

# Faculty of Electrical and Electronic Engineering Technology



PHOTOVOLTAIC WITH SMART BACKUP POWER SOURCE

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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**Bachelor of Electrical Engineering Technology (Industrial Power) with Honours** 

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# DEVELOPMENT OF AN IOT-BASED INTEGRATED PHOTOVOLTAIC WITH SMART BACKUP POWER SOURCE

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A project report submitted in partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours



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2021

## **DECLARATION**

I declare that this project report entitled "Development of an IoT-Based Integrated Photovoltaic With Smart Backup Power Source" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



# APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours.

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# DEDICATION

This work dedicated especially to my both parents, Mohamed Sallehulldin Bin Abbas and Mazlah Binti Abd Rahman that always give full support to me. Not to forget my supervisor, Ts Ahmad Idil Bin Abdul Rahman and co-supervisor, Ts Johar Akbar Bin Mohamat Gani that gives idea for this project. Also, not to forget my friends who are standing by me and give fully support during making this project.



#### ABSTRACT

Nowadays engineers are widely inventing modern technology in which new technologies will be introduced around the world every day that will make human life efficient. The Internet of Things (IoT) is one of the most ground-breaking inventions ever devised by engineers all over the world. The wireless automation system is one of the IoT applications that allows for real-time control and monitoring of home appliances through the Internet. This project is developed to help the users to achieve full time electrical supplies for houses, hospitals, server room's etc. The main appliances such as refrigerator, aquarium oxygen tank, medical supply equipment and aircond are such examples of electrical appliances. In this project, the ESP32 microcontroller is used and programmed to the Arduino IDE. The ESP32 microcontroller will be used to detect and read the input from the current and voltage sensor. At the same time, the ESP32 will process the input signal and inform to the relay to perform the solar output. The users can monitor the voltage, current, power, Kwh and battery backup indicator value from the blynk application. Besides, the users will be informed once the power supply is changed to solar battery backup from the blynk app notification. The blynk application is integrated with the ESP32 Wi-Fi module. The backup supply is from the battery unit. It have been charged from two types of solar panel. Those two types of solar panel is Monocrystalline and Polycrystalline. This two solar panel are used in order to analyze and compare the efficiency of those solar panels different themselves. The analysis of this project is carried out by recording the timing for charging and discharging the solar panels with the battery backup. The benefits from this project will enable the user to monitor the power consumption and to achive full time power supply more efficiency.

#### ABSTRAK

Jurutera pada masa kini banyak mencipta teknologi moden, dimana teknologi baru sentiasa bertambah di seluruh dunia setiap hari yang akan menjadikan kehidupan manusia lebih efisien. Internet of Things (IoT) adalah salah satu penemuan paling hebat yang diperkenalkan oleh jurutera seantero dunia. Sistem automasi tanpa wayar adalah salah satu aplikasi IoT yang membolehkan kawalan dan pemantauan masa nyata bagi peralatan rumah melalui Internet. Projek ini dibangunkan untuk membantu pengguna mendapatkan bekalan elektrik sepenuh masa untuk rumah, hospital, bilik server dan lain-lain. Peralatan utama seperti peti sejuk, akuarium oksigen, peralatan bekalan perubatan dan pendingin udara adalah contoh perkakasan elektrik yang digunakan oleh kebanyakan pengguna. Mikrokontroler dalam projek ini digunakan oleh ESP32 dan diprogramkan ke Arduino IDE. Mikropengawal ESP32 akan digunakan di dalam projek ini, di mana ia akan diprogramkan ke Arduino IDE. ESP32 akan digunakan untuk mengesan dan membaca input dari sensor arus dan voltan. Pada masa yang sama, ESP32 akan diproses dari isyarat input yang akan memberitahu genganti untuk melakukan keluaran solar. Pengguna dapat memantau nilai voltan, arus, kuasa, kwh dan penunjuk sandaran batery dari aplikasi blynk. Di samping itu, pengguna akan diberitahu setelah bekalan kuasa diubah menjadi bateri bantuan solar melalui pemberitahuan aplikasi blynk. Aplikasi blynk digunakan dengan bantuan modul Wi-Fi ESP32. Bekalan bantuan adalah dari unit bateri. Ia telah dikendalikan dari dua jenis panel solar. Dua jenis panel solar tersebut ialah dari jenis solar Monocrystalline dan Polycrystalline. Dua panel solar ini digunakan untuk menganalisis dan membuat perbandingan dari segi kecekapan kedua-dua solar panel tersebut. Analisis projek ini dijalankan dengan mencatat masa untuk mengecas dan mengeluarkan cas dari panel solar ke unit bateri. Kelebihan dari projek ini membolehkan pengguna memantau penggunaan tenaga dan mendapatkan bekalan kuasa sepenuh masa dengan lebih efisien.

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# LIST OF SYMBOLS

 $\delta$  - Voltage angle



# LIST OF ABBREVIATIONS

V	-	Voltage
W	-	Watts
Kwh	-	Kilo Watts Hour
IoT	-	Internet of Thing



#### **CHAPTER 1**

#### **INTRODUCTION**

## 1.1 Background

In recent years, engineers have applied advanced technology, where numerous devices have been developed. When the smart power backup is connected to the internet via a phone application, it is classified as an Internet of Things (IoT) system. This technology was created to achieve a full-time operated home power supply which includes an easy process for persons in need. The smart power backup is made up of several electrical components that will come together to form a single technological system. This system primarily uses photovoltaic solar panels, sensors, a phone device, and a microprocessor to process tasks automatically without the need for human intervention. The system may perform any action based on the settings that have already been programmed to operate with the home appliances. Photovoltaics, or PV for short, is a direct procedure for producing electricity from sunlight that works all the time while the sun is shining. However, the amount of energy generated is dependent on the intensity and hits of sunlight rays that directly reach the PV modules (means that the ray of sunlight is perpendicular to the PV modules). It will produce power without causing any noise or pollution, and it will provide users with a quiet, quick, and stable electrical supply. Due to the decrease of fossil fuel energy consumption and the concern of environmental effect out of it, this accessible of energy resources is expanding and becoming well-known across the world. As people grow more conscious of the importance of the environment, more eco-friendly energy resources are being developed to prevent issues from becoming more serious. Global warming and climate change are two examples of environmental causes or challenges that have led to the increased usage of renewable energy in recent years.

## **1.2 Problem Statement**

In general, the smart power backup source is the most significant element in order to achieve full time power supply. By using the photovoltaic module, it will provide the power source to the battery that has been charged during daylight. The problem can occured to hospitals or big companies that have server rooms that need to maintain temperature rooms. On top of that, when there is no power supply to hospitals, it will automaticly switch off the medical supply or equipment thus it will risk to the patient.

Furthermore, it can impact the user when there is no people present at home for a long time when blackouts happen. Thus, it will turn off the main home appliance such as the fridge or aquarium oxygen. Moreover, it can impact the temperature in server room. When the temperature around and within the server and networking equipment becomes too high the server will shut down and there will be a loss of data.

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# **1.3 Project Objective**

In order for this project to be successful, the following objectives need to be achieved as follows:

- a) To develop an IoT-based integrated photovoltaic with smart backup power source.
- b) To design and build an IoT-based circuit and hardware for a BIPV-powered home automation system.
- c) To analyze and compare the efficiency between the monocrystalline solar panel and the polycrystalline solar panel.

