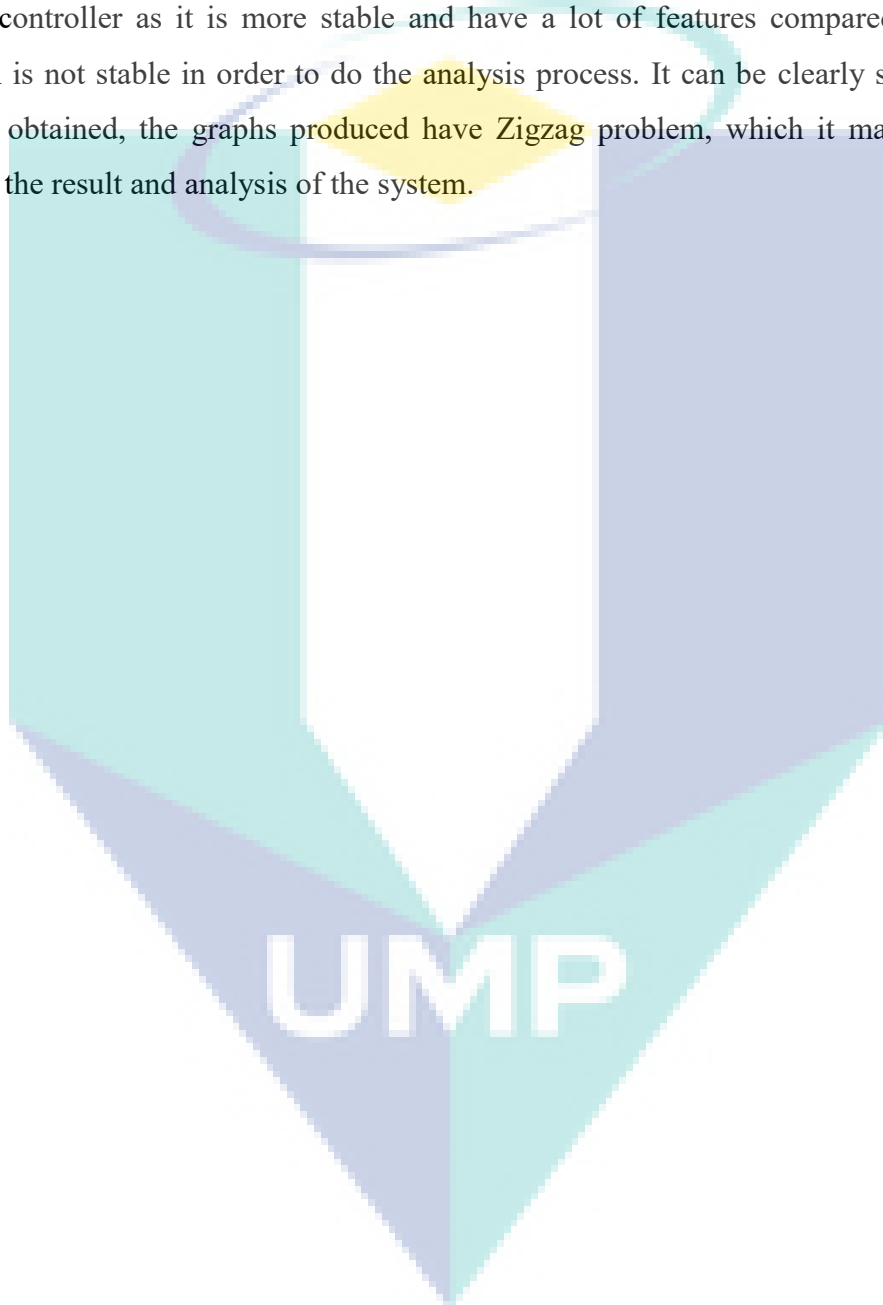
4.2 Conclusion

Based on the result, this whole project was successful and can be used clearly as expected. When the whole system is assembled, user can use this system with any kind of load they want including heavy loads such as air conditioner, freezer and so on. However, the difference compared to small load is the duration of battery in order to supply the energy to the system becomes shorter. Next, from the collected data, all data that displayed on charge controller, TFT module and Blynk application were exactly the same. Thus, it can be said that the data displayed is valid. Then, the forecasted data and time for load to be ON state can be sent successfully using Blynk application which required Wifi connection. Therefore, user can use this system freely and manage the load as they want. However, a single problem that we faced in this project was the instability of reading voltage by the Arduino that makes the graph produced related to battery voltage was slightly Zigzag. In order to overcome this problem, we plan to change the Arduino with another microcontroller such as Raspberry Pie, next time in the future.

4.3 Recommendation

After doing this project, there are some recommendation that can be made to improve the system in order to make it more efficient in managing energy. Firstly, AC load need

to be managed clearly which is for now, only DC load has been managed. Therefore, the management system will be more perfect by doing both AC and DC load management, simultaneously. Then, forecasted data analysis need to be done properly so that it can be combined together into this system, which is for now forecasted data used is dummy data. Finally, this whole project may need Raspberry Pie as microcontroller as it is more stable and have a lot of features compared to Arduino which is not stable in order to do the analysis process. It can be clearly seen from the result obtained, the graphs produced have Zigzag problem, which it may marginally affect the result and analysis of the system.



CHAPTER 5

JOURNAL PAPERS

5.1 **Efficient Operation of Lithium-Ion Batteries Based on GPV-Forecasted PV Output**

Journal of Telecommunication, Electronic and Computer Engineering (Scopus)

Vol. 10, No. 1-2, pp. 161-167, January 2018

ISSN: 2889-8131

A. S. M. Shah¹, M. S. A. Karim¹, M. S. Jadin¹, A. S. Abdullah¹, R. Ishak¹, Y. Ishikawa², H. Takahashi², S. Odakura² and N. Kakimoto²

¹Faculty of Electrical and Electronic Engineering, Universiti Malaysia Pahang, Pekan, Pahang, Malaysia.

²Department of Electrical and Electronic Engineering, Ibaraki University, Hitachi, Ibaraki, Japan.

Abstract

Load forecasting is essential in order to fulfil a demand of the consumer. Nevertheless, for a small-scale Battery Energy Storage System (BESS) based on sole photovoltaic (PV), it needs a very strong effort to always meet a consumer's demand due to unstable meteorological conditions. An ideal PV system requires a constructive control strategy in order to alleviate its fluctuating output. In this study, an energy control scheme that executes next-day forecast of generation for the purpose of fully utilizing the stored energy in the batteries has been proposed. Experimental equipment was structured and the operation was completely administered by RX621 microcontroller. The implemented system worked very well without any distractions and it succeeded in controlling and preventing the batteries from being over-charged or over-discharged. Impressively, average consumption for September 2015 is considerably high, which suggests that the proposed control succeeded in utilizing energy corresponded to 98.6 % of the monthly-average generation.

5.2 Real-Time Wireless Energy Management System of Miniature Standalone Photovoltaic Application

Journal of Advanced Research in Dynamical and Control Systems (Scopus)

Vol. 11, No. 9-Special Issue, pp. 52-61, September 2019

ISSN: 1943-023X, DOI: [10.5373/JARDCS/V11/20192535](https://doi.org/10.5373/JARDCS/V11/20192535)

A. N. A. Bakar, M. R. Zahariman, R. Ishak, A. S. M. Shah

Faculty of Electrical and Electronic Engineering, Universiti Malaysia Pahang, Pekan, Pahang, Malaysia.

Abstract

Standalone photovoltaic (PV) system is practical and beneficial for the place where the physical power transmission line is not feasible. Nevertheless, for miniature scale standalone PV system, efficient and interactive energy management is extremely necessary to ensure that the battery is capable of supplying energy to the load uninterruptedly without any failure as its condition is being monitored, time by time. In this paper, a real-time energy management system equipped with wireless monitoring features has been developed and tested. All energy information such as battery voltage, generating current, discharging current, etc. are well displayed and extracted directly from the developed system. The high-power switching system is able to be controlled remotely as several MOSFETs attached to the main circuit are feasible to be flagged on or off via Blynk application instantaneously without any time lags. Therefore, the proposed system may become a good model for better small-storage-capacity based real-time energy management system in the future.

5.3 A Review on Factors Affecting Heat Transfer Efficiency of Nanofluids for Application in Plate Heat Exchanger

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences (Scopus)

Vol. 60, No. 1, pp. 144-154, August 2019

ISSN: 2289-7879

H. Ibrahim¹, N. Sazali^{1,2}, A. S. M. Shah³, M. S. A. Karim³, F. Aziz⁴, W. N. W. Salleh⁴

¹Faculty of Mechanical Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia.

²Centre of Excellence for Advanced Research in Fluid Flow (CARIFF), Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, kuantan, Pahang, Malaysia

³Faculty of Electrical and Electronic Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia.

⁴Advanced Membrane Technology Research Centre (AMTEC), School of Chemical and Energy, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor Darul Takzim, Malaysia.

Abstract

With the rapid advancement in science and technology, the enhancement in heat transfer is also making its way forward towards modern nanotechnology. It was noted that heat transfer efficacy of heat exchangers depends on the working fluid and nanofluid were discovered to enhance the heat transfer, making nanofluid our focus in this review. While shell and tube heat exchanger type were given attention since past decades, there are scarce on nanofluid application in plate heat exchanger. To add, thermophysical properties of nanofluids such as specific heat, viscosity, thermal conductivity and its heat transfer coefficient are very important for heat transfer application in heat exchangers. Therefore, this review article will cover the compilation of information and data collected from numerous previous researchers.