Faculty of Electrical Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF SOLAR POWERED SMOKE DETECTOR DEVICE USING A MICROCONTROLLER

NOOR SAFWAN BIN AZLAN

Bachelor of Electrical Engineering Technology with Honours

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DEVELOPMENT OF SOLAR POWERED SMOKE DETECTOR DEVICE USING A MICROCONTROLLER

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A project report submitted
in partial fulfillment of the requirements for the degree of
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Faculty of Electrical Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DEDICATION

To my beloved mother, Salina Binti Dawam, and my beloved father, Azlan Bin Basir, who have been with me and supporting me from the start of my life until now.

اونيۏرسيتي تيكنيكل مليسيا ملاك
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ABSTRACT

As growth in cities is accelerating, fire safety issues are becoming more important. Some of the buildings may not implement and enforce the requirement of fire safety regulations and building codes which include necessary fire safety features. Large amounts of smoke can be produced while a building is on fire which makes most fire fatalities are caused by inhaling too much smoke. Hence, it is necessary to develop a device that can detect smoke or fire as an alert and safety. To overcome this problem, this project aims to design and develop an IoT system for the smart smoke detector using ESP8266 microcontroller powered by solar. The developement of a smoke detector device is using a gas sensor and flame sensor to sense smoke particles and potential fire that are produced when fire occurs. PV solar panel system has been used as renewable energy source to power the smoke detector device. The smoke detector can sense the smoke particles within a range of 300 to 1000 ppm. When the sensor was triggered it sent a signal to microcontroller to activate the LED and buzzer. The LCD displayed the result and Blynk application sent a notification to inform the authorities that the smoke was detected. This device enables immediate responses so that loss of life, damage, financial losses and other mishaps that can occur from fire burning can be prevented.

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ABSTRAK

Memandangkan pertumbuhan di bandar semakin pesat, isu keselamatan kebakaran menjadi lebih penting. Sesetengah bangunan mungkin tidak melaksanakan dan menguatkuasakan keperluan peraturan keselamatan kebakaran dan kod bangunan yang termasuk ciri keselamatan kebakaran yang diperlukan. Banyak asap boleh dihasilkan semasa sebuah bangunan terbakar yang menyebabkan kebanyakan kematian akibat kebakaran disebabkan oleh terhidu asap yang terlalu banyak. Oleh itu, adalah perlu untuk membangunkan peranti yang boleh mengesan asap atau api sebagai amaran dan keselamatan. Untuk mengatasi masalah ini, projek ini bertujuan untuk mereka bentuk dan membangunkan sistem IoT untuk pengesan asap pintar menggunakan mikropengawal ESP8266 yang dikuasakan oleh solar. Perkembangan peranti pengesan asap menggunakan sensor gas dan sensor nyalaan untuk mengesan zarah asap dan potensi kebakaran yang dihasilkan apabila kebakaran berlaku. Sistem panel solar PV telah digunakan sebagai sumber tenaga boleh diperbaharui untuk menggerakkan peranti pengesan asap. Pengesan asap dapat mengesan zarah asap dalam lingkungan 300 hingga 1000 ppm. Apabila sensor dicetuskan ia menghantar isyarat kepada mikropengawal untuk mengaktifkan LED dan buzzer. LCD memaparkan keputusan dan aplikasi Blynk menghantar pemberitahuan untuk memaklumkan pihak berkuasa bahawa asap itu dikesan. Peranti ini membolehkan tindak balas segera supaya kehilangan nyawa, kerosakan, kerugian kewangan dan kemalangan lain yang boleh berlaku akibat kebakaran boleh dicegah.

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

TABLE OF CONTENTS

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF TABLES

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF FIGURES

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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LIST OF ABBREVIATIONS

V	-	Voltage
IoT	-	Internet of Things
PPM	-	Part Per Million
LCD	-	Liquid-crystal display
IDE	-	Integrated Development Environment
MCU	-	Micro Controller Unit
API	-	Application Programming Interface
LINE	-	Logistic Information Network Enterprise
Wi-Fi	-	Wireless Fidelity
A	-	Ampere
IR	-	Infrared Radiation
LED	-	Light-Emitting Diode
PWM	-	Pulse Width Modulation
KB	-	Kilo Byte
B	-	Byte
RAM	-	Random-Access Memory
ADC	-	Analog-to-Digital Converter
CPU	-	Central Processing Unit
PV	-	Photovoltaic
SMS	-	Short Message Service
CO	-	Carbon Monoxide
mAh	-	Milliampere Hour
DHT	-	Digital Temperature and Humidity Sensor
DC	-	Direct Current
AC	-	Alternating Current
GSM	-	Global System for Mobile Communication
Ni-MH	-	Nickel Metal Hydride
W	-	Watt
Ah	-	Ampere Hour
Wh	-	Watt Hour
GPS	-	Global Positioning System
USB	-	Universal Serial Bus
LPG	-	Liquefied Petroleum Gas
MHz	-	Megahertz
Nm	-	Nanometer
IEEE	-	Institute of Electrical and Electronics Engineers
BDP	-	Bachelor Degree Project
mm	-	Milimeter

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 1

INTRODUCTION

1.1 Background

A controlled fire can be very beneficial. Yet, a fire that is out of control could do serious damage. A devastating fire occurs accidentally from a flammable source, it spreads quickly from a small area to the entire building. Many categories, including residential, factory, office, public place and others can be used to further categorise the different types of buildings. Residential properties were responsible for the most annual building fire incidences of any of these categories.

According to the National Fire Protection Association (NFPA) (2018), smoke inhalation rather than burns makes up the majority of fire-related deaths. The smoke itself kills the victims even before they are able to make it to the building's exit. One of the causes is that the fire itself used up the majority of the oxygen during burning, resulting in a drop in the air's oxygen content. Furthermore, carbon monoxide could be present and replace oxygen in the blood. The victims will initially experience some light headedness due to the lack of oxygen. The victims may become unconscious and perhaps run the risk of dying as the oxygen content continues to drop.

1.2 Addressing Global Warming Issue for Smoke Detector

One global issue related to smoke detectors is the lack of widespread availability and use in developing countries. Smoke detectors are a crucial piece of equipment for spotting and telling locals of the presence of smoke, which can be a fire's first warning sign. Smoke detectors aren't widely available or inexpensive for most households in many poor nations, which increases the danger of fire-related events and fatalities. This global problem is a result of various reasons. The price of smoke detectors is a significant aspect. Smoke detectors can be expensive, especially ones with high-tech capabilities like carbon monoxide detection, which prevents many low-income homes in developing nations from purchasing them. Additionally, the restricted use of smoke detectors in some areas may be caused by a lack of understanding on the significance of those devices and other fire safety precautions in general.

1.3 Problem Statement

As we know, fire can be used for a variety of things. However, uncontrolled fire has the potential to cause both property damage and fatalities. Fires occurs in a building can create a huge amount of smoke. Excessive smoke inhalation is the main cause of fire deaths. National Fire Protection Association (NFPA) (2018) stated that most of that fire-related deaths cause by smoke inhalation rather than being burn. Any sort of fire, including those that start in combustible items such as trees, buildings or trash emits smoke that is made up of particles and chemicals from the incomplete burning of carbon-containing materials. Carbon monoxide, carbon dioxide, and particulates are present in every smoke (PM or soot).

Most of existed smoke detector use regular alkaline battery which need to replace the battery of the device often. Moreover, some of the existed smoke detector not able to inform the authorities about the location of fire. Thus this project aims to develop an IoT based smoke detector device using ESP8266, to monitor and detect if there are smoke which caused by fire. This device can inform certain authorities where the fire is located and can prevent false fire detection.

1.4 Project Objective

The main aim of this project is to propose a device that can detect smoke which is caused by fire. Specifically, the objectives are as follows:

a) To analyze the existing smoke detector device or system.

b) To design and develop an IoT system for the smart smoke detector using Esp8266 microcontroller powered by solar.

c) To evaluate the performance of the smoke detector device developed for this project.

1.5 Scope of Project

The scope of this project are as follows:

a) To use the Arduino IDE software to write a programme for an Esp8266 microcontroller to control the components in the device.

b) To use polycrystalline solar panel as the source of electricity.

c) To use a gas sensor to detect smoke.

d) To construct circuit using PROTEUS software which can display the output of circuit.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A smoke detector is a device that detects smoke and warns users of any potential hazard. It is an essential safety device that is commonly used in homes, businesses and other public places to protect against fire. A smoke detector's main function is to detect smoke particles in the air and trigger an alarm to alert occupants to a possible fire. Smoke detectors can be powered by batteries or can be linked directly into a building's electrical system. They can be put on walls or ceilings and come in a variety of sizes and forms. Smoke detectors are an essential part of any fire safety plan since they have been shown to be highly effective in reducing the number of fire-related injuries and fatalities.

2.2 An Overview of Previous Studies Related to Smoke Detection Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Over the years, many researchers have focused on smoke detection to lessen the harm caused by fires since smoke can alert individuals to fires much earlier than flames There have been numerous studies conducted on smoke detectors, exploring topics such as their effectiveness, reliability and placement. These studies have contributed to the development of new technologies and standards for smoke detectors and have helped to improve their overall effectiveness in detecting fires and reducing the number of fire-related injuries and fatalities.

2.2.1 Cigarette Smoke Detectors for Non-Smoking Areas in The Building

This research aims to create smoke detectors for cigarette smoke in non-smoking areas of the building. It refers to the waterfall model of the system development cycle and uses ESP8266 -12E as a control device and to transfer data into the internet via wireless connection [1]. The type of sensor used to detect smoke is Gas Sensor (MQ-2). Software used in this article is Arduino IDE to write and send arduino code to the microcontroller. A control box contains all electronic equipment and a sensor is installed in the space.

The usage of the MQ-2 gas sensor, ESP8266-12e and LINE API for validation ensured that the sensor and smoke detectors accurately detected the gas and smoke. To evaluate the capacity to produce smoke in the location and distance, 5 days were split into three stages of twice, each at a various time. A message was sent via LINE and the setting determined how long the alert messages would last after smoke was detected.

2.2.2 Design of Embedded Home Wi-Fi Smoke Alarm

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

This article discusses the development and popularisation of domestic Wi-Fi smoke alarms. It uses ESP8685 as a primary control chip and TCRT5000L reflective optical sensor. As for EPS8685, one of the key features is its low power consumption. The EPS8685 has a number of power-saving modes, such as a deep sleep mode, which can lower power consumption to as low as 20uA [2]. Sensor utilized in this study is the TCRT5000L sensor, an optical sensor used to sense the presence or absence of objects within a certain range. It is low cost and easy to use, but may not be suitable for applications that require high precision or accuracy. The wireless communication module ESP8266 is used as its inexpensive cost and easy to use. It is frequently implemented in tasks such as remote monitoring and control, sensor networks, and home automation, but may not be appropriatefor applications that need a lot of memory or great performance.

2.2.3 Innovative Fire Detection and Alarm System for Sustainable City Development

This study used an experimental design and construction process to create a low-cost artifact using an Arduino Nano board and a variety of sensors, including a MQ-2 sensor, an IR sensor, an LCD panel and a buzzer. The power supply unit used is the Arduino Nano, which is a compact and low-cost microcontroller board designed on the ATmega328P microcontroller chip [3]. The project used an MQ-2 gas sensor and an IR flame sensor, without a temperature sensor, as a smoke and flame detector. Process of this project is the green LED turns on when the device is first turned on, signaling less smoke in the area. The red LED flashes and the green LED goes out, signaling substantial smoke, if it rises beyond 400. The buzzer sounds and the display "fire detected" is shown on the LCD panel if a fire is gets near to the IR flame sensor.

2.2.4 New Design and Improved Performance for Smoke Detector

Smoke detectors may be classified into two categories, photoelectric and ionization.. In this article the research uses a photoelectric smoke detector which employs both a light source and a photosensor to detect smoke. Photoelectric smoke detectors may not be as sensitive to fast-burning, flame fires, but they are often more responsive to slow-burning, smouldering fires [4]. Most detectors rely on light scattering to operate, however this method employs a fundamentally new inner smoke chamber design with less restriction on the flow of smoke particles and greater performance. The sensor uses software to detect internal status, compensating drift, and transient signal rejection. In order to prevent false alarms and improve performance, moisture, tiny insects, dust, and other big airborne particles are removed. Before removing or cleaning the dirt off the sensor, the microprocessor provides signals that are split for different degrees of sensitivity.

2.2.5 Quick Fire Sensing Model and Extinguishing by Using an Arduino Based Fire Protection Device

Multisensory systems are reliable and capable of avoiding false alarms. This proposed system detects fire using sensors for smoke/gas, flame, and temperature. The owner will be informed of the malfunctioning sensor by this system, which will be able to identify it. The system features a flame, smoke and temperature sensor, fire extinguisher with siren, a transformer, a servo and single-phase induction motor, relay and microcontroller [5]. Three different kinds of sensors are used by the system which is a flame sensor, a temperature sensor and a smoke detector. MQ2 sensor which has strong sensitivity response to flammable gases is utilised for smoke and gas detection purposes. The microcontroller is an Arduino Uno, which interprets the sensor data and sends the outcome to the extinguishing system.

2.2.6 Monitoring of Smoke in the Room with the Fuzzy Method Based on Internet of Thing (IoT)

This study is designing and implementing a device to detect the temperature and the existence of cigarette smoke using the DS18B20 temperature sensor and the MQ-135 smoke sensor. The Esp8266 Wi-Fi Module is an extra component for Arduino, the display acts as a screen or display medium for the data acquired, the motor driver controls the speed or slowness of a rotating fan, and the fan eliminates heat in the area. When the MQ-135 Sensor and DB18B20 Sensor detect elements or smoke and associated temperatures, the device starts to operate. The LCD will display the smoke, temperature and defuzzification value which activated a fan to suck the smoke and air in the room if an object is detected. However, this article stated that this project have a weakness which is this device can still be enhanced by including extra precise sensors and fans [6]. The response from the Wi-Fi module is still

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

delayed and not accurate due to bad network. To solve this problem, a good network is needed.

2.2.7 Smoke Alarm-Analyzer and Site Evacuation System

This proposal is an improved version of the widely used smoke alarm systems in buildings. It uses a conventional smoke detector to sense smoke and in case of malfunction, a backup power supply is offered. The hardware part consists of a microcontroller, an opamp, a launchpad, a beaglebone, a wireless development tool, MQ-2 gas sensor and web camera. The software part consists of CCS, energia, openCV and python. The smoke detecting circuit uses a 16-bit MSP430F2012 microcontroller with a 128B RAM and 2KB Flash memory.

Then the presence of smoke is detect by using infrared diode and infrared receiver. The IR receiver current is amplified by an operational amplifier (TLV2780) and sampled by the MSP430's ADC. The gas sensor is connected to the launchpad through the analog input pins, which is then analyze by the built-in ADCs. The advantages of this project is the smoke detector is an improvement over commercial smoke detectors, incorporating a smoke analyzer. It works even during power unavailability, although there has been no field testing to evaluate real-time performance. [7].

2.2.8 Intelligent Fire Alarm System Based on MCU

This study chooses a single-chip microcontroller from the 51 series as the main processor. To prevent false alarms and omissions, the detecting method combines temperature, smoke concentration and flame. The following sensors are chosen for information detection which is a DS18B20 sensor, a MQ-2 sensor, an IR flame sensor, an ADC, a LCD, and other components [8]. The STM89C52 microcontroller has been used in this project as it is commonly used in industrial control, automotive, and consumer electronics applications. It features a high-performance 8-bit CPU, on-chip RAM and Flash memory, a range of peripherals, and security features. The microcontroller is a easy programming as it can be programmed using various programming languages and can be programmed in-system, eliminating the need for external programming equipment.

2.2.9 A Fire Prevention/Monitoring Smart System

This article explores the use of solar panels to power a design a system that can monitor and regulate dangerous buildings or areas that are on fire in real time, alert authorities and detect flames, smoke and gas emissions. The MQ-6 sensor is a key component in the performance of the alarm programme and has six pins, four of which are used for receiving signals and the other two for the heating element [9]. The system's six subsystems include a dedicated website, cloud, PV, gas, temperature, and wind sensors, as well as people detection and identification. A storage battery is needed to run continuously and a charge controller is needed to transfer the charge appropriately between the load and the battery. The TMP36 sensor is used to measure temperature and the monocrystalline PV panels are used as its power source. A voltage and current sensor is required to control the PV power supply. The MQ5 sensor is used to detect gas and the highly sensitive MQ-136 sensor is used to find the highly poisonous and combustible H2S gas.

2.2.10 Automatic Circuit Breaker Design Based on Fire Identification

This study focuses on developing microcontroller-based fire-prevention devices that deliver brief messages to pre-registered phone and turn off the electricity depending on detection of smoke and fire. The components includes an Arduino Uno, MQ-2 sensor, fire sensor, relay, buzzer and LCD. The Arduino Uno microcontroller processes the data that the MQ2 sensor generates when a gas cylinder leaks into an output that is delivered to other components. Infrared fire sensors are effective for detecting light produced on by the absence of fire and transform digital impulses into data output through an Arduino [10]. The fire interface uses SIM900A, which sends brief messages when there is a fire occurs, to remotely notify users of the presence of gas leaks close to gas tanks.

2.2.11 Low Power Wireless Smoke Alarm System in Home Fires

This study focuses on developing a sensor system that can detect fires in household settings. It uses a numbers of sensors to differentiate between various forms of smoke, preventing false warnings and issuing situational warnings. The hardware and software have been optimised to reduce power consumption, offering a long period of autonomy of almost five years [11]. The device includes a microcontroller, a short-range radio transceiver, a battery, temperature sensors, CO sensors, smoke sensors, capacitive touch buttons, red LEDs, and buzzers. The motherboard is the essential component of the sensing device because it collects all temperature, gas and smoke measurements and deliver them as alarms to the control center. The PIC24FJ128GA306 from Microchip was selected as the microcontroller. There is a single AA lithium-ion with 1600 mAh battery used as the power source which can lasts around 5 years.

2.2.12 Design and Implementation of an Automatic Gas and Smoke Detector

This study proposed an improved design that reduces the danger of gas-related fires and harmful emissions by using an embedded system and a gas and smoke sensor. The device which makes use of the intelligent MQ2 gas sensor, was created and tested using Proteus programming software [12]. When a gas leak or smoke is detected, a buzzer will ring an alarm and a solenoid valve will automatically shut off the cylinder valve. The power supply is made to supply the microcontroller and the MQ2 sensor with +12V, -12V, and +5V. The microcontroller receives analogue signals from the temperature and MQ2 gas sensors, which are then converted to digital signals by the embedded ADC. The ventilation system is set up to begin if the outside temperature is more than 40 degrees and stop when it reaches 30 degrees or lower.

2.2.13 Smart Cigarettes Smoke Detection System and Alert via IoT Cloud

This article introduces a smart cigarette smoke detection system using IoT technologies on the Blynk application. The system is intended to assist authorities in enforcing the prohibition on smoking in public places, particularly in no-smoking areas like restaurants, workplaces, and other such places [13]. The input used is a MQ2 sensor and a DHT sensor. The Arduino Uno was used as the system's brain, and four output components were employed. When a smoke is detected, the MQ2 smoke sensor detects it and its output increases. Proteus and Arduino software were used to develop the cigarette smoke detector, with Blynk Cloud providing notifications and emails when cigarette smoke is detected. The sensor uses a digital pin to generate an output interfaced with LED, buzzer, DC motor, and LCD display.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2.2.14 IOT Based Surveillance System for Fire and Smoke Detection

This study presents a prototype for outdoor fire detection based on sensors and the Internet of Things (IoT). The Arduino UNO development board, which is made up of an obstacle detection and free route navigation system, a gas sensor (MQ2), a temperature sensor, and a fire flame sensor, controls the fire fighting system [14]. Additionally, it includes a water tank and a system for spraying water on the flames. Maxim integrated DS18B20 as temperature sensors are used to measure the temperature of chemical solutions, mines, and soil. The flame sensor makes use of an LM393 comparator chip. MQ2 gas sensors are capable of detecting and identifying a wide range of gases. The ESP8266 module is a cheap, easy-to-use gadget that can act as both a hotspot and a station. The C and C++ programming languages are used to create the all-in-one IoT development environment known as Arduino IDE.

2.2.15 Development of a Solar-Powered Wildfire Detector System for Remote Location with Xbee and GSM Capabilities

This project develops an XBee/Zigbee and GSM as communication method for a wildfire detector system. Ni-MH battery packs and solar panels are used to power the fire detectors. To save energy and lower the wildfire detector's cost and maintenance, all optical detection has been removed. A 10-W solar panel, a charge controller, and a battery pack are connected to supply power. Low-cost variations of the KY-026 flame sensor are used for the infrared and CO sensors. An MQ-7 Carbon Monoxide Sensor is used for smoke detection. The system is powered by 8 Ni-MH Energizer batteries connected in series, each rated at 1.5V and 2300mAh/Cell, with a nominal voltage of 12V and a capacity of 2.3-Ah, or 27.6Wh. For PV modules, monocrystalline solar panels are used due to their internal losses being lower than those of polycrystalline panels [15].

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2.2.16 Wireless Smoke Detection System

The proposed system involves a smoke detector that detects smoke and transmits a low-voltage signal to every other smoke detector nearby. The other smoke detectors then transmit a tone to notify nearby homeowners that one of the detectors has detected smoke. No external connections are needed because they run on batteries. The smoke detector has a built-in relay, which is activated when smoke is detected. The MC145010 is a very-low-power analogue and digital circuitry smoke detector component that detects scattered light from tiny smoke particles and activates the relay when it detects scattered light [16]. The transistor that powers the relay and LED will turn on after all of the signals are in sync. As the relay is turned on, the alarm goes off.

2.2.17 Solar Powered Wireless Forest Fire Detection

The proposed system is made with a smart sensor that operates on solar power and a GSM module that connects to the GSM network to transmit the signal of the detected fire alarm. The components are attached to the output of the Arduino UNO and include the smoke sensor, temperature sensor, toxic gas sensor, and flame sensor. The GSM and GPS module, which is powered by a 12V solar panel, is attached to the Arduino UNO. The GSM module transmits the signals and measurements collected by these sensors to the control center in order to automatically evaluate and combine sensor data and find the existence of fire or smoke [17]. The main advantage of installing fire detection and alarm systems is the benefit of early warning, which can help to prevent damage and the project's low cost. However, due to technical limitations, the system may occasionally fail to deliver satisfactory results, and it only assists in detecting fires but does not have features to extinguish them.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2.2.18 Smoke Detector Alarm

The suggested system utilises a smoke detector to transmit a low voltage signal to every other smoke detector nearby, which causes them to sound an alarm. There is no requirement for a base because the transmitter and receiver are integrated into a single unit. The system is affordable, compact, easily extensible, straightforward to install, and composed of replaceable parts. The fundamental parts are an Arduino Uno, a MQ2 sensor, an LED light, a buzzer, and a power source (9V battery). The Arduino Uno is a microcontroller board based on the ATmega328 that is powered by a battery or an AC-to-

DC adapter and connected to a computer using a USB cable [18]. The MQ2 sensor module was used to detect smoke and other combustible gases.

2.2.19 IoT Based Smoke Detection with Air Temperature and Air Humidity; High Accuracy with Machine Language

In this article, an IoT is in charge of operating this smoke detection system, and a Wi-Fi shield acts as a link to connect the devices to the network. The MQ-5 gas sensor is used to determine whether harmful gasses are present in the environment [19]. The Arduino mega is chosen to act as the controller of the device system and the ESP8266 is used to connect the device to the network. When a gasses is identified, a buzzer will activate and the words "Leakage detected" will appear on an LCD display. The sensors are randomly positioned to gather data on the surrounding environment. There are numerous areas where these installations can be found.

2.2.20 Design of Fire Alarm System with Automatic Position

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This paper presents a fire detector that uses a CC2530 chip. The sensing part uses photoelectric sensor to collect signals, while the temperature and carbon monoxide parts use DS18B20 and MQ-7 sensors. The CC2530 is chosen as the external storage chip to process the related data after receiving the collected data through the filter and amplification circuit. The smoke-sensing circuit uses a photoelectric induction mechanism based on infrared radiation [20]. After the signal has been amplified by an LM324, a band-pass filter circuit is added to it and a LM324 is used for auxiliary amplification. The circuits for the temperature sensor and carbon monoxide detector employ the widely known DS18B20 and MQ-7 chips. It is connected to the ZigBee chip for instantaneous early temperature and carbon monoxide alarm.

2.3 Comparison of previous work

Table 2.1 shows that the comparison of previous work from various method.

Table 2.1 Comparison of previous work from various method.

No.	Author(s)	Title	Functional	Advantages/Disadvantages
1	Sancha Panpaeng, Phattharamon Phanpeang, Ekkasit Metharak. (2018)	Cigarette Smoke Detectors for Non-Smoking Areas in the Building.	• To develop and design cigarette smoke detectors in various places.	Advantage • Can detect smoke in a brief time and can send a message. • Sensor will resets to prevent redundant data transmission.
2	Changsong Zhao. (2022)	Design of Embedded Home Wi-Fi Smoke Alarm.	• Designed to solve network communication, monitoring methods, installation and maintenance issues.	Advantage • Fast, easy to use and highly accurate.

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3	Amevi Acakpovi, Douglas Tetteh Ayitey, Edward Nagai Adjaloko. (2021)	Innovative Fire Detection and Alarm System for Sustainable City Development.	• Capable of early smoke detection, trigger an alarm and displayed status of the system on an LCD display.	Advantage • Low-cost, reliable equipment was used to create a fire alarm system.
4	Drd. Ing. Aurelian Costea, Prof.Univ.Dr.Ing. Paul Şchiopu. (2018)	New Design and Improved Performance for Smoke Detector	• Uses a simpler inner smoke chamber architecture with less smoke particles flow restriction and more performance.	Advantage • Have a improved performance sensor.
5	Md. Rawshan Habib, Naureen Khan, Koushik Ahmed, Mahbubur Rahman Kiran, A.K.M.	Quick Fire Sensing Model and Extinguishing by Using an Arduino Based Fire Protection Device.	• Sensors have been inserted twice to increase system reliability.	Advantages • The proposed system is economical due to self-made transducers. Disadvantage

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	Asif, Mohaiminul Islam Bhuiyan, and Omar Farrok. (2019)		• Has both water and fire extinguishers to quickly extinguish a fire.	• the limited range of the fire alarm
6	Iwan Fitrianto Rahmad, Evri Ekadiansyah, Budi Triandi, Ratih Puspasari, Dwi Ardiyanti. (2021)	Monitoring of Smoke in the Room with the Fuzzy Method Based on The Internet of Things (IoT).	• Develop and implement a device that can detect the temperature and presence of cigarette smoke.	Advantage • The smoke is filtered through the air neutralizer. Disadvantage • A fast network is needed to improve the speed of the WiFi module's response.
7	Prashant Shrivastava, Edwin Basil Mathew, Ayush Yadav, Parijat P. Bezbaruah, Malaya D. Borah (2014)	Smoke Alarm-Analyzer and Site Evacuation System (S.A.A.N.S).	• To develop a new alarm and evacuation system. • to make a device much more effective to assist people in evacuation.	Advantage • This system is inexpensive and efficient. • Low power consuming system and very economical.

				Disadvantage • No field testing to evaluate real-time performance
8	Sheng Zeng, Wen Xiao, Xusheng Hu, Guanhongwei Teng, Hong Gao. (2020)	Intelligent Fire Alarm System Based on MCU	• To design an alarm system that can collect data from environment and warns the user about fire hazard.	Advantage • Optimises the use of energy
9	Ashraf Zaher, Ahmed Al-Faqsh, Hasan Abdulredha, Husain Al-Qudaihi, Mohamad Toaube. (2021)	A Fire Prevention/Monitoring Smart System.	• Designed to perform the multitasks detection and monitor gas leaks, smoke, and flames.	Advantage • Capable of providing superior results. • The design is compact and easy to install
10	Nora Fitriawati, Lena, Dina Fitria Murad, Siwi Piranti Rahayu. (2020)	Automatic Circuit Breaker Design Based on Fire	• To stop fires caused by electrical short circuits and gas leaks.	Advantage • Can reduces the flames or sparks into a gaseous substance.

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		Identification (Smoke and Fire).	• To create a device that can turn off electricity automatically when it detects fire	
11	Juan Aponte Luis, Juan Antonio Gómez Galán, Javier Alcina Espigado. (2015)	Low Power Wireless Smoke Alarm System in Home Fires.	• To develop a device allows deploying a wireless network where the data gathered are sent to a base station.	Advantage • Low cost and compact design
12	Yasir Uthman, Dudu Watsai, Daniel Nwude, Grace. Oletu. (2022)	Design and Implementation of an Automatic Gas and Smoke Detector.	• An improved design that will reduce the danger of gas-related fires and environmental pollutions.	Advantage • can block the inflow of gas by equip a solenoid valve. • Simple and is easily adaptable to other fire suppression systems.
13	Zainal Hisham Che Soh, Mohammad Afwan Bin Mohd Daud,	Smart Cigarettes Smoke Detection System and Alert	• Designed to assist law enforcement in enforcing the	Advantage

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	Mohd Hanapiah bin Abdullah, Muhamad Syazwan Mohamad Sarudin, Rosheila Binti Darus, Kamarulazhar Daud. (2021)	via IoT Cloud.	law of no smoking in public area. • To monitor the activity of smoking in the non-smoking zone.	• It was efficient at reducing smoking and encouraging smokers to follow the law.
14	Dr.Nandita Tripathi, Dr. D. Obulesu, Dr. A S S Murugan, Dr. Varsha Mittal, Ravindra Babu B, Dr. Sandeep Sharma. (2022)	IOT Based Surveillance System for Fire and Smoke Detection.	• Design to helping firefighting forces put out fires. • To develop a low-cost prototype for the Internet of Things (IoT) for smoke and fire detection.	Advantage • Have new elements that increase the accuracy of detecting the intensity and types of gases present. • A low cost and easy to use system.
15	Brallan Alvares, Eric Perez,	Development of a Solar-Powered Wildfire Detector System	• To develops an XBee/Zigbee and GSM Many-to-One	Advantage • Low power consumption.

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	Joshua Trigueros, Jerry Ho, Eric Ly, Ha Thu Le. (2021)	for Remote Locations with XBee and GSM Capabilities.	communication technique for a wildfire detector system.	• A self sustainable and long lasting device. • Compact and effective.
16	Othman O. Khalifa, A. Albagul, Sheroz Khan, Mohd Rafiqul Islam, Noruzaihan Mod Usman. (2008)	Wireless Smoke Detection System.	• To create a system that is cost-effective, simple installation, replaceable parts, easily extendable design.	Advantage • Low cost design and simple to install.
17	Aparna Gosavi, Aniket Pawar, Supriya Bhosale, Vaibhav Pokharkar. (2021)	Solar Powered Wireless Forest Fire Detection.	• To design a system which operate on solar power for its operation and a GSM module.	Advantage • Had good performance in terms of a better rate of fire detection and a lower rate of false alarms. • Low cost efficient and easy to install

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				Disadvantage • This system only help to detect fire and unable to extinguish fire. • The system may not produce satisfactory results due to technical errors.
18	M. Pavan Kumar, R.Raja, R . Akhil Ganesh, K .Venkata Reddy, V. Sai Bhargav. (2020)	Smoke Detector Alarm.	• To design a microcontroller-based smoke alarm to detect smoke and prompt safety measures.	Advantage • Low cost and easy to get.
19	Chen Xinhao, Wang Siqi, Han Chenghao. (2020)	Design of Fire Alarm System with Automatic Position	• To design a fire alarm system with automatic positioning function.	Advantage • Improved accuracy of fire alarm. • Effectively reduce the casualties during the fire.

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Based on the comparison table as shown in Table 2.1, the important thing of the smoke detector device is the smoke sensing element, the microcontroller, the alarm system and interconnectivity. Most of the previous studies were using MQ-2 sensor as the input sensor. Some of the past studies also use flame sensor or even temperature sensor as their additional input. For IoT system, GSM and Blynk application are commonly used as an output of the smoke detector device. For this project, MQ-2 sensor will be chosen due to its wide range of sensing detection and it has a fast response time. Blynk application will be used since it is a user-friendly software, and Arduino uno will be used as the microcontroller.

2.4 Summary

Based on the previous work, the implementation of an effective system of the smoke detector will give a big impact for the user of this system and may save many life. By implementing the uses of internet of thing (IoT) it can greatly improve the fire detection in the next technology which effective to inform the user about the location of the fire hazard. Data collected by the smoke detector will be transfer to the user through the network technologies. Other than that, this device provides a reliable assistance for monitoring and early identification of fire risks, which may help protect lives and property. For the next chapter 3 will discuss about the methodology of the project and components used based on the study of previous result. The hardware and the software also will be included in the next topic.

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CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will discuss about the method and procedure used to develop this project. This is a crucial chapter that will explain the used of hardware and software to accomplish the objective of this project. The use of proteus 8 software and Arduino IDE will show how the device operate by designing the simulation.

3.2 Selecting and Evaluating Tools for a Sustainable Development

The development of an IoT based smoke detector powered by solar energy features makes a variety of contributions to sustainable development. The technology and tools that will be used to gather and analyze data need to be properly chosen and assessed. In doing so, it is necessary to evaluate the precision and dependability of sensors designed specifically for smoke detection, the compatibility of IoT hardware and software and the project's potential environmental effects. By utilizing solar energy, the device reduces reliance on non-renewable energy sources and lowering greenhouse gas emissions while optimize performance, minimize resource consumption, eliminate hazardous waste and offer long-term cost savings by eliminating battery replacements. Additionally, social and economic implications should be considered, including the advantages and disadvantages of integrating solar power and IoT connectivity. By verifying smoke detector efficiency and performance through field tests and life cycle analyses, it can promote sustainability and reliable detection capabilities. A successful project can be achieved by a careful selection and assessment tool and technology.

3.3 Methodology

This project presents an IoT based smoke detector device using Arduino, to monitor and detect if there are smoke which caused by fire. The essence of the project is to develop device that can detect smoke and flame to prevent fire. The device will be able to store data output received from sensors. The method and procedure used in this project is experimental, which utilizes empirical modelling and statistical approach.

3.4 Project Architecture

Flowcharts are visual representations of intricate processes or algorithms which using symbols and arrows to illustrate the progression of decisions or steps in a sequence. They make complex procedures simpler to comprehend and interpret, opening them up to a wider range of audiences. The flowchart aids to get a better understanding about the flow of the project. Figure 3.1 shows the implementation flowchart of the project.

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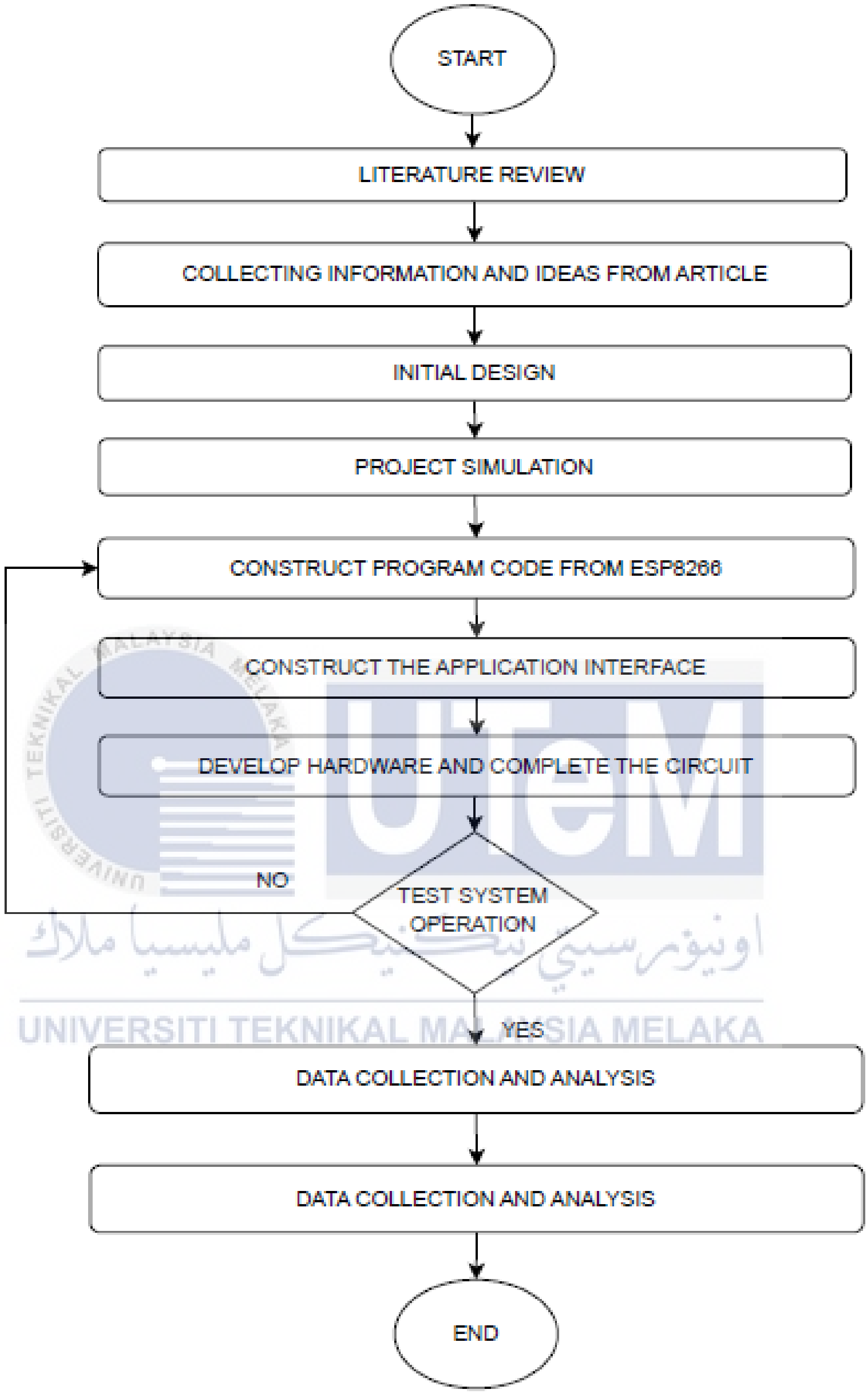

Figure 3.1 Project Implementation Flowchart

3.4.1 Project System Flowchart

The aim of this project system flowchart as shown in Figure 3.2 is to visualize how the system operate. First step of the operation is the microcontroller will initialize system and show display on the LCD. When gas or smoke is detected by the sensor the LCD will display the concentration value. The use of a buzzer and LED is to alert the people around that there is a gas leaking that may lead to fire. While ESP8266 will send a notification to the user by sending a message “ smoke detected ! fire occur. evacuate immediately !!” to their smartphone.

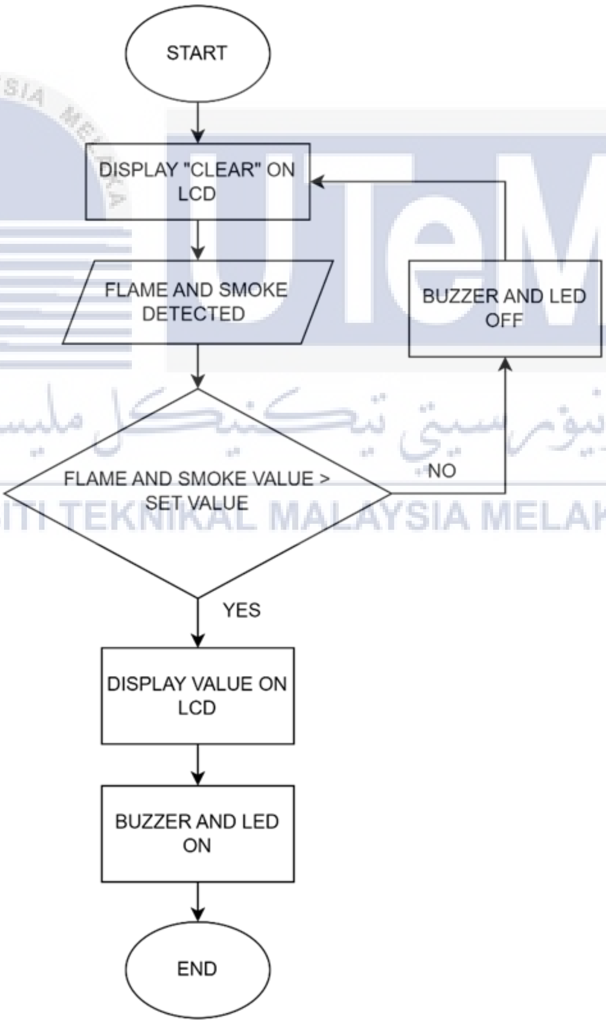

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Figure 3.2 Software Flowchart

3.5 System Architecture

IoT-based smoke detectors are made up of a number of functional and connectivity-related components. In order to detect smoke, the microcontroller evaluates sensor data, examines trends, and runs algorithms. The microcontroller will control all the components in order to operate the device Figure 3.3 presents a block diagram of this project.

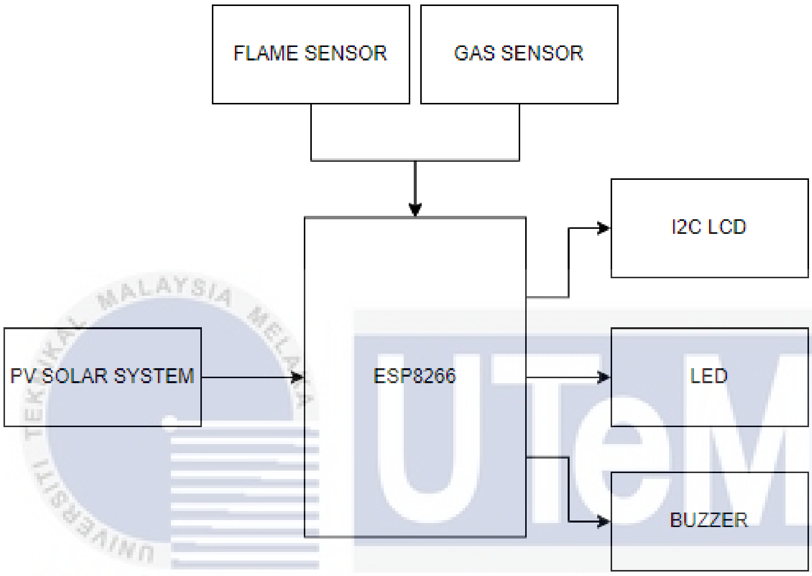

Figure 3.3 A block diagram of the project

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a) Based on Figure 3.3, the microcontroller will receive 5V from the supply and control all the components to operate the device.

b) At the initial state when there is no smoke detected, the LCD will display " CLEAR" to inform that the environment is safe.

c) When the smoke and flame sensor start to detect any smoke, the LCD display will display the concentration value.

d) Then the buzzer rings to inform people in that area that there is a fire nearby.

e) The ESP8266 will send a notification to the authorities to inform them about the situation.

3.6 Hardware Components

Hardware plays a crucial role in any project, particularly in the field of technology and engineering. Hardware is responsible for implementing the core functionalities of a project. Without hardware, the project would simply be an idea or concept. While software plays a significant role in controlling and programming the simulation, hardware is required to transform theoretical concepts and ideas into attainable, practical implementations. It enables practical testing, validation, and demonstration of the project's features and performance.

3.6.1 MQ-2 Gas Sensor

The MQ2 gas sensor as shown in Figure 3.5 is a sensor that can detect various types of smoke and flammable gases in the air. LPG, propane, methane, hydrogen, alcohol, and other flammable gases are among the gases that the MQ2 sensor is sensitive to. It is capable of detecting airborne quantities of these gases. MQ2 sensor module includes analog output, power supply and digital output pins which can trigger alarms or digital signals when gas concentration thresholds are reached.

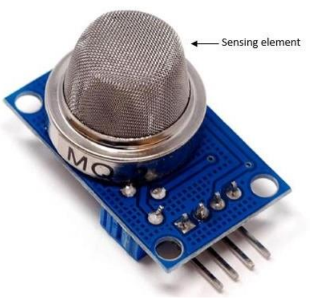

Figure 3.4 MQ-2 Gas Sensor

3.6.2 KY-026 Flame Sensor

The KY-026 flame sensor as shown in Figure 3.6 is a sensor that can detect flames by detecting infrared radiation, with a wavelength range of 760-1100 nm. It can be adjusted using a potentiometer, allowing precise control of flame intensities and distances. The module has three pins for digital output and power supply, making it easy to connect to electronic circuits. It has a signal processing circuitry built into the device that helps to filter out noise and inaccurate detections to provide a stable and reliable performance.

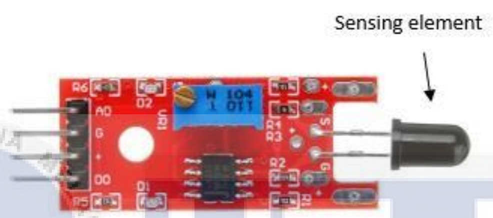

Figure 3.5 KY-026 Flame Sensor

3.6.3 Light Emitting Diode (LED)

The use of LED in this project as shown in Figure 3.7 is to act as output to inform whether the device detects or not a harmful gases or smoke which can lead to a fire. LEDs are energy-efficient, compact, long-lasting and providing instant illumination without warm-up time.

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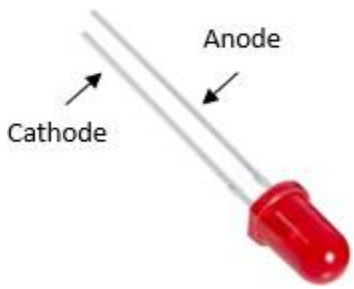

Figure 3.6 LED

3.6.4 I2C Liquid Crystal Display (LCD)

The I2C Liquid Crystal Display as shown in Figure 3.8 is a flat-panel display with two rows and 16 characters per row, allowing it to display a total of 32 characters. In this project, the result of the sensor will be display on LCD.

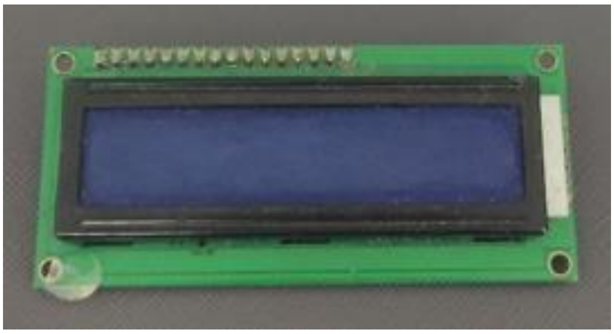

Figure 3.7 LCD

3.6.5 Solar Panel

In this project polycrystalline solar panel is used due to the performance in high temperature and variety of weather conditions. Polycrystalline solar panels as shown in Figure 3.9 are generally more cost effective option than other solar panel. Polycrystalline solar panels are suitable for areas with a variety of weather patterns since they produce a substantial amount of electricity from sunshine, making them suitable for residential and commercial uses in low-light situations.

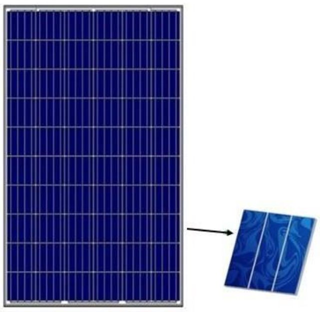

Figure 3.8 Polycrystalline solar panel

3.6.6 CN3791 Charge Controller

A charge controller as shown in Figure 3.10 is an important component of solar power systems that controls and manages how batteries are charged by solar panels. A charge controller's primary function is to keep the batteries from being overcharged and over discharged, extending both their lifespan and the solar system's effectiveness.

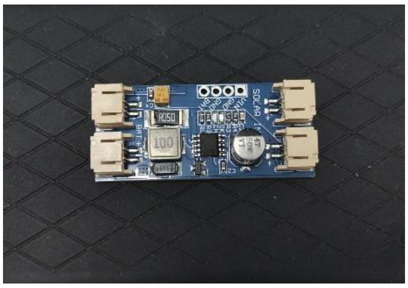

Figure 3.9 Charge controller

3.6.7 ESP8266

The ESP8266 as shown in Figure 3.11 is a 32-bit MCU with Wi-Fi capabilities and a number of peripherals that provides wireless connectivity for microcontroller-based projects. The Arduino IDE or other platforms can be used to code it and it supports IEEE 802.11 b/g/n standards. Due to its inexpensive price, small size, and Wi-Fi connectivity, the ESP8266 is frequently utilised in IoT applications and is ideal for home automation, environmental monitoring, and remote control systems.

Figure 3.10 ESP8266

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3.6.8 Lithium-Ion Battery

A lithium-ion battery as shown in Figure 3.12 is a rechargeable battery that is commonly used in various types of electronic devices such as smartphones and portable devices. A lithium-ion battery offers higher energy density than other rechargeable batteries. A lithium-ion battery also has a longer life cycle of about 5 years compared to a Ni-Mh battery. This battery can last to 10 years which is an average lifespan of smoke detector.

Figure 3.11 Lithium-ion battery

3.6.9 MT3608 DC-DC Boost Converter

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A DC-DC boost converter is an electrical circuit that steps up or boosts a low input voltage to a greater output value. This sort of converter is widely employed in a variety of electronic devices and systems where the input voltage is less than the desired output voltage.

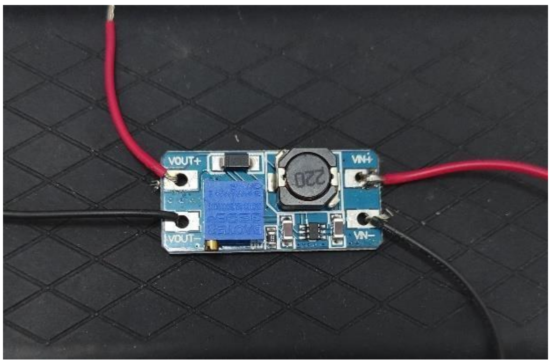

Figure 3.12 MT3608 DC-DC boost converter

3.6.10 LM2596 DC-DC Step Down Converter

A DC-DC step-down converter, often known as a buck converter, is an electrical circuit that converts a greater input voltage to a lower output voltage. Buck converters are commonly used in electrical systems and devices that require a reliable lower voltage.

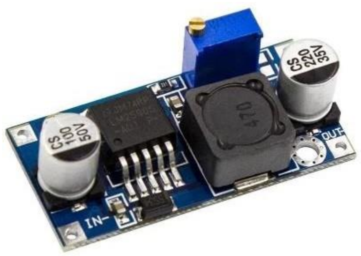

Figure 3.13 LM2596 DC-DC step down converter

3.6.11 Buzzer

A buzzer is a basic electronic gadget that emits sound when electricity flows through it. Buzzer devices are extensively utilised for a variety of applications, from basic signaling to more intricate ones. These buzzers produce sound by the use of the piezoelectric effect. When an electric field is produced, a piezoelectric material within the buzzer deforms, causing vibrations and sound waves.

Figure 3.14 Buzzer

3.7 Software Components

Software is in responsible for implementing the necessary functionality and features of a project into practice, including those that do particular tasks, process data, interact with external systems, and provide the desired results. It offers the opportunity to build workflows, configure settings, and modify functionalities as needed. The use of software improves project automation and control which resulting in less manual work and better efficiency.

3.7.1 Proteus 8

Proteus 8 is an electronic design automation (EDA) software that aids in developing and validating electronic projects. It features a user-friendly schematic capture module that allow user to design electrical circuit using a vast library of components and also supports Arduino development boards. Proteus 8 also allows for virtual prototype creation, real-time simulation of microcontrollers, sensors and actuators which making it useful for testing and debugging embedded systems.

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3.7.2 Arduino IDE

The Arduino IDE (Integrated Development Environment) is a user-friendly software programme for programming Arduino boards with a set of tools to develop, compile, and upload code to Arduino microcontrollers. The Arduino IDE offers a code editor, Board Manager, and Serial Monitor. It enables real-time data exchange, debugging, and writing, building, and uploading of code. Additionally, Arduino is compatible with Proteus because it can simulate Proteus' circuit simulation.

3.8 Gantt Chart and Key Milestones

Table 3.1 shows the tasks or activities which have been planned towards achieving the goals of BDP 1 and BDP 2.

Table 3.1 Gantt chart of the project

No.	Task	PSM1														PSM2													
	Weeks	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	Work on the Software/Hardware																												
2	Project Title Conformation and Registeration																												
3	Briefing with Supervisor																												
4	Study the Project Background																												
5	Drafting Chapter 1: Introduction																												
6	Task progress evaluation 1																												
7	Drafting Chapter 2: Literature Review																												
8	Table of Summary Literature Review																												
9	Drafting Chapter 3: Methodology																												
10	Work on the Software/Hardware																												
11	First Draft submission to Supervisor																												
12	Task progress evaluation 2																												
13	Submisiion Report to the Panel																												
14	Presentation of BDP1																												
15	Drafting Chapter 4: Analyse Data and Result																												
16	Data Analyse and Result																												
17	Record the Result																												
18	Drafting Chapter 5: Conclusion and Recommendation																												
19	Compiling Chapter 4 and Chapter 5																												
20	Submit Latest Report to Supervisor																												
21	Finalizze the Report																												
22	Presentation of BDP2																												

Figure 3.12, on the other hand, shows a key milestone of the project as a reference that helps the process of completing the project in more organized manner.

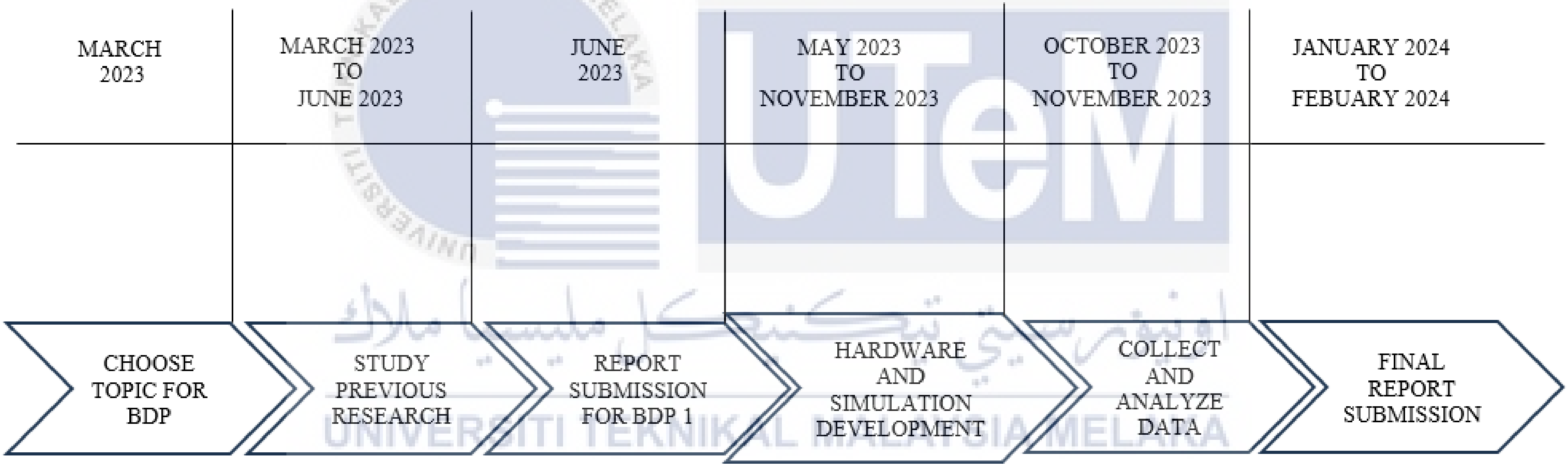

Figure 3.15 Key Milestones of the Project

3.9 Summary

As conclusion, based on this chapter the project design process and the materials to be utilized have been laid out. This chapter provides flow chart of the project to visualize how the whole process will work. This also include the flow chart of the software simulation to show how the project will operate. Due to the way the circuits work, the value of some components may vary. For the next chapter 4, the design and the preliminary result of the project will be discussed.

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CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the troubleshooting process and results obtained based on the data of the output of the project. The expect result is focusing on two parts which are the electric power produced by the standalone PV solar system and also sensitivity and the efficiency of the sensors in this smart smoke detector. The tabulated project result will be analyzed and explained in this chapter.

Based on the research carried out in Chapter 2, the project prototype has been created using all of the selected components and equipment. Based on the calculations performed in Chapter 3, the components that were employed were chosen. Additionally, the selected hardware for the smart smoke detector and standalone PV solar system has been constructed in accordance with the circuit design simulation in Chapter 3. All the software and tools stated in Chapter 3 are used during the project's design, simulation, assembly and troubleshooting process. To get the desired result, the system coding is tested and modified several times.

4.2 Prototype Development

This project involves two connected systems: a smart smoke detector and a standalone photovoltaic solar system.

In this project, Firstly, the components used for the standalone PV solar systems are a polycrystalline PV solar panel, CN3791 charge controllers, 3.7 V 18650 Li-ion batteries, a MT3608 DC-DC boost converter, and LM2596 DC-DC step down converter module. The system has been developed by connecting the solar panel to the DC-DC step down converter input port to decrease the voltage of the solar panel from 18V to 10V. Then the output port of DC-DC step down converter is connected to the CN3791 charge controller which is used to charge a three cells of a Li-ion battery and protect the battery from overcharging or undercharging. Next, the charging port of CN3791 is attached to the battery terminal. The 18650 Li-ion batteries are used as the battery bank for standalone solar systems. The output port of the charge controllers is connected to the DC-DC boost converter module, which is used to increase the voltage to power the ESP8266 microcontrollers. The standalone PV solar systems is shown in Figure 4.1.

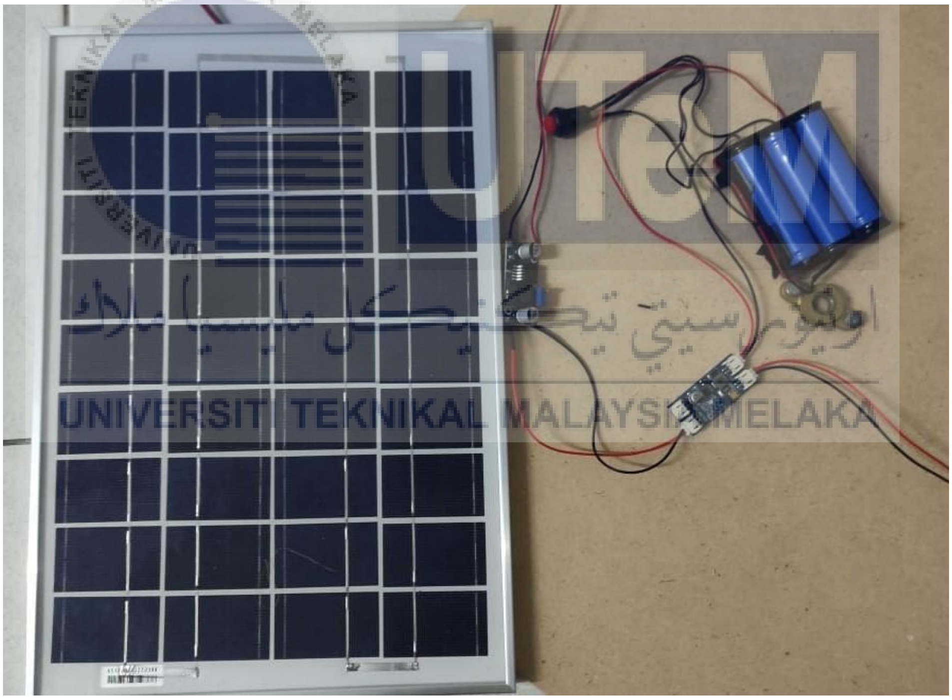
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Figure 4.1 Standalone PV Solar Systems

In addition , the development of the smart smoke detector consist of several components including a NodeMCU ESP8266, a KY-026 flame sensor, a MQ-2 gas sensor, an I2C LCD display, an LED, and a buzzer. Following to the circuit design, the flame sensor, gas sensor, I2C LCD display, LED, and buzzer are connected to the pins of the ESP8266.

The Arduino IDE software is used to create the programme, which is uploaded into the ESP8266 microcontroller. Afterwards, the DC-DC converter module is connected to the ESP8266's Vin pin, combining the standalone PV solar panel system with the smoke detection device.

To prevent the circuit from blowing up and damaging the hardware, precautions are taken to make sure that the connections, especially the components' terminals are made appropriately. The completed prototype of the project is shown in Figure 4.2.


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Figure 4.2 Complete project prototype

4.3 Project Testing Results

Experiments were conducted for two day on 4/1/2024 until 5/1/2024 and three days in a row from 8/1/2024 until 10/1/2024 as part of the data collection method to evaluate the system's functionality and acquire more accurate data. Moreover, the data collection procedure is conducted every 30 minutes for four hours a day, from 11 a.m. to 3 p.m. The data is collected during peak sun hours. This procedure has been performed in order to ensure that the solar panel will receive the most sunlight possible and operate as expected. In order to ensure the battery bank's efficiency based on the calculation, a load has also been connected to the output side.

The electrical power formula is used to calculate the power generated by the solar panel during data collection. The relationship between the solar panel power, voltage and current is shown in Equation 4.1. Meanwhile, the battery charging time data has been obtained by referring to Equation 4.2.

$$\boldsymbol{P = VI} \tag{4.1}$$

Where P = Solar panel power (mW)

V = Solar panel voltage (V)

I = Solar panel current (mA)

$$T = \frac{C}{R} \tag{4.1}$$

Where *T* = Battery bank charging time (Hours)

C = Battery bank capacity (mAh)

R = Charging current (mA)

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4.3.1 PV Solar System Data on Day 1

Table 4.1 shows the data obtained from the standalone PV solar system on 4/1/2024. The weather condition during data collection recorded on that day was cloudy in the morning but there is sunlight for a while in the afternoon. It start to get cloudy again in the evening.

Table 4.1 Result for Polycrystalline Solar Panel On Day 1

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)
11.30 am	10.69	0.08	0.855	3.7	157.5
12.00 pm	10.64	0.09	0.958	3.7	140
12.30 pm	10.7	0.27	2.889	3.7	46.67
1.00 pm	10.68	0.16	1.709	3.7	78.75
1.30 pm	10.64	0.05	0.532	3.7	252
2.00 pm	10.63	0.03	0.319	3.7	420
2.30 pm	10.63	0.06	0.638	3.7	210
3.00 pm	10.63	0.05	0.532	3.7	252

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Based on Table 4.1, at 11.30 a.m the output power generated by the solar panel is 0.85W as the sky is clear with just enough sunlight. The power generated by solar panel keep increasing until it reach the highest power at 12.30 p.m with a value of 2.89W. At 1 p.m. the power decreasing due to clouds starts to covering the sky. The output power starts to decrease to 0.53W at 3 p.m as the sky starts to get cloudy.

4.3.2 PV Solar System Data on Day 2

Table 4.2 shows the data obtained from the standalone PV solar system on 5/1/2024. The weather condition during data collection recorded on that day was bright for the whole day.

Table 4.2 Result for Polycrystalline Solar Panel On Day 2

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)
11.30 am	10.69	0.13	1.389	3.7	96.92
12.00 pm	10.69	0.14	1.497	3.7	90
12.30 pm	10.7	0.14	1.498	3.7	90
1.00 pm	10.65	0.07	0.746	3.7	180
1.30 pm	10.67	0.07	0.747	3.7	180
2.00 pm	10.68	0.09	0.961	3.7	140
2.30 pm	10.69	0.13	1.389	3.7	96.92
3.00 pm	10.69	0.15	1.603	3.7	84

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Based on Table 4.2, at 11.30 a.m the output power generated by the solar panel is 1.39W as the sky is clear with enough sunlight. The power generated by solar panel increasing to 1.49W at 12.30 p.m. At 1 p.m. the power decreasing due to clouds starts to covering the sky. The output power starts to increase again to the highest power with a value of 1.603W at 3 p.m as the sky is getting brighter.

4.3.3 PV Solar System Data on Day 3

Table 4.3 shows the data obtained from the standalone PV solar system on 8/1/2024. The weather condition during data collection recorded on that day was cloudy for the whole day.

Table 4.3 Result for Polycrystalline Solar Panel On Day 3

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)
11.30 am	10.64	0.03	0.319	3.7	420
12.00 pm	10.66	0.05	0.533	3.7	252
12.30 pm	10.63	0.03	0.319	3.7	420
1.00 pm	10.63	0.03	0.319	3.7	420
1.30 pm	10.68	0.06	0.641	3.7	210
2.00 pm	10.62	0.01	0.106	3.7	1260
2.30 pm	10.62	0.02	0.212	3.7	630
3.00 pm	10.62	0.02	0.212	3.7	630

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Based on Table 4.3, at 11.30 a.m the output power generated by the solar panel is 0.32W as the clouds is covering the sky. The power generated by solar panel at 1.30 p.m is the highest with the value of 0.64W. At 2 p.m. the power decreasing due to cloudy weather.

4.3.4 PV Solar System Data on Day 4

Table 4.3 shows the data obtained from the standalone PV solar system on 9/1/2024. The weather condition during data collection recorded on that day was cloudy for the whole day.

Table 4.4 Result for Polycrystalline Solar Panel On Day 4

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)
11.30 am	10.63	0.03	0.319	3.7	420
12.00 pm	10.63	0.03	0.319	3.7	420
12.30 pm	10.66	0.07	0.746	3.7	180
1.00 pm	10.64	0.05	0.532	3.7	252
1.30 pm	10.64	0.05	0.532	3.7	252
2.00 pm	10.63	0.03	0.319	3.7	420
2.30 pm	10.64	0.02	0.213	3.7	630
3.00 pm	10.63	0.01	0.106	3.7	1260

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Based on Table 4.4, at 11.30 a.m the output power generated by the solar panel is 0.32W as the clouds is covering the sky. The power generated by solar panel at 12.30 p.m is the highest with the value of 0.75W. At 1 p.m. the power keep decreasing due to cloudy weather.

4.3.5 PV Solar System Data on Day 5

Table 4.5 shows the data obtained from the standalone PV solar system on 10/1/2024. The weather condition during data collection recorded on that day was bright in the morning. It start to get cloudy again in the evening.

Table 4.5 Result for Polycrystalline Solar Panel On Day 5

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)
11.30 am	10.69	0.25	2.673	3.7	50.4
12.00 pm	10.68	0.19	2.029	3.7	66.32
12.30 pm	10.66	0.14	1.492	3.7	90
1.00 pm	10.64	0.07	0.745	3.7	180
1.30 pm	10.62	0.01	0.106	3.7	1260
2.00 pm	10.62	0.01	0.106	3.7	1260
2.30 pm	10.63	0.02	0.213	3.7	630
3.00 pm	10.63	0.02	0.213	3.7	630

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Based on Table 4.5, at 11.30 a.m the output power generated by the solar panel is the highest power with a value of 2.89W as the sky was bright. The power generated by solar panel start decrease drastically at 1.30 p.m with value 0.106W as the sky is getting cloudy and windy.

4.4 Standalone PV Solar System Average Data Analysis

The result obtained from the experiment has been analyzed and calculated to get the average data value. The average output of solar panel voltage, current, power, battery voltage and charging time data for the 5 days are shown in Table 4.6 below.

Table 4.6 The average data obtained from the standalone solar system for 5 days

Day	Average				
	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)
1	10.65	0.099	1.054	3.7	194.62
2	10.68	0.115	1.228	3.7	119.73
3	10.64	0.031	0.332	3.7	530.25
4	10.64	0.036	0.383	3.7	479.25
5	10.65	0.089	0.948	3.7	520.84

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Based on Table 4.6, the average solar panel has produced at the lowest output power on the third day with a value of 0.332W. On the other hand, the average power produced by the solar panel on the second day is the highest recorded, with a value of 1.228W.

Figure 4.3 illustrates the graph of the relationship between the average solar panel power and average solar panel current. According to the graph in Figure 4.5, average solar panel power will increases as average solar panel current also increases.

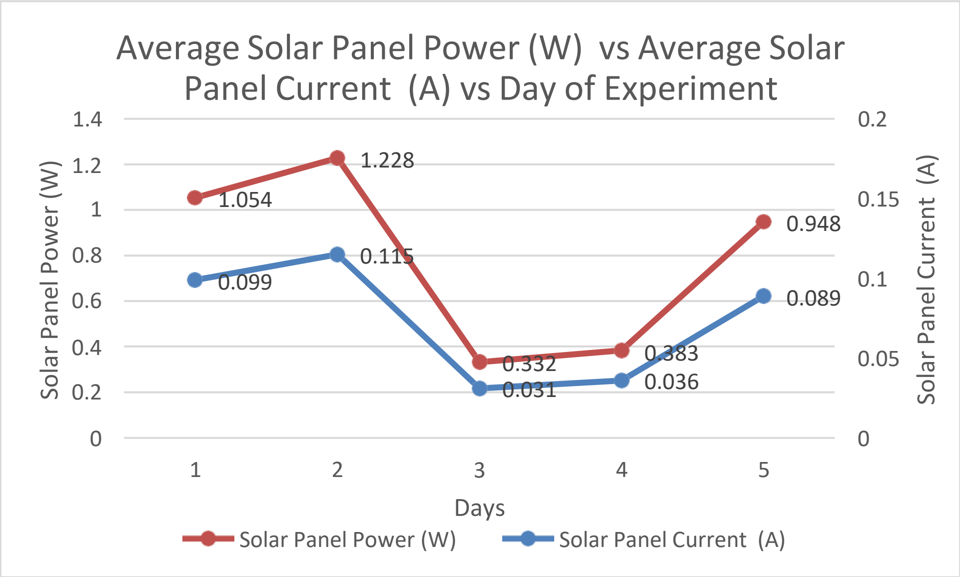

Figure 4.3 Graph of the relationship between the average solar panel power and average solar panel current

The prototype was tested at the end of the year, during Malaysia's rainy season, when sunlight amounts were not optimal for the solar panel. Because of the mostly cloudy and rainy weather, the 5-day average solar radiation intensity was low. The daily data that was collected changed significantly as a result of this.

In addition, the proposed solar panel size for this project is another factor that contributes to the solar panel's low output current. The experiment is expected to be performed on a bright and sunny day, leading to the peak sun hour given in the calculation is four hours based on the solar panel PV size calculation in Chapter 3. However, the weather is consistently cloudy for the whole week on the testing day, which has an impact on the PV solar panel performance. The projected 10 W, 18 V PV solar panel is estimated to be able to generate a maximum current output of 550 mA on a sunny day. However, this PV solar panel cannot achieve its maximum output current in cloudy weather and only provide a modest current which is due to the incompatibility of PV solar panel specifications. As a result, there is less potential for the solar panel to convert more sunlight into power. The highest average output power of the solar panel, based on the experimental results, is only 1.228W, with an average output current of 0.115A.

Next, the most crucial component in the process of charging the 18650 Li-ion batteries is the charge controller. It controls the charging current to prevent the battery bank from overcharging and over-discharging. According to the experimental data in Table 4.6 it took the battery bank over 24 hours to fully charge. The charge controller module become malfunctions because of the panel's output current is too low.

The connection between average solar panel current and battery bank charging time is shown in Figure 4.4. As shown by the graph in Figure 4.4, when the average solar panel output current rises, the battery bank's average charging time will reduces. This relationship states that the time it takes for the battery bank to completely charge will decrease with the increasing solar panel output current.

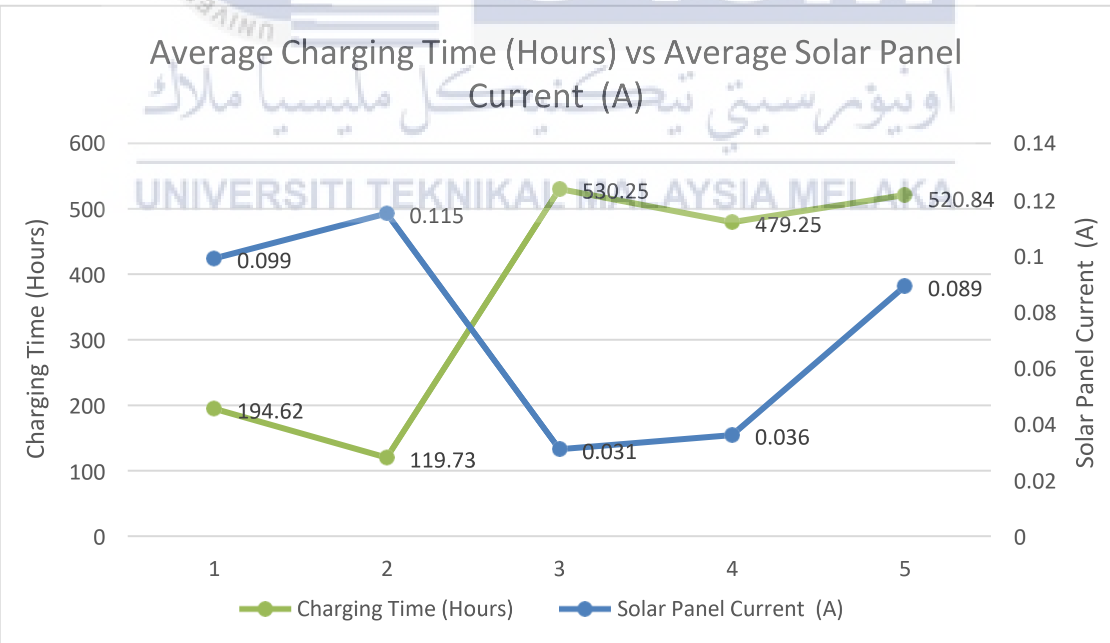

Figure 4.4 Graph of the relationship between the average battery bank charging time and average solar panel current

4.5 Battery bank performance

The power produced by solar panels and the amount of time needed for battery charging are recorded based on data collected over a period of five days, with three and a half hours of data taken each day. Over a period of five days, with the solar panel exposed to sunlight for three and a half hours each day, an average of 0.789W of electricity is generated, while the battery bank takes an average of 368.94 hours to charge. The battery bank will be charged with a load during the day while the system is operational for approximately 24 hours every day. The system will operate at maximum capacity at night when the battery bank is completely charged throughout the day.

Furthermore, the battery's endurance has been analyzed and evaluated to make sure that the battery bank can supply a maximum amount of power to the load. The battery endurance of a battery bank is the maximum duration of time it can sustain the load on its own. The formula (4.3) shown below is used to determine the battery bank endurance.

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$$Battery\ Bank\ Endurance = \frac{Vdc \times Ah}{Load} \tag{4.3}$$

The battery endurance is able to calculated in this project by applying the battery specifications. Presuming the battery is operating at maximum capacity,

$$Battery\ Bank\ Endurance = \frac{3.7V \times 12.6\ Ah}{1.1W} \tag{4.4}$$

$$Battery\ Bank\ Endurance = 42.38\ Hours$$

The calculation indicates that the system can function completely on the battery bank for a maximum of 42.38 hours without charging. However, any battery bank's performance is only about 85% of its stated specification. As a result, the real battery endurance is given below.

$$Battery\ Bank\ Endurance = \frac{3.7V \times 12.6\ Ah}{1.1W} \times 85\% \tag{4.5}$$

$$Battery\ Bank\ Endurance = 36.02\ Hours$$

According to (4.5), the actual battery bank endurance will be 36.02 hours with a capacity loss of around 1.89 Ah.

4.6 Smart Smoke Detector Performance Analysis

The smart smoke detector is an intelligent fire safety system that uses solar power as its primary energy source to detecting possible fire. This system consists of 6 essential elements such as the Node MCU ESP8266 microcontroller, MQ-2 gas sensor, flame sensor, I2C LCD, buzzer, and LED. All these elements consume about 1.1W of power per hour. The sensors, strategically located at an elevated location, interfaces with the ESP8266 to detect any possible fire.

Upon initialization, the system ensures that only green LED is activated, indicating a normal or safe condition. By taking this preventive action, needless alerts and false alarms are avoided. The initial value of the gas sensor is set at 500ppm while flame sensor will detect any possible fire. The LCD will show the value of the particle detected in the air and any potential fire as shown in Figure 4.5.

Figure 4.5 Green LED light on in normal condition.

Whenever the gas sensor value exceed the set value or the flame sensor sense any potential fire, the red LED will activated accompanied by a notification sent to the user via the Blynk application, as shown in Figure 4.6 and Figure 4.7. This provides a clear visual representation of the detecting smoke particle in the air.

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Figure 4.6 Red LED light on when value exceed 500ppm.

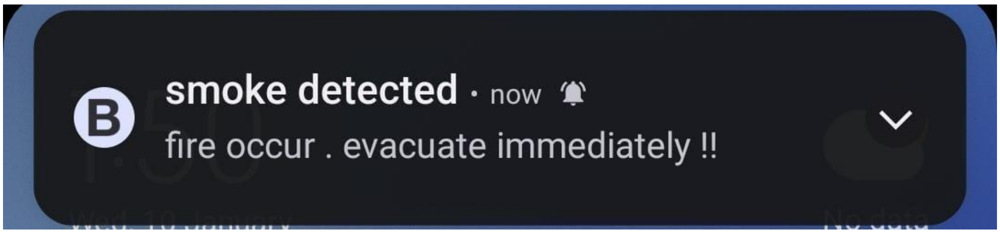

Figure 4.7 Notification from the Blynk Application.

In addition, the sensors has been placed at a considerable location to detect any potential fire or smoke. Table 4.8 shows the time response for the gas sensor in detecting smoke.

Table 4.7 Time response for the gas sensor in detecting smoke

Sensor detecting smoke	Time Response
Trial 1	1 second
Trial 2	1 second
Trial 3	1 second

In order to evaluate the device response time in detecting smoke, three trial of sensor for detecting any presence smoke has been done. For all three attempts, the time for the sensor response to the smoke particle is 1 second. For the flame sensor, test has been made to ensure the maximum distance for the sensor detecting flame. The result indicates that the sensor can detect flame at 100cm as maximum distance.

4.7 Summary

In conclusion, this chapter outlines the experimental data collecting and analysis carried out in this project for evaluating system performance. In order for the PV solar panels to generate their maximum output power and charge the battery more rapidly, the suggested standalone PV solar system is intended to be used on a bright, and sunny day. The experiment indicates that the suggested system sizing is ineffective for testing on a cloudy day. During the rainy season, the sunlight is insufficient to fully charge the battery bank to power the load when sunlight is limited. The essential objective of this research is to determine whether the solar panel, charge controller, battery, and sensor are appropriate for use with a smart smoke detector device. In general, the suggested specifications for the PV solar panel, charge controller, and battery bank are inadequate to power the smart smoke detection device as expected, indicating an under-design of the standalone PV solar system. However, the smart smoke detector has been effectively used to identify any possible fire or smoke.

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CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

In conclusion, a smoke detector is an essential safety device that is commonly used in homes, businesses and other public places to protect and warns users against fire. This project offers a solution that plays a crucial part in fire safety by sending out early warning signals, enabling building evacuation, and swiftly informing emergency services by designing a smart smoke detector.

This smoke detector device will use a smoke and flame sensor as an input and a microcontroller that will control all the components. The output of this device is I2C LCD which is used to display the value from sensors and a buzzer. This smoke detector also included a Blynk application as a platform to inform the authorities about the fire occurs. For the simulation, this device used Proteus 8 and Arduino IDE. This smoke detector device will be operates when the sensors detected a smoke particle and the microcontroller will send a signal to I2C LCD and buzzer to activate. As the signal will be also received by Blynk and send a notification to authorities. As a result, this project can save a life by sending an early warning of a fire.

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5.2 Project Objectives

The three main objectives of this project are briefly revisited and discussed as follows:

5.2.1 To analyze the existing smoke detector device or system.

In Chapter 2, a few current smoke detectors were studied by reviewing related articles, journals, and the works of other researchers. The study was conducted to examine the work of other researchers, particularly how other project systems are created and operate. In order to determine which components would work best together to construct a smart smoke detector device that is powered by a standalone PV system, a number of parts have been compared based on the literature research.

5.2.2 To design and develop an IoT system for the smart smoke detector using Esp8266 microcontroller powered by solar

The second objective was met by developing a standalone PV solar system with a smart smoke detector device. The flow of the smart smoke detector device and standalone PV solar system has been designed to make sure that both systems function as expected. In addition, the components of the smart smoke detector device and PV solar system were chosen by comparing their features with those discussed in Chapter 2. The size of the solar panel, charge controller, and batteries was also estimated in Chapter 3 based on the system power consumption. To ensure that the development of the prototype proceeds according to plan, the project design is important. Based on the recommended design, a standalone PV solar system and a smart smoke detector have been developed successfully. Thus, the second objective has been completely accomplished.

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5.2.3 To evaluate the performance of the smoke detector device developed for this project.

In this project, the hardware used to create the system must be compatible with one another in order to develop a standalone system. Through research and calculation, the ideal dimensions for solar panels, batteries, and charge controllers have been identified. The solar panel must provide enough energy to match the smart smoke detector's requirements, and the battery bank must have enough reserve power to keep the system running when the sunlight is not available.

A suitable solar charge controller is necessary to charge a battery bank without overcharging or over-discharging. Moreover, a suitable sensor for detecting particle in the air has also been selected for the smart smoke detector device. In order to determine if the components selected for the development of the standalone PV solar system and smart smoke detector device are suitable, Chapter 4 provides further details on the analysis of the acquired experimental data. Based on the experiment, the suggested solar panel is insufficient to produce the required output due to the weather and rainy season.

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5.3 Project Limitation

Many obstacles and difficulties were faced throughout the development of the project prototype and the data, which had an impact on the experimental output data. The average intensity of solar radiation is relatively low, and the peak sun hour during that season is also shorter, because the project testing is conducted at the end of the year, during Malaysia's rainy season. The recommended PV solar system size was designed to be performed on a sunny day because the sizing calculation indicated that the peak sun hour was four hours.

Due to the cloudy weather the solar panel's capacity to convert additional solar energy into electricity would decrease so it not practical to used it at that time. In addition, a 18650 Lithium-Ion battery has a low voltage, thus a DC-DC boost converter module is needed in the PV solar system to raise the voltage needed to run the ESP8266 microcontroller.

5.4 Recommendations

This project is focusing on studying the compatibility of the component used to build the smart smoke detector device with a standalone PV solar system. To make sure the PV solar system is able to power the smoke detector device in any weather, it is crucial to calculated the sizing of the solar panel, charge controller and battery bank.

Several aspects have been examined, such as the battery bank durability, charge controller, and solar panel performance. Thus, this project may be improved in a few ways. The suggestions made are as follows:

i. Collaboration with emergency services to provide immediate action in the event of a confirmed fire incident.

ii. Add a system that can extinguish fire in the event of a fire such as water sprinkler system.

iii. Add more sensors to widen the detection area to make the device more efficient in detecting smoke or fire.

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5.5 Project Potential

Every new invention must have its commercialization potential. Commercialization is the process of transforming anything into a product or service. This process would elevate the project to a level where any company or factory would be interested in the product or system developed from the invention products. Two systems from this project have great potential to be implemented commercially: standalone PV solar systems and smart smoke detector device. The potentials of the device using a solar-powered standalone PV system project are as follows:

i. Automatically notify emergency to the user in case of a confirmed fire event, potentially reducing response times and improving overall safety.

ii. This smart smoke detectors are ecologically friendly due to their use of energy-efficient parts and features like solar power and rechargeable batteries.

iii. Integration with IoT platforms allows users to receive real-time alerts on their smartphones.

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