## **1.4** Scope of Project

The project is divided into two sections, one for software design and the other for hardware design. The circuit development for the IoT-based integrated photovoltaic with smart backup power source is designed using software implementation, in which written program in the ESP32 microcontrooler will be able to monitor all of the hardware components. At the same time, the microcontroller for this project is programmed using the Arduino IDE. The Wi-Fi Module is also used as a modem in this project to transmit notifications to the user. This project proposes the best design and implementation for the immersive development of an IOT-based integrated photovoltaic system with a smart backup power source.

#### 1.5 Summary

This report consists of five chapters in general and in this segment a brief description is given for each chapter respectively. Chapter 1 explains briefly the project background, problem statement, objective, scope and the significance of the project in order to create and develop of an-IoT based integrated photovoltaic with smart power source. In addition, this chapter also clearly explains and addresses how the project is being carried out and states the objective scope and of project accordingly.

#### **CHAPTER 2**

#### LITERATURE REVIEW

#### 2.1 Introduction

This chapter explains the context and basic concept of an IoT-based integrated pv system using the ESP32 to control the relay output and energy monitoring. On top of that, this chapter covers the ELCB design, components inside the ELCB, Microcontroller, Wi-Fi module and the BIPV solar system which acts as a backup supply. Furthermore, the previous project's worth will also be discussed in this chapter. This chapter has been covered in all the research related to the project. This will provide more clarity about the project and a better understanding particular towards the project design and system implementation.

# 2.2 Internet of Things (IoT) Technology

The Internet of Things (IoT) would be a necessary component of this project's progress. The ESP32Wi-Fi module will be enabled by following the device instructions, which will then be connected to the Internet, allowing the user to track and manage the ELCB even though they are not at home. The Arduino UNO microcontroller can be able to receive signal data from the Wi-Fi module while the user uses the software on their mobile device, where the electrical equipment can be operated by adding or disconnecting the power supply to the relay module. The proposed project prototype was easy to use and the user could manage and track it from everywhere and anywhere as long as the internet connectivity exists.

The Internet of Things (IoT) refers to a network made up of small devices that can collect and share electronic information. Via the Internet, Bluetooth, or other methods, these

devices can be attached to each other and to a device or software that can operate them. In general, the Internet of Things (IoT) applies to several contexts in which network access and computing capability are extended to objects, sensors, and ordinary products that are not usually called computers, thus allowing these devices to produce, share, and consume data with little or no human interference. This technology also has a broad range of features, including knowledge about the manufacturing process, data transmission, and the ability to monitor human data from sensors (Chaudhari et al., 2018).

Embedded technologies, such as processors, sensors, and communication hardware, are used in IoT technology, which includes smart devices that can capture and transfer data from their surroundings. IoT computers would be able to share data gathered in the past to the cloud to be analyzed or manually analyzed by linking them to the internet gateway. This technology has the potential to benefit a large number of individuals, whether in their personal lives or at work, and it is critical for businesses to have a smart system to simplify their business activities. IoT devices will be able to simplify the user's daily routine, and the technologies will undoubtedly become more widely used and common across current and IoT future industries.

#### 2.3 Earth Leakage Circuit Breaker (ELCB)

In the electrical system, an ELCB is a protective unit with a high earth impedance. This device is used to identify currents that are leaking to the ground and cut the power supply. It is used to track minor stray voltages around the metal enclosures in electrical installations. For single phase, it consists of a two-pole switch, and for three phase, it consists of a four-pole switch with those poles linking the supply and load ends. A solenoid trip coil is deeply attached to this two-pole switch. The trip coil was also attached to the earth's electrical installation's.





Figure 2.2: Three phase with four-pole ELCB

ELCBs were invented about 60 years ago and were once commonly used in electrical installations. Since the voltage-operated ELCB and the current-operated ELCB

were known as ELCB to avoid confusion between the two separate systems, The ELCB is now commonly referred to as Residual Current Device (RCD). If the incorrect type of equipment is used on an electrical system, the protection provided can be inadequate.

Today, the ELCB is one of the safety equipment that helps to protect the residential electrical grid. When the circuit breaker trips, the reset button reacts by closing the circuit breaker off. The fault normally occurs while no one is at home, and it is potentially caused by an overcurrent, short circuit, or leakage current on the live conductor, which may cause the ELCB to trip "Down" and switch off the entire residential power supply.

As a result of this situation, some important household appliances can be rendered inoperable. When the user is not at home, most ELCB must be manually reclosed during tripping, which can be a major concern. The ELCB was used extensively in the TT earthing system. The consumer's protective earth link is created by a local connection to the earth in a TT earthing system, irrespective of any earth connection at the generator unit.

# 2.4 Voltage Earth Leakage Circuit Breaker (vELCB)

This technology has been widely used since then, however it is no longer installed in new buildings. Voltage controlled ELCBs are devices that run depending on the amount of voltage flowing in the circuit. It detects a voltage increase in the covered enclosures as well as a distant isolated earth reference electrode. If the voltage reaches 50 volts, the main breaker will trip and the supply will be cut off. From the earth terminal to the vELCB, there are two links. One terminal was attached to the earth cable, while the other was connected to the earth rod. As compared to current-operated ELCBs, this ELCB has many drawbacks, including the need for an extra wire from the load to the ELCB and the inability to ground individual units. The ELCB's goal is to detect voltage and current leakage. The vELCB's level of shock protection was however restricted, as these devices would not have shock protection if they came into direct contact with live components. (Tarmizi & Rahim, 2009). Figure 2.3 shows the vELCB circuit connection.



2.5 Current Earth Leakage Circuit Breaker (iELCB)

Residual Current Device is the another name for iELCB (RCD). This device activates when a leak is detected and it trips the circuit breaker when a failure occurs. By using it as a separate operating system, it also guards against earth leakage. Since this system is less vulnerable to fault conditions, it can cause fewer disruptions on the ride. In comparison to the vELCB, this system has a number of drawbacks, including the fact that it cannot detect failures and does not pass current through the grounding wire to the earthing rod. Since earthing systems are often bonded to pipelines network, it is often difficult to split a single building earthing system into several sections with separate fault protection. Figure 2.4 depicts the current connection of iELCB.



Figure 2.4: iELCB circuit connection



Figure 2.5: ELCB housing

The ELCB is a tripping system that protects electrical appliances from excessive current. 15mA, 30mA, 100mA, 200mA, and 500mA are the standard rating of tripping values available in the market. This device's covering or housing serves to shield the particular device inside. (Engineering, 2016). Figure 2.5 depicts the ELCB housing while Table 2.1 shows the ELCB's range of voltage.

Rated	Number of	Rated	Action	Dead	Time
Voltage	Pole	Current	Current	Current	Leakage
( <b>V</b> )		(A)	Leakage (mA)	Leakage	Action
				(mA)	(s)
220V	1P	1~10	30	15	
		15~32			
380V	2P,3P,4P	40~60	100	50	<0.1

Table 2.1: Table shows the range of voltage for ELCB

# 2.7 ELCB Design



Figure 2.6: ELCB device

The magnetic coil is induced in the black box which is also de-energized in the same black box. The black box is a coil that is attached to the touch, which is a mechanical switch where its function is to shut off all power supplies. When this part is triggered, the power is turned off, as well as the neutral and live lines. Figure 2.6 shows the block diagram of the ELCB device.

Using a High-Level Resistor, the user can detect whether the ELCB is working or not. Allowing a short circuit flow inside the internal ELCB neutral and live lines may be used to test the device. The current flow through the live wire is isolated by making a recent current flow during the examination. The current in the live wire is greater than the current in the neutral wire when the reset button is pressed.

The reset button function is to determine if the device is disabled or not to trip and to return the device to its original state. As started previously, the magnetic coil is induced as well as de-energized in the black box.(Mohd Anuar Bin Mohamed Ayub, 2013).



Figure 2.7: ELCB schematic design

Figure 2.7 illustrate the ELCB actual schematic design. The aim of the ZCT is to detect an unbalanced current from the ground and the determine whether it is a live or negative live and neutral connection. The ZCT sensitivity is used to activate an ELCB. ELCBs with a current rating of 0.1 A are often used at home. When there is an unbalance current of less than 0.1 A, the current is occured, induced by the ZCT and the magnetic coil

is de-energized, causing the device to be disconnected by a mechanical switch. (Ahmad Khairuddin Bonari, 2015).

## 2.8 The basic concept of ELCB

If a malfunction occurs, the ZCT will be notified and a signal will be sent to the ELCB. Next, the ELCB is going to trip. If the load remains associated with the power supply after 10 seconds, the ELCB will reconnect the power to the load, indicating that the loss is only temporary. The temporary breakdown is like a bolt of lightning. If the ELCB also detects a malfunction after the electricity is restored, the ELCB will turn on back. This procedure will be repeated three times, and if any fault is found, the ELCB will disconnect the load from the main supply. It will show irreversible failures such as over-current or short circuit until the user repairs the fault; the ELCB will remain tripped until the failure is fixed. To escape any danger or risk, the ELCB must be manually switched on by the user until the failure has been fixed. (Mohd Anuar Bin Mohamed Ayub, 2013).

# 2.9 Operation of ELCB\_\_\_\_EKNIKAL MALAYSIA MELAKA

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The ELCB is operated by a relay and a sensing coil. When the fault occurs, ZCT can sense the imbalance value between the neutral current and live current, causing the caused current to occur. The black box will obtain the signal from the coil until the induced current has reached the minimum value. Once the coil is working, the contact detects it and the mechanical switch is activated automatically. The mainline supply will be closed off consequently. (Mohd Anuar Bin Mohamed Ayub, 2013).

#### 2.10 Earthing System



Figure 2.8: TT earthing system

Low and high-frequency sounds travel through the neutral wire from a number of electrical devices attached to the system, indicating the existence of a TT earthing system. As a result, TT the earthing system is the device of choice for applications such as telecommunication sites that require interference-free earthing. In addition, TT does not have the issue of harm neutrality. If a disaster occurs, such as a falling tree, there would be no damage to the earth conductor installation in the region where electricity is delivered and the TT system is used. This system is not as common as the TN earthing system because of its failure to obtain the maximum current in the event of a PE to live short circuit. (Mohd Anuar Bin Mohamed Ayub, 2013).

# 2.11 ELCB trip condition

Usually, there are two kinds of failure normally detected by ELCB, which are a permanent failure and temporary failure.

i. Permanent failure or permanent default

ii. Temporary failure or temporary default

## 2.11.1 Permanent Default

Trip occurs when any leakage current in the device to ground is detected. Before the ELCB can be automatically triggered again, the fault must be repaired or replaced. The machine will trip again if the fault is not repaired or replaced until the ELCB automatically triggers. If this occurs repeatedly, the ELCB may become defective. (Ahmad Khairuddin Bonari, 2015).

# 2.11.2 Temporary Default

In this case, the ELCB is triggered without the necessity of first repairing the fault or isolating it from the power supply. For example, if there is an overload of lightning in a suburban area, the occupant can have the difficulty of turning on the lights.

## 2.12 Microcontroller



Figure 2.9: Microcontroller configuration

The Central Processing Unit (CPU), Random Access Memory (RAM), Read Only Memory (ROM), INPUT, OUTPUT, ADC, and TIMER are all the available on-chip resources in this small chip computer. Since this unit is lightweight, it is referred to as a micro device. The unit is known as a microcontroller since it is commonly used in control applications. Since the microcontroller is a built-in feature, this technology is also commonly used in embedded systems. Microcontrollers, for example, are used in washing machines, microwaves, robots, and other devices. Microcontrollers have traditionally been coded in assembly language. Microcontrollers are now available in a variety of languages, including High-Level languages like PASCAL, BASIC, and C. The microcontroller has a number of drawbacks, including restricted internal memory (RAM/ROM) and limited input and output (I/O) capabilities. (Alfatih, Mohammed, Alfatih, & Shreef, 2017).



Figure 2.10: Wi-Fi Module ESP8266

The ESP8266 WiFi Module is a self-contained SOC with an optimized TCP/IP protocol stack that will provide connectivity to the user's WiFi network to any

microcontroller. The ESP8266 will either host an application or offload all WiFi networking features to a separate application processor. Each ESP8266 module is pre-programmed with AT command set firmware, so the user can just plug it into an Arduino and get around as much WiFi functionality as a WiFi Shield. The ESP8266 module is a low-cost board with a large and rapidly growing, usage in nowadays community.

This module has sufficient on-board processing and storage capabilities to enable it to be integrated with sensors and other application-specific devices through its GPIOs with minimal creation and load drawbacks during runtime. Its high on-chip integration makes for limited external circuitry, and the front-end module is planned to take up as little PCB space as possible. The ESP8266 supports APSD for VoIP applications and Bluetooth co-existence interfaces, which has a self-calibrated RF that allows it to function in any environment and does not require any external RF components.

## 2.14 Building Integrated Photovoltaic (BIPV) Technology

The Arduino UNO will be the main controller for all of the modules attached to the board in this project. Since solar energy is lost throughout the day, renewable energy can be used to power the Arduino microcontroller for 24 hours by incorporating the BIPV technology into the device. The solar panel would be fixed to the house's roof and walls, allowing it to capture the sun's rays from sunrise to sunset. As a result, if the battery dries out, the supply to the Arduino UNO microcontroller does not need to be replaced all of the time since the solar renewable energy will refresh the battery power.

Building Integrated Photovoltaics (BIPV) Technology entails the integration of photovoltaic (PV) modules that are used to cover conventional building components of the building envelope, such as the roof or the facade. The BIPV Technology performs two functions, it acts as a structural skin, replacing traditional building envelope materials, and it also acts as a power generator. BIPV devices save money on supplies and energy by performing all functions at the same time. This technology are considered as an alternate source of electrical electricity, the BIPV technology can have benefits over conventional non-integrated systems by lowering the initial cost of construction materials and labour, making it one of the fastest-growing segments of the photovoltaic industry. Photovoltaics (PV) modules, mounting systems, and energy systems are the three major types of the BIPV Technology internal structure. PV modules are designed for building incorporation which have attractive features such as colour, texture, shape, surface finishing and light materials, as well as designed to fit into existing structures. PV modules may be mounted on the building envelope, such as facades, roofs and external devices for the mounting system. This will assist the PV modules in obtaining a better angle for sunlight absorption by the solar panel. Finally, the energy system would provide storage, power conversion, heating and cooling, power management, and e-mobility systems to link the PV modules to the building, as well as district energy system to optimize the local usage of the electricity produced. BIPV Technology will become a one-of-a-kind option for providing people with clean and inexpensive energy by converting building surfaces into solar panel collectors.

# 2.15 Software Selection

The following section will describe the details about the selected software that is suitable for this project for the purpose to understand the function of the software more clearly.

#### 2.15.1 Arduino IDE

The Arduino Integrated Development Environment (IDE) is a cross-platform program developed in C and C++ functions for Windows, macOS, and Linux. It is used to

create and upload programs to the Arduino-compatible boards, as well as other vendor development boards with the support of third-party cores. The GNU General Public License, version 2 is used to license the IDE's source code. The Arduino IDE has specific code structure guidelines to support the languages of C and C++. The wiring project is a software library that is included with the Arduino IDE and offers numerous common input and output processes. The user-written code just needs two basic functions to start the sketch and the main program loop, which are built and linked into an executable cyclic executive program with the GNU toolchain, this is included also with the IDE release. The Arduino IDE uses the avrdude software to convert executable code into a text file in hexadecimal encoding, which is then loaded into the Arduino board's firmware via a loader software. Avrdude is the uploading tool by default for flashing user code onto official Arduino boards. Figure 2.11 shows the actual environment of the Arduino IDE software interface.



Figure 2.11: Arduino IDE software

#### 2.15.2 Blynk Apps

Blynk is an IoT business app that offers a platform for developing mobile (IOS and Android) applications that may connect electronic equipment to the Internet and remotely monitor and manage them. Pavel Bayborodin, a user experience (UX) expert in the mobile and automotive arena, is the person that launched the Blynk. In 2014, the IoT platform was released. Engineers use the Blynk platform to link MCUs and prototype development boards such as Arduino, ESP8266, or SBCs such as Raspberry Pi to the Internet through Wi-Fi, Ethernet, or cellular, as well as to create bespoke mobile applications to remotely monitor and operate electrical equipment. The Blynk Cloud is a free and open-source platform. Smart home, environmental monitoring, and industrial equipment remote control are examples of the IoT platform applications. Figure 2.12 shows the process flow of the blynk apps.



Figure 2.12: The Flow of Blynk Apps

#### 2.16 Hardware Selection

This section will describe the details about the selected hardware that are suitable for this project, as well as to understand the function and datasheet of the project's hardware clearly.

## 2.16.1 ESP32 NodeMCU

The ESP32 is a family of low-cost, low-power system-on-a-chip microcontrollers that have built-in Wi-Fi and dual-mode Bluetooth. The ESP32 series contains built-in antenna switches, RF baluns, power amplifiers, low-noise receive amplifiers, filters, and power-management modules, as well as a Tensilica Xtensa LX6 CPU in dual-core and single-core versions. Espressif Systems, a Shanghai-based Chinese firm, designed and developed the ESP32, which is produced by TSMC using their 40 nm technology. It is the version of ESP8266 microcontroller's replacement. Figure 2.13 illustrates the pin configurations of the ESP32 board.



Figure 2.13: ESP32 Board
#### 2.16.2 AC Current Sensor (SCT-013)

To monitor current, the non-invasive AC Current Sensor is a current transformer that may be clamped around the supply line of an electrical load. This device a current transformer that can be used to measure AC current up to 100 amperes. It accomplishes this by functioning as an inductor and reacting to the magnetic field created by a current-carrying wire. The current travelling through the conductor may be determined by reading the amount of current produced by the coil. This device is especially handy for calculating the total electricity used or energy generation in a particular building. Figure 2.14 shows the hardware AC current sensor. Table 2.2 show the table AC current sensor module. Figure 2.15 shows the current sensor electric parameters



Figure 2.14: AC Current sensor (SCT-013)

Table 2.2: AC Curre	ent Sensor Module
---------------------	-------------------

30A Module	50A Module	100A Module
Rated Output: 1V at 30A	Rated Output: 1V at 50A	Rated Output: 50mA

Model	Rated input (rms)	Max.Input	Rated output	Accuracy	max:Sampling resistance
SCT013-000	100A	120A	50mA	±1%	10Ω
SCT013-005	5A	30A	1V	±1%	Built-in
SCT013-010	10A	35A	1V	±1%	Built-in
SCT013-015	15A	40A	1V	±1%	Built-in
SCT013-020	20A	50A	1V	±1%	Built-in
SCT013-025	25A	55A	1V	±1%	Built-in
SCT013-030	30A	60A	1V	±1%	Built-in
SCT013-050	50A	70A	1V	±1%	Built-in
SCT013-060	60A	75A	1V	±1%	Built-in
SCT013-100	100A	120A	1V	±1%	10Ω

Figure 2.15: Current Sensor (SCT-013) Electric Parameter

#### 2.16.3 AC Voltage Sensor Module (ZMPT101B)

The ZMPT101B is a voltage transformer that may be used to monitor AC voltage. It can detect voltage and power up to 250V AC with excellent accuracy and consistency. The device is simple to operate and has a multiturn trim potentiometer for adjusting and calibrating the ADC output.



Figure 2.16: AC Voltage Sensor (ZMPT101B)

#### 2.16.4 DC Voltage Sensor Module (DC 0-25V)

2.16.5

The Voltage Sensor Module is a basic but highly useful module that reduces an input voltage by a factor of 5 using a potential divider. The 0-25V Voltage Sensor Module allows you to utilise a microcontroller's analogue input to monitor voltages far higher than it can sense.



A solar panel, also known as a photovoltaic (PV) module, is an installation of photovoltaic cells arranged in a particular framework. Solar panels create direct current electricity using sunlight as a source of energy. A PV panel is a collection of PV modules, while an array is a group of panels. A photovoltaic system's arrays provide solar energy to electrical devices. Figure 2.18 show the hardware of solar panel.



Figure 2.18: Solar Panel

## 2.16.6 Solar Control Charger

The rate at which electrical current is added to or extracted from electric batteries is limited by a charge controller, charge regulator, or battery regulator. It protects against overcharging and overvoltage, which can impair battery performance and longevity while also posing a safety concern. Depending on the battery technology, it may also prevent a battery from totally draining ("deep discharging") or execute regulated discharges to extend battery life. The phrases "charge controller" and "charge regulator" can apply to separate devices as well as control circuitry included into a battery pack, battery-powered device, or battery charger. Figure 2.19 shows the hardware solar charge controller.



Figure 2.19: Solar Charge Controller

#### 2.16.7 Inverter

A power inverter, often known as an inverter, is a device or circuit that converts direct current (DC) to alternating current (AC) (AC). The frequency of the generated AC is determined by the equipment used. Inverters are the polar opposite of "converters," which were massive electromechanical devices that converted AC to DC in the past. The design of the individual device or circuitry determines the input voltage, output voltage, frequency, and overall power management. The power is supplied by the DC source, not the inverter. A power inverter can be all-electronic or a mixture of mechanical and electrical circuitry (such as a rotating equipment). Figure 2.20 depicts the hardware power inverter.



Figure 2.20: Power Inverter

#### 2.16.8 Battery Backup

When the primary source of power is missing, a backup battery supplies power to the system. Small single cells are used to keep the clock time and date in computers, while huge battery room facilities are used to power uninterruptible power supply systems for major data centers. Small backup batteries might be primary cells, whereas rechargeable backup batteries are charged by the primary power source. Figure 2.21 illustrates hardware battery backup.



Figure 2.21: Battery Backup

#### 2.16.9 Relay Driver

For the project's development, relay driver is used to switching the motor. The relay that has been use for this project is 4 channel relay modules. This module is a LOW level 5V 4 channel relay and each channel needs a 15-20mA driver current. This relay can be used in many equipment and appliances with large current. It come with high-current relay that work under 250V AC 10A or 30V DC 10A and it is a standard interface that can be controlled directly by using the microcontroller. This relay is separated from high voltage side for safety conditions and to avoid ground loop when being interfaced to the microcontroller.

The switch is operated by an electromagnetic principle to open or close one or many sets of contacts. The relay can control the output circuit of higher power than the input circuit. The relay switch connections are usually labelled COMMAND (COM), NORMALLY CLOSED (NC) and NORMALLY OPEN (NO). The circuit connected to COM and NO if the user wants the switched circuit to be OFF. While, the circuit connected to COM and NC if to the user wants the to be on. The figure below shows the protective relay that has been used for this project. Figure 2.22 shows the hardware relay driver 4 channel.



Figure 2.22 : Relay Driver 4 Channel

## 2.17 Overview Previous Report

Previous report has been researched thoroughly in order to provide further details about the process used and the observations involved when carried out this project. Additionally, this serves as a checklist to ensure that all of the project's objectives are fully achieved.

# 2.17.1 Stand-alone backup power system for electrical appliances with solar PV and grid options

Based on the research from (Sabry et al., 2019), in order to address the recent concerns of global warming, a portable backup power system would lead to increasing energy transfer efficiency between the source and the electrical household appliances. This paper proposes a Backup Power System (BPS) compatible to match with two primary power sources; Grid-Connected power as an AC and solar-PV as a DC power source. This device includes a 300V rechargeable battery bank, with a voltage matching principle that keeps the battery completely charged as long as the power source is available. To show the principle of the adopted voltage-matching, a MATLAB-based simulation was implemented. When all the main power options are unavailable, a relay loop circuit powered by the main power source is used to transfer the load/appliances between the direct link and storage battery power by bypassing the main power. The results show that the proposed topology achieved around 99 percent power efficiency as compared to the conventional one, this demonstrating an excellent use of traditional BPS losses.

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#### 2.17.2 Automatic Earth Leakage Circuit Breaker with Backup Supply

The aim of this project is to improve an existing ELCB design by using a PIC Microcontroller to reconnect an ELCB circuit that has been flipped back to its original state when short circuits and overcurrent occur. When the user is away from home, this device provides them with incentives. In tis project, the PIC16F877A controller is used to monitor the whole operating system as well as the Power Relay / Protection Relay, which has been replaced with a mechanical switch. After multiple examinations, the average ELCB

sensitivity test to the leakage current is 76mA, which is 24 percent higher than the manufacturer's set value of 100mA. An Uninterrupted Power Supply (UPS) is a system that provides backup power in the event of a power outage. The aim of this project is to protect all of the household appliances from destruction. The ELCB will be backed up and kept running as soon as the UPS is turned on if there is a power outage. (Mohd Anuar Bin Mohamed Ayub, 2013).

#### 2.17.3 Arduino Based Home Automation Control Powered by Photovoltaic Cells

Based on the research from (Singh et al., 2018), an Arduino-based Home Automation Control that is controlled by Photovoltaic Cells was developed. The Arduino microcontroller served as the brain for the home automation system, but it needs power to operate it. A 12V battery is usually sufficient for the Arduino microcontroller, but it must be replaced manually until it runs out. An alternative method had been devised to keep recharging the 12V battery, eliminating the need for the Arduino board to replace the battery on a regular basis. Solar energy is converted to electrical energy by a solar panel that receives or gathers rays directly from the sun. When the solar panel absorbs electricity, the transferred electrical energy will continue to charge the battery. This will cause the Arduino microcontroller to run for 24 hours without the need to replace the battery. The home automation system would not stop operating for the user if the Arduino board is kept powered up.

# 2.17.4 Internet of Things (IoT) enabled Sustainable Home Automation along with Security using Solar Energy

In order to conduct research for a paper entitiled IoT enabled Sustainable Home Automation with Security features, (Amit et al., 2019) where the project used solar energy as a source of energy. The device can only function due to the power supply of 12 battery, which was obtained from the solar energy collected from the solar panel. The solar energy, which was later turned into electrical energy, had a voltage output of 21V, hence it was a first step-down before being fed to the microcontroller. The solar panel was supposed to be turned on and off based on the supply of the solar energy.

# 2.17.5 Effective Environmental Monitoring Domestic Home Conditions by Implementation of IoT

The ESP8266 Wi-Fi module was used to build an IoT-based Arduino microcontroller that allows the user to link to the internet and track the domestic home conditions. The user is able to verify the state of the area around the house and monitor its surroundings using smart phone apps or web servers. The Arduino microcontroller was able to react to signal data sent through the app or server and alter the desired result from the user, such as turning on/off the electrical appliances, whenever the data was sent through the app via mobile devices or server. (Chaudhari et al., 2018).

# 2.18 Comparison ESP32 with Arduino UNO

Table 2.3: Shows the comparison between the ESP32 Node MCU and Arduino

Comparison	ESP32 NodeMCU	Arduino UNO R3
Microcontroller	ESP32	ATmega328p
Operating Voltage	3.3V	5V
Power supply	7V – 12V	7V – 12V
Current consumption	20 mA – 240 mA	45 mA – 80 mA
Current consumption Deep Sleep	5 μΑ	35 mA
Digital I/O Pins	36	14
Digital I/O Pins with PWM	36	6
Analog Input Pins	15	6
SPI/I2C/I2S/UART	4/2/2/2	1/1/1/1
DC Current per I/O Pin	20 mA	40 mA
DC Current for 3.3V Pin	40 mA	150 mA
Flash Memory	4 MB	32 KB
SRAM	520 KB	2 KB
EEPROM	مىتى ي <u>ە</u> خنىك	1024 bytes
Clock Speed	80 MHz / 160 MHz	16 MHz
Length	52 mm	69 mm
Width	31 mm	53 mm
WIFI	yes	no
Bluetooth	yes	no
Touch sensor	10	no
CAN	yes	no
Ethernet MAC Interface	yes	no
Temperature Sensor	yes	no
Hall effect sensor	yes	no
Power jack	no	yes
USB connection	yes	yes
Price	RM45	RM90

UNO Microcontroller

# 2.19 Advantages and Disadvantages of ESP32 and Arduino UNO

	Advantages	Disadvantages
ESP32	The ESP32 dev kit is actually	- The uploading of the code may take a
	less expensive than the Arduino	little longer at times, but this is a random
	Uno, hence user get a more	occurrence. It's most likely due to the
	powerful board for less money.	USB/UART bridge.
	The user may approach the	- When compared to Wi-Fi functions,
	ESP32 as a supercharged	Bluetooth capabilities are more difficult
	Arduino Uno at the level where	to install.
4	the user can utilize current	-Power consumption is higher than
TEK	Arduino abilities to deal with it:	ESP8266
	quicker, better in many ways.	- When using Wi-Fi and Bluetooth at the
	كنيكا ملسيا ملا	same time, large power spikes might
		occur (biggest was 790mA)
Arduino UNO	Arduino offers a number of	Its disadvantages include its compact size
	appealing features, including a	and the fact that the user must operate in
	big user base, a free and	a confined (or fairly tiny) location. Its
	extensive library of code, and	necessities to hunt for third-party sources
	relatively low-cost components.	in addition to Arduino scripts in many
		large and multi-purpose projects. Another
		problem is that some mistakes might
		continue for a long time, and error
		messages may not be very informative.

Table 2.4: Depicts the pros and cons of both the ESP32 and Arduino UNO

From my research, i choose to use microcontroller ESP32 because the ESP32 dev kit is actually less expensive than the Arduino Uno, hence user get a more powerful board for less money. The user may approach the ESP32 as a supercharged Arduino Uno at the level where the user can utilize current Arduino abilities to deal with it: quicker, better in many ways.

#### 2.20 Summary

Chapter 2 explains briefly about the introduction of integrated circuit, as well as the overview of ELCB and microcontroller. This chapter also describes the previous research on the development of an IoT-based integrated photovoltaic with smart power source that has been carried out through few previous works. The research that has been carried out basically give a clear understanding on the components and the necessary programming to be used for the proposed project, as well as suitable methods to be carried out for the project's system development.

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#### **CHAPTER 3**

#### METHODOLOGY

#### 3.1 Introduction

A methodology is a set of procedures and methods for identifying and analyzing specific problems within a given topic's scope. This chapter will outline the approach that will be employed as well as provides an overview of the project's outcomes The most important aspect that requires greater attention is to ensure that each phase of the project's flow is not skipped so that the work can be completed accordingly.

### **3.2** Introduction to the project flowchart

For the development of an IoT-Based Integrated Photovoltaic With smart Backup Power Source, a flowchart was made to show all the means for the general application. Based on the flowchart of this project illustrated in figure 3.1 it will show the project's system flow. The first flow process will start by turning on the power supply from the 3-pin plug. After that, it will initiallize the home electrical appliances. The input of this project are used voltage and current sunsor. These sensors are used to monitor and display the value of voltage, current, power, Kwh of the home appliances and battery backup indicator. The condition for this project is used for blackout situation. If the condition is "Yes" meaning there is no supply in the home appliance. Therefore, voltage sensor will detect by reading the voltage value. If the value voltage is less than 24v, the input signal will be sent to ESP32 to process the output by notifying the user for power outages alert from the blynk app. At the same time it will enable the relay automatically. The relay will be triggered from power backup thus the electricity is generated. Otherwise for the "No" condition, meaning there is supply is flow. Therefore it will return back to the first flow which is the condition where the power supply is on.



Figure 3.1: Flowchart of the process

#### 3.3 The Block diagram of Project

Figure 3.2 illustrates the block diagram of the project. The power supply from the block diagram is used from the 3-pin plug unit. On the left side of the block diagram is the input of the voltage sensor and current sensor. While the middle part of the block diagram is for the processing unit of the project in which the ESP32 microcontroller is used. The right side of the block diagram was for the output that had been processed from the ESP32 microcontroller. The output for this project is enabling the relay that come from the solar system. Furthermore, the output of this project will be sent to Blynk app that is processed from the ESP32 wifi module. The blynk app will notify the alert of power outage and provide the energy monitoring data to the user.



Figure 3.2: Block diagram of the project

#### **3.4** The Flow of the Process Project

Figure 3.3 showed the process of the project flow process. The process starts from the voltage supply of 220V that will supply the electricity to the home appliances. The next process is the input which is the voltage sensor and current sensor. These input signals will read the data values supplied and then is processed to display of the energy monitoring. The next process when there is a blackout situation. In this stage, the voltage sensor will process to read the voltage signal that had fixed and sent to the ESP32 to process the output. The output process will send notification alert to user and at the same time it will enable the relay to operate the solar charge controller, rechargeable battery and inverter. The final process for this project is when there are electrical supplies to those home appliances.



Figure 3.3: Flow of the Process

#### **3.5** The Circuit Design for the Project

The circuit design is needed as the guidance for the connection of hardware installation. Figure 3.4 illustrates the circuit diagram for the overall project connection. The circuit design used the Draw IO online software to generate the circuit flow. Overall, there are fourteen main components as shown. For this project, the power supply comes from TNB. The power supply is given to certain electrical components with the connection of life, earth and neutral wire accordingly. There are 2 channels for the relay component. As for the supply from TNB, the life wire is connected to channel 2 relay and also to the main switch of the DB box. On top of that, the channel 1 relay component is used to switch on the output component to the solar system. The voltage sensor component is connected to the TNB supply which is life and neutral cable to obtain the reading of voltage value. It is used to recognize if there is no voltage supply, it is caused by the power outage. While for the current sensor component it is clamped into the life cable from TNB supply. Both of the current and voltage sensor is connected to the ESP32 microcontroller as their input. The main component for DB box is naturally the basic connection to the switch, bulb and the two socket 3-pin UNIVERSITI TEKNIKAL MALAYSIA MELAKA plug that will be used and connected to a mini fridge and a load. The solar component is divided into four minor components which is the battery for the storage power backup, inverter to change DC to AC, solar control charger to control the incoming supply from the solar panel. The last component is the microcontoroller for ESP32 which controls the process of the input of voltage and current sensor to display energy monitoring on the blynk app. If power outages happend the relay automatic changes to solar system supply. Figure 3.5 shows the legend from the drawn circuit diagram.



Figure 3.5: Lagend for Circuit Diagram

## 3.6 Summary

Chapter 3 discusses the methods used to develop the project referring to the previous Literature Review in Chapter 2. This section also discuss the proposed block diagram and flow chart of the project. As well as explain and describe the software and hardware selection features in brief.



#### **CHAPTER 4**

#### **RESULTS AND DISCUSSIONS**

#### 4.1 Introduction

In this chapter, the ESP32 microcontroller was chosen for this project. Several previous research have been compared. The language for this microcontroller is the C language. The program has been done and developed in Arduino IDE software. This software is easy to modify and compiled. Therefore, the Arduino IDE is the most suitable microcontroller for this project.

#### 4.2 **Overall Project and Operation**

To operate this project, the program is constructed and compiled on the Arduino IDE software. As there is no error during execution, the project run successfully. The circuit diagram had been created in the diagram.net website and saved the version of in draw.io file. The program then accordingly had been uploaded on the ESP32, and it can start to be simulated to the circuit. The simulation of the circuit is showed on Figure 4.4 until Figure 4.5, respectively

#### 4.3 The Process of DB Box Installation

In the making of the project, the installation of the Distribution Board (DB) box is needed to show the prototype of the result. The process of making the DB box is consists of, plain playwood, ELCB, two units of 3- pin plug socket, as well as switch and bulb. The connection for the installation is achieved by using life,neutral and earth wire. Figure 3.16 shows the installation of the base. The plain playwood is used as the base and the case of the ELCB,socket,switch and bulb had been screw to the plywood is used as the base and the housing case of ELCB which include the socket, switch and bulb which has been screwed to the plywood. The connection of the life,neutral and earth wires are inserted in the case. In the figure 3.17 depicts the installation of the wire to the main components followed by the datasheet of every components. While figure 3.18 shows the final result of the installation and had been succesfully tested with the bulb and the USB wire charger.



Figure 4.1 : Base Installation DB Box





Figure 4.3: The final prototype result

#### 4.4 Software Testing

4.5.

This project was tested through software and hardware testing. In the software testing, the program was run and simulated from Arduino IDE to output monitor in COM3 port. The output monitor in COM 3 showed the output values of Vrms, Irms, Power, Kwh and Battery Voltage. Figure 4.1 displayed the values when the circuit was turn on ELCB plug through project circuit. Therefore, the value of Vrms, Irms, Power, and Kwh in Figure 4.4 is higher due to output from the bulb and mini fridge. While in Figure 4.5 showed the value when the plug on ELCB is turning off. As shown on the monitor showed, the value is drop from the initial state. The value drop is highlighted in Figure

```
о сомз
Battery V= 13.4721
Vrms: 228.50V Irms: 0.0053A
                                Power: 1.2089W kWh: 0.0008kWh
Battery V= 13.5455
Vrms: 227.87V Irms: 0.0050A
Battery V= 13.5455
                               Power: 1.1370W kWh: 0.0008kWh
Vrms: 228.29V Irms: 0.0061A Power: 1.3818W kWh: 0.0008kWh
Battery V= 13.4477
Vrms: 227.66V Irms: 0.0056A
                                Power: 1.2721W
                                               kWh: 0.0008kWh
Battery V= 13.3744
Vrms: 228.53V Irms: 0.0060A Power: 1.3805W kWh: 0.0008kWh
Battery V= 13.4233
Vrms: 227.20V Irms: 0.0054A
                               Power: 1.2263W kWh: 0.0008kWh
Battery V= 13.4233
Vrms: 228.19V
              Irms: 0.0060A
                               Power: 1.3720W
                                               kWh: 0.0008kWh
Batterv V= 13.4477
Autoscroll Show timestamp
```

Figure 4.4: Arduino Output Monitor During ELCB on

💿 сомз						
Vrms: 4.46V	Irms:	0.0177A	Power:	0.0788₩	kWh:	0.0001kWh
Battery V= 10.04	449					
Vrms: 4.54V	Irms:	0.0183A	Power:	0.0834W	kWh:	0.0001kWh
Battery V= 10.12	182					
Vrms: 4.44V	Irms:	0.0174A	Power:	0.0770W	kWh:	0.0001kWh
Battery V= 10.1	671					
Vrms: 4.51V	Irms:	0.0178A	Power:	0.0804W	kWh:	0.0001kWh
Battery V= 10.13	182					
Vrms: 0.33V	Irms:	0.0012A	Power:	0.0004W	kWh:	0.0001kWh
Battery V= 10.04	449					
Vrms: 0.00V	Irms:	0.0000A	Power:	0.000W	kWh:	0.0001kWh
Battery V= 9.99	50					
Vrms: 0.07V	Irms:	0.0032A	Power:	0.0002W	kWh:	0.0001kWh
Battery V= 10.02	204					
Vrms: 0.49V	Irms:	0.0000A	Power:	W0000.0	kWh:	0.0001kWh
Battery V= 10.2	159					
Autoscroll Sh	ow timest	amp	portunal S	and had noth		anal. Maadd yaar



## 4.5 Hardware Testing

The hardware circuit project shows the actual visual output of the bulb and mini fridge. The hardware main components were assembled and arranged on the woodboard. Figure 4.6 illustrates the final hardware project circuit and the energy monitoring on the blynk app when the project is enabled. As the result, the output showed the bulb is light up and the values in energy monitoring is increased. Figure 4.7 depicts the output result when the project is disabled. Therefore, the output of bulb and mini fridge is turned off. At the same time, Figure 4.8 showed. The blynkk app that pushed up the notification to the device to alert the user.



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Figure 4.7: Hardware Circuit and Energy Monitoring During ELCB Disable



Figure 4.8: Energy Monitoring During ELCB Disable

#### 4.6 Charging and Discharging Hardware Circuit

In this part, there are two types of solar panel involved. The first solar panel is monocrystalline and the second solar panel is polycrystalline. Figure 4.9 showed the process of solar panel during the sun shines onto a solar panel. The energy from the sunlight is absorbed by the PV cells in the panel. This energy creates electrical charges that move in response to an internal electrical field in the cell, causing electricity to flow.

Figure 4.10 then showed the process of charging the solar panel. There are three components involved, the first one is the solar panel, second is the solar charge controller and third is the battery backup. The connection between the component is shown in those arrow flow depicted in Figure 4.10.

On top of that, Figure 4.11 showed the discharging process of the battery backup. The circuit connection of this process is shown on the arrow flow in Figure 4.11. The connection of the discharging component is from the battery backup to the solar charger controller. The solar charger controller is connected to power inverter and at the same time its linked to the DB box. Finally, the discharging process allows the circuit to display the project's output.



Figure 4.9: Type of Solar Panel





Figure 4.11: Process of Discharging Battery Backup

#### 4.7 Result and Data

The result and data for this project were recorded and shown in Table 4.1. This data was recorded based on time taken for charging and discharging from solar panel to battery backup. The output that has been discharged is bulb and mini fridge. Every time taken is recorded for five days in a row to depicts the accuracy and the efficiency of the project's system. In the Table 4.1 shows two types of solar panel and the time taken to charge from 25% until 100%. There is also time taken for discharged from battery backup that used in the project, as shown on the same table. While in Table 4.2 is to shows the run time data for single output load of bulb, mini fridge, fan and charging smart phone with every single full power supply from battery backup.

E .	Day 1(Daylight)	
Type of Solar Panel	Charging Battery backup	Discharging Battery backup
Monocrystalline		
1	25%: 11 min	Fully discharge from battery
سيا ملاك	50%: 22 min	backup:
	75%: 33 min	a la la
LINIVEDSI	100%: 44 min	
Total:	44 min	17 min
Polycrystalline		
	25%: 23 min	Fully discharge from battery
	50%: 46 min	backup:
		1
	75%: 69 min	1
	75%: 69 min 100%: 92 min	

Table 4.1: Time taken for charging and discharging battery backup

	Day 2(Daylight)	
Type of Solar Panel	Charging Battery backup	Discharging Battery backup
Monocrystalline		
	25%: 12 min	Fully discharge from battery
	50%: 24 min	backup:
	75%: 36 min	
	100%: 48 min	
Total:	48 min	15 min
Polycrystalline		
	25%: 24 min	Fully discharge from battery
	50%: 48 min	backup:
	75%: 72 min	
	100%: 95 min	
Total:	1 h 35 min	8 min

	Day S(Daylight)	
Type of Solar Panel	Charging Battery backup	Discharging Battery backup
Monocrystalline		
	25%: 12 min	Fully discharge from
MALAYSI	50%: 24 min	battery backup:
and the second se	75%: 36 min	
N. N	100%: 48 min	
Total:	48 min	13 min
Polycrystalline		
A AND	25%: 25 min	Fully discharge from
	50%: 50 min	battery backup:
سيبا ملاك	75%: 75 min	lever m
14	100%: 100 min	
Total:	1 h 40 min	7min

	Day 4(Cloudy)	
Type of Solar Panel	Charging Battery backup	Discharging Battery backup
Monocrystalline		
	25%: 32 min	Fully discharge from
	50%: 52 min	battery backup:
	75%: 72 min	
	100%: 92 min	
Total:	1 h 32 min	15 min
Polycrystalline	· · ·	
	25%: 45 min	Fully discharge from
	50%: 65 min	battery backup:
	75%: 85 min	
	100%: 105 min	
Total:	1 h 45 min	6min

Charging Battery backup	Discharging Battery backup
25%: 42 min	Fully discharge from
50%: 72 min	battery backup:
75%: 102 min	
100%: 132 min	]
2 h 12 min	14 min
25%: 55 min	Fully discharge from
50%: 85 min	battery backup:
75%: 115 min	]
100%: 145 min	]
2 h 25 min	8min
	25%: 42 min         50%: 72 min         75%: 102 min         100%: 132 min         2 h 12 min         25%: 55 min         50%: 85 min         75%: 115 min         100%: 145 min         2 h 25 min

Table 4.2: Run time data for single output load



#### 4.8 Discussion

Based on the data recorded in table 4.1, the charging battery backup is recorded by staged from 0% until 100% of battery is fully charged. The time taken for Monocrystalline to charge battery backup from solar panel is faster compared to Polycrystalline. While the time taken for Monocrystalline to discharge the supply to the project is system takes longer time compared to Polycrystalline. As conclusion, the Monocrystalline is more efficient because of the duration of charging and discharging.

On top of that, Monocrystalline are more efficient since they are cut from a single source of silicon while Polycrystalline solar cells are blended from multiple silicon sources. Finally, Monocrystalline perform better in high heat and lower light environments, which means that Monocrystalline will produce closer to their rated output in less-than-ideal conditions. Figure 4.12, 4.13 4.14, 4.15 and 4.16 below showed the pivot graph that had been generated from data recorded of charging and discharging of battery backup from day 1, day 2 and day 3 for daylight while day 4 cloudy and day 5 light rain respectively.

While for the data recorded in table 4.2 is the run time of the output load. Each of the load is used from full charged of battery backup until it drains. After the battery backup is drain the output will automatically turn off. On the first output appliances is mini fridge of 40W which can run up to 2 hours for single charged of battery backup. Next, On the second output appliances is bulb with 18W which can run up to 3 hours for single charged of battery backup. Thirdly, the output from fan which can run up to 2 hours for single charged of battery backup. Other that, charging smart phone can used to charge the smart phone until 2 times.



Figure 4.12: Histogram graph for Day 1



Figure 4.13: Histogram graph for Day 2



Figure 4.14: Histogram graph for Day 3


Figure 4.15: Histogram graph for Day 4



Figure 4.16: Histogram graph for Day 5

#### 4.9 Solar Size Calculator

In this section, the calculation for the solar size are shown which include the on grid and off grid situation. The off-grid systems can approximate the solar PV system wattage by calculating the total Watts (W) the electrical appliances, as well as will consume, for how long the planning to run these devices, the Charge Controller efficiency (PWM: 80%, MPPT: 92%) and the average Sun Hours per day, respectively. All this have been calculated in the Table 4.3 data and the Figure 4.17 is the graph of the calculation. While accordingly the ongrid calculator approximate the on-grid system wattage with calculations that include the total KiloWatts-Hours (KWh) to use per month, the percentage of this power will be used by renewable solar energy and average Sun Hours per day. Table 4.4 illustrated the on-grid calculator systems to approximate the solar PV system wattage.

Table 4.3: Off-grid calculator systems to approximate the solar PV system wattage

What is the total Watts (W) your electronics will consume?	<u>600</u>	Watts
For how long are you planning to run these devices?	8 LAKA	Hour(s)
Charge Controller efficiency (PWM: 80%, MPPT: 92%)	<u>80%</u>	Efficiency
Average Sun Hours per day?	<u>6</u>	Hours

Minimum System Size: 800 Watts

Recommended System Size: 1000 watts

Recommended Battery Size (12V): 800 Amp-hours

Recommended Battery Size (24V): 400 Amp-hours



Figure 4.17: The graph of the solar system size for off-grid

Table 4.4: On-grid calculator systems to approximate the solar PV system wattage

How many KiloWatts-Hours (kWh) do you use per month?	<u>600</u>	kWh/Month
What percentage of this power will be used by renewable solar energy?	50 9 9	%
What percentage of this power will be used by renewable solar energy?	<u>8</u>	Hours

System Size: 1250 Wat

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# 4.10 Summary

This chapter shows the data that been recorded throughout the project's system in order to achieve the project's objective. The data recorded is then discussed thoroughly especially the time taken for charging and discharging of the battery backup from the solar panel. From the discussion and the data captured, the pivot graph is then generated, accordingly.



#### **CHAPTER 5**

#### CONCLUSION AND RECOMMENDATIONS

#### 5.1 Introduction

This chapter discuss the development of IoT-based integrated photovoltaic with smart backup power source and summarizes the objective, methodology and result obtained from data. This would assist in future projects to further improve and develop the system to be more efficient and productive.

### 5.2 Summary of Project

This project is to aimed an IoT-based integrated photovoltaic with smart backup power source. The crucial part for this project is when there is problem on designing the hardware circuit. The voltage sensor is the main input component that detect the absent of the voltage from building or houses. While the input of current sensor used to display the monitoring on the blynk app. From the monitoring, the application can calculate and display the power and KWh of the electrical appliances.

The main objective of this project is to develop an IoT-based integrated photovoltaic with smart backup power source. Other than that, this project also targeted to design and build IoT-based circuit and hardware for a BIPV-powered home automation system Finally, this project also analyze and compare the efficiency between two solar panel of monocrystalline and polycrystalline, accordingly. The analyzation is done by recording all the data of charging and discharging solar panel to battery backup. From the data results, this project can compare and define more clearly the efficiency of the solar panel. As conclusion, the monocrystalline solar panel is more competence than the polycrystalline. Finally, this project is successfully accomplished and achieve all of the objective stated.

### 5.3 Recommendation

For the future project and work, the following recommendations can be carried out to improve the study and experimental model of the project's process:

- i. The application on user is to display the monitoring value and alert the user only for the current project. Therefore, it is recommended to make the application more user friendly by adding several features such as controlling the usage between the solar panel system from TNB power source for energy saving mode purposes.
- ii. The solar panel for this project currently not using the sensor of photo resistor. For the future work, this sensor is recommended to used in solar energy tracking systems to capture maximum power by photovoltaic (PV) cells or systems at the time of uniform or partial irradiance of the sun as well as the effect of shade during clouds. PV cells or modules' generating power is affected due to the partial shading.
- iii. To improve the quality of this project in order to be commercialized to the market, the main component such as the solar panel requires bigger size to accommodate more Watt. While the usage battery backup need to increase the capacity of the storage to discharge the power accordingly for future project's improvement.

### 5.4 **Project Potential**

This project has the potential to be commercialized to the building or houses that prioritize the power energy consumption such as hotels, schools, hospital or server room. This project able to provide a low-cost instrument installation compared to the existing instrument that available in the market. Additionally, this project offers a compact design, convenient, and user friendly. In such a way the electrical consumption monitoring can be carried out in a more efficient way.

## 5.5 Summary Chapter

The aim of this chapter is to sum up the project achievement and make recommendations for future projects improvement. The goal of this project is to provide ideas for creating effective ones, as well as to assist the innovator in evaluating draughts and advising them on what to avoid. The above suggestion is intended to improve the project's quality for future works.

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