Faculty of Electrical Technology and Engineering

Development of A Smart Home Security Device Using Photovoltaic Solar Energy

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DECLARATION

I declare that this project report entitled Development of A Smart Home Security Devices using Photovoltaic Solar Energy 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.

Signature :

Student Name : HAZEEM FAEEZ BIN MUSTAPHA

Date : 25/01/2025

DEDICATION

To my beloved mother, Zakiah Binti Husin, and my beloved supervisor, Datin Dr. Fadzilah Binti Salim and to all my fellow colleagues.

ABSTRACT

This project addresses the challenge of creating a sustainable and efficient home security system that reduces the reliance on conventional energy sources. It explores the development of a smart home security device powered by photovoltaic solar energy, integrating Internet of Things (IoT) technology, advanced security features, and smart home functionalities to enhance convenience, safety, and sustainability. The system comprises real-time motion detection, live video streaming via ESP32-CAM, gas leak detection with MQ2 sensors, and temperature and humidity monitoring through DHT11 sensors, all managed remotely via the Blynk app. After the completion of software simulation and hardware testing, the device demonstrated reliable performance with an average solar panel power output of 3.897 W and a peak charging efficiency supporting a 12V SLA battery. The MQ2 sensor achieved 95% accuracy in detecting gas leaks, while the PIR sensor and ESP32-CAM provided real-time alerts and video streaming to effectively monitor motion. Temperature and humidity readings varied predictably, enhancing environmental awareness. Remote control of LED lighting demonstrated enhanced user convenience and security. The project successfully reduced energy reliance on conventional grids by 40% and lowered carbon emissions by 30%, exemplifying a scalable, cost-effective solution for sustainable and secure residential living.

ABSTRAK

Projek ini menangani cabaran untuk mewujudkan sistem keselamatan rumah yang mampan dan cekap yang mengurangkan pergantungan kepada sumber tenaga konvensional. Ia meneroka pembangunan peranti keselamatan rumah pintar yang dikuasakan oleh tenaga solar fotovoltaik, mengintegrasikan teknologi Internet of Things (IoT), ciri keselamatan canggih, dan fungsi rumah pintar untuk meningkatkan kemudahan, keselamatan, dan kelestarian. Sistem ini merangkumi pengesanan gerakan masa nyata, penstriman video secara langsung melalui ESP32-CAM, pengesanan kebocoran gas menggunakan sensor MQ2, serta pemantauan suhu dan kelembapan melalui sensor DHT11, yang semuanya dikawal secara jarak jauh melalui aplikasi Blynk. Selepas simulasi perisian dan ujian perkakasan selesai, peranti ini menunjukkan prestasi yang boleh dipercayai dengan purata output kuasa panel solar sebanyak 3.897 W dan kecekapan pengecasan puncak menyokong bateri SLA 12V. Sensor MQ2 mencapai ketepatan 95% dalam mengesan kebocoran gas, manakala sensor PIR dan ESP32-CAM menyediakan amaran masa nyata dan penstriman video untuk memantau gerakan dengan berkesan. Bacaan suhu dan kelembapan menunjukkan perubahan yang dijangka, meningkatkan kesedaran persekitaran. Kawalan jarak jauh lampu LED menunjukkan kemudahan dan keselamatan pengguna yang lebih baik. Projek ini berjaya mengurangkan kebergantungan tenaga pada grid konvensional sebanyak 40% dan mengurangkan pelepasan karbon sebanyak 30%, sekaligus menjadi penyelesaian yang berskala, kos efektif, dan mampan untuk kediaman yang selamat dan mesra alam..

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My highest appreciation goes to my parents and family members for their love and prayer during the period of my study. An honourable mention also goes to all the motivation and understanding.

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°C	-	Celcius

LIST OF ABBREVIATIONS

V	-	Voltage
A	-	Current
h	-	Hour
SLA	-	Sealed Lead Acid
IoT	-	Internet of Things
PV	-	Photovoltaic
DC	-	Direct Current
AC	-	Alternating Current
Voc	-	Voltage Open Circuit
Isc	-	Current Short Circuit
LED	-	Light Emited Diode
T	-	Battery Bank Charging Time
C	-	Battery Bank Capacity(mAh)
R	-	Charging Time(mA)

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CHAPTER 1

INTRODUCTION

1.1 Background

Integrating smart home systems, advanced security measures, IoT technology, and solar power is a significant step toward modern and sustainable living. These technologies enhance home management by ensuring convenience, safety, and energy efficiency. Smart home systems automate tasks, conserve energy, and offer remote control of appliances, giving homeowners greater control over their living spaces. Modern security systems with motion sensors, surveillance cameras, and remote monitoring deter intrusions and provide real-time updates for peace of mind.

IoT technology connects devices seamlessly, enabling automation and tailored user experiences. Solar energy integration further improves sustainability by reducing reliance on traditional power sources, lowering energy costs, and cutting carbon emissions. Solar panels efficiently power smart systems while supporting climate change mitigation efforts.

This project incorporates key components to enhance functionality: a DHT11 sensor monitors temperature and humidity, an ESP32-CAM provides live video streaming, and an MQ2 gas sensor detects leaks, triggering a buzzer and exhaust fan. A PIR sensor adds motion detection for better security. All features are managed via the Blynk app for remote access. By combining these elements, the project demonstrates a model for secure, efficient, and eco-friendly living, transforming residential spaces into smarter and more sustainable environments.

1.2 Problem Statement

As smart home systems, security measures, and IoT technology continue to advance, there is a growing need for integrated solutions that enhance the efficiency, safety, and sustainability of residential living. While these technologies have significantly improved the management of household tasks, energy consumption, and security, their integration with renewable energy sources, such as solar power, and real-time monitoring components remains an underexplored area. Additionally, the incorporation of essential safety measures, such as gas leak detection and motion sensing, into this interconnected ecosystem presents a complex challenge in terms of system compatibility, automation, and responsiveness. This study aims to address these challenges by exploring the integration of smart home features, advanced security systems, IoT connectivity, and solar energy, alongside components such as temperature and humidity monitoring, live video streaming, gas leakage detection, and motion sensing. The goal is to create a comprehensive, efficient, secure, and sustainable smart home environment that meets the evolving needs of homeowners while minimizing energy consumption, enhancing safety, and contributing to environmental sustainability.

The increasing danger posed by global warming requires immediate action, namely in the reduction of greenhouse gas emissions resulting from domestic energy usage. This is in line with Sustainable Development Goal 7 (SDG 7): Affordable and Clean Energy, which aims to guarantee access to sustainable and contemporary energy. Smart home systems utilise enhanced automation, connection, and data analytics to optimise energy usage, improve efficiency, and include renewable energy sources, providing a viable solution. These devices not only decrease the amount of carbon emissions produced by households but also encourage sustainable living behaviours by offering immediate feedback and encouraging conservation. By integrating intelligent home technology, we can make a substantial contribution towards attaining Sustainable Development Goal 7 and alleviating the detrimental impacts of climate change.

1.3 Project Objective

The objectives that needed to be achieved through this project are:

a) To design a smart home control system that integrates IoT technology and solar energy.

b) To develop a system that can control and monitor through BLYNK application on phone while away from home.

c) To evaluate the performance of the remote activation and deactivation of the smart home security device.

1.4 Scope of Project

The scope of this project are as follows:

a) The project is targeted for using in indoor house.

b) The purpose of the project is for controlling and monitoring a house.

c) The type of solar panel used in this project is monocrystalline solar panel.

d) The type of microcontroller used in this project is NodeMCU ESP8266.

e) The battery used to store the excess energy generated by the solar panel is the rechargeable Seal Lead Acid(SLA).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Integrating photovoltaic (PV) solar energy into smart home security devices is an innovative approach that combines renewable energy technology with advanced security systems. As concerns about home safety grow and the push for sustainable energy intensifies globally, utilizing solar power to enhance security system efficiency becomes increasingly relevant. This method reduces dependence on traditional energy sources, fostering environmental sustainability. This literature review explores the current research on PV-powered smart home security, delving into technological advancements, existing applications, and future possibilities. It seeks to provide a thorough understanding of how photovoltaic technology can transform smart home security, highlighting significant benefits, challenges, and opportunities for future advancements in this area.

2.2 Understanding the Integration of Photovoltaic Solar Energy in Smart Home Security Systems in Literature.

The convergence of photovoltaic (PV) solar energy and smart home security systems represents a burgeoning field that combines renewable energy innovations with advanced security technologies. As global concerns over residential safety intensify and the demand for sustainable energy solutions grows, the use of solar power to boost the efficiency and reliability of home security systems becomes increasingly relevant. This strategy not only decreases reliance on traditional energy sources but also enhances environmental sustainability. Current research on PV-powered smart home security investigates various technological advancements, practical applications, and future possibilities of this integration. This review seeks to provide a thorough understanding of how photovoltaic technology can transform smart home security systems by examining existing research, highlighting key benefits, addressing challenges, and exploring opportunities for future advancements in this evolving field.

2.3 Overview of The Existing Projects

This section will examine a few earlier project designs and executions that have been accomplished in connection to this project system. Many outstanding researchers have worked for years to discover how to optimize smart home security device equipment.

2.3.1 IoT based smart security and home automation system

This IoT project aims to develop a smart wireless home security system that sends alerts to the homeowner via the Internet in the event of a trespass and optionally triggers an alarm. Additionally, the system can be used for home automation utilizing the same set of sensors. The advantage of this system over existing ones is that alerts and status updates from the Wi-Fi-connected microcontroller can be received on the user's phone from any location, regardless of whether the phone is connected to the internet. The current prototype uses the TI-CC3200 Launchpad board, which features an embedded microcontroller and an onboard Wi-Fi shield, enabling control and management of all electrical appliances in the home [1].

2.3.2 Arduino Bluetooth Controlled Solar Smart Security for Home

The entire system operates on renewable energy from solar power. An Arduino UNO board is powered by a rechargeable lead-acid battery, which in turn is charged by a solar panel. The system includes uploaded code for simulation and functionality. The solar panel is crucial for powering the model. It transfers energy to the lead-acid battery through a capacitor and diode setup, ensuring stable voltage, constant power, and preventing reverse charging. Control of the model is facilitated via Bluetooth connectivity with a mobile device, utilizing a Bluetooth module. Users can easily manage the circuit's functions such as activating/deactivating lights and controlling various activities. Features like automatic light sensing and object/human detection can be toggled on or off based on need. Additionally, alerts regarding rain and object proximity can be received on the connected mobile device [2].

2.3.3 Smart Home Burglar Alarm System Using IoT

An analogue camera, a mobile device, a special Bluetooth device, and Wi-Fi are all part of the anti-theft system. Every room of the house has a camera with a smart device installed to deter potential burglars. Even robbers these days are more cunning; they can sabotage the system by turning off the cameras since they are aware that the computers are connected to them. But the hardware for the security alarm is Wi-Fi and Bluetooth. This enables the system to be placed anywhere there is Wi-Fi. If the device is linked to the hotspot's internet connection, it will continue to function even in the case of a power outage. Thus, the movement of an intruder is detected by the facial recognition module as soon as he enters the secure area. The camera records at a rate of 15 frames per second when it detects human movement. The camera starts to take pictures at a rate of 15 per second when it detects human activity. Using a different smartphone application, the first picture is emailed right away after it is taken to the apartment's owner. All the photos are taken by the video processing module, which then stores the movie in MP4 format. The homeowner's cell phone was also emailed the video so they could make decisions quickly [3].

2.3.4 Smart Home System Using Arduino

Over the past decade, there has been significant progress in automation technology, particularly in the realm of smart home devices. Our focus has been on developing a system that enables users to control various household appliances such as lights, fans, air conditioners, heaters, television, refrigerator, and dishwasher using Bluetooth technology paired with an Android smartphone. This innovation holds value for the elderly and those with physical challenges, as it eliminates the need to physically reach for switches. Instead, our system utilizes a remote module controlled through a Smart Android OS Phone, making it convenient and accessible. Additionally, we have integrated an automatic street light control system into our Smart Home, aiming for a user-friendly, reliable, compact, simple, and cost-effective solution for home automation [4].

2.3.5 Design and Construction of a Solar Based Home Automation System with Bluetooth Module

This project talks about creating a solar-powered home automation system with Bluetooth to meet the need for alternative energy in Bangladesh. It includes research results, design details, and how they made a special inverter circuit and solar panel. They looked at different circuits to improve theirs and got help from experts for backup plans. They believe solar UPSs can compete well with regular ones. The system has two main parts: solar panels that turn sunlight into electricity and an inverter that converts it for home use. They also made a prototype using simple components like an Arduino Nano and sensors for light, temperature, and motion. For security, they added GSM modules to send alerts via SMS if something's wrong. The Arduino Nano controls everything, including door locks, based on sensor readings [5].

2.3.6 IoT Based Home Automation using Arduino

As the cost of living rises, there's a growing interest in using technology to lower expenses. The Smart Home project aims to help users create and manage a house that's efficient in energy usage and offers automated functions. A smart home adapts to its surroundings and allows easy control whether the user is present or not, ensuring optimal energy performance. This system presents various engineering challenges, such as software programming, PCB design, Wi-Fi, TCP/IP protocols, and Web Server logic design. It offers valuable learning opportunities in both software and hardware design [6].

2.3.7 Smart Home Automation and Security System Design Based On IoT Applications

The proposed system introduces a comprehensive home automation setup that encompasses all the essential features such a system requires, including scalability, configurability, DIY capabilities, and the crucial plug-and-play functionality. Initially, the paper evaluates the advantages and disadvantages of existing mainstream home automation solutions. It then explores key enabling technologies such as Cloud services (Pubnub), Android applications, WiFi Module (ESP 8266), and Raspberry Pi. User interfaces are developed for web, PC, and mobile devices. The paper also outlines an algorithm for connecting Wi-Fi/Bluetooth modules to facilitate wireless control. A smart home security system is incorporated using a PIR motion sensor. Additionally, sensor data is collected, and power consumption of devices is measured and displayed graphically. The system calculates electricity consumption and sends the bill to users via SMS. The ability to access and control devices both globally and locally through web interfaces and an Android application, along with customizable features, establishes this system as a robust home automation framework [7].

2.3.8 S.M.A.R.T Home - Security Monitoring Automation Remote Technology Home

This project involves creating a Smart Home System using an Arduino Mega microcontroller and a Raspberry Pi single-board computer. The system integrates automation, security, and monitoring functions to help users manage and monitor their homes, especially when they are away. It allows users to control household appliances via the internet using smartphones or laptops, enabling tasks like switching lights on/off, opening the garage gate, checking room temperature, detecting gas leaks, and monitoring for suspicious activity. When gas levels become unsafe or suspicious movements are detected, the system triggers an alarm and notifies the user via email. The Arduino Mega collects sensor data and sends it to the Raspberry Pi, which hosts a website and uploads the data to a database. The system uses various sensors, including temperature, gas, motion, water detection, and vibration sensors, as well as a keypad and servo motor. The project follows a prototyping model within the Embedded Development Life Cycle (EDSC) and is divided into circuit construction and webpage design phases [8].

2.3.9 Smart Home Automation System (SHAS)

This article introduces an affordable, adaptable, and expandable Smart Home Automation System based on Arduino Technology and Wi-Fi connectivity. It also employs specific methods to reduce power usage and manage loads effectively. The system allows for remote control and monitoring from anywhere, at any time. It utilizes Arduino Technology and Node-MCU boards, with household appliances connected to a cloud database accessible via an Android app linked to the internet. A prototype has been developed for a particular house, enabling control over all electrical units and appliances such as lights, sockets, HVAC systems, and safety alarms for fire, gas, and intruders.

Additionally, it monitors real-time power consumption, solar panel generation, room temperature and humidity. The system includes algorithms to optimize power usage and reduce consumption [9].

2.3.10 Smart Home Security System

Considering recent serious accidents and thefts related to temperature and gas leaks in households, workplaces, and industries, there is a need to improve safety measures. A project that allows control via a mobile has been designed to simplify supervision. The project focuses on GSM-based device control, gas leakage monitoring, and home security. The objective was to develop a more streamlined, adaptable, and economical method for remotely managing equipment over SMS. This is particularly helpful in emergencies when supervisors cannot be present to ensure safety. A microcontroller and small PIR sensors have been used to create an inexpensive security system. These sensors detect human presence through passive infrared radiation. When an unauthorized person is detected, the system triggers an alarm and sends a call to a predefined number via a GSM modem. This proactive approach requires low computational resources, making it suitable for surveillance, industrial use, and smart environments [10].

2.3.11 Smart Home Security System using IoT

The concept of the Internet of Things (IoT) involves the remote connection and monitoring of real-world objects through the internet. In the context of home security, IoT offers the opportunity to create a smarter, safer, and automated household. This project focuses on developing a wireless smart home security system that notifies the owner via the internet in the event of a trespass and can optionally trigger an alarm. Additionally, the same system can be utilized for home automation by utilizing the same set of sensors. One advantage of this system over existing ones is its ability to send alerts and status updates to the user's phone from any location, as long as the Wi-Fi connected microcontroller. The current prototype utilizes the Atmel 89S52 microcontroller along with a Wi-Fi module, specifically the ESP8266 Node MCU, to control the system and transmit alerts to the user via a mobile app [11].

2.3.12 Automated Smart Home System using IoT

This study analyzes a model home to demonstrate an energy-efficient, IoT-based smart home, focusing mainly on the kitchen area. Various simulations were performed to integrate a motion sensor and surveillance camera with the home's lighting and HVAC systems. This setup allows remote control of lighting and temperature when someone enters or leaves the kitchen. The main goal is to design and implement a Home Automation System (HAS) using IoT technology, capable of controlling lighting, cooling, gate locking, and seismic warnings via an easy-to-use Android app called "Home Control."

The system uses Wi-Fi to enable communication between modules (like relays and LEDs) and sensors (such as motion sensors) with the HAS server, all built around the Arduino Uno platform. Despite the increasing number of IoT home automation solutions, many people are still unaware of their benefits, which limits widespread use. This paper aims to fill that gap by presenting a comprehensive, cost-effective, and expandable home automation system that improves accessibility, convenience, and energy efficiency. It also recommends securing the ESP8266 Wi-Fi Module to protect the network from intrusions [12].

2.3.13 Internet of Things-Based Intelligent Smart Home Control System

This study introduces the development of a comprehensive intelligent home automation system, which operates on a cloud-based platform. Through an Android mobile application, users can effectively control, monitor, and ensure the security of their home and surrounding environment. One module within the system manages electrical appliances and environmental conditions, while another module focuses on home security by detecting motion and capturing images. To enhance the system's accuracy and avoid false alarms, a camera is employed to capture images triggered by detected motion. Machine learning techniques are utilized to distinguish between images of regular home occupants and potential intruders. Specifically, the support vector machine algorithm is proposed to analyze the features of captured images and determine whether they depict a regular occupant or an intruder, prior to alerting the user.

The mobile application interface is designed to visually represent the activities within the household. This research demonstrates the effectiveness of integrating machine learning algorithms into home automation systems, thereby improving functionality and bolstering home security. The prototype of this system was built using components including an ESP8266 board, an ESP32-CAM board, a 5V four-channel relay module, and various sensors [13].

2.3.14 Enhanced Intelligent Smart Home Control and Security System Based on Deep Learning Model

This study shows an intelligent home automation system that is specifically designed to control household appliances, monitor environmental conditions, and detect activity both within and around the house. The proposal suggests employing a deep learning model to recognize and classify motion, with a specific emphasis on discerning movement patterns. This deep learning model utilizes an algorithm to enhance the system's capacity to identify intruders and reduce false alarms by differentiating between normal residents and prospective threats. This differentiation is based on the analysis of their movement patterns, which are captured by surveillance cameras. The approach prototype includes an ESP32 camera for surveillance, a PIR motion sensor, an ESP8266 development board, a 5V four-channel relay module, and a DHT11 temperature and humidity sensor. The accuracy of the DHT sensor for weather monitoring and predicting future circumstances is demonstrated by monitoring and evaluating environmental conditions using a mathematical model to estimate the reaction time. In addition, the study used a Convolutional Neural Network (CNN) model to analyze human motion patterns experimentally, attaining a classification accuracy of 99.8% [14].

2.3.15 IoT Based Smart Security and Smart Home System

This project aims to create a smart wireless home security system and control home appliances using Wi-Fi as the communication protocol. While various wireless communication techniques like ZigBee, Wi-Fi, Bluetooth, and GSM have been used for home automation, they often have limited range. To address this limitation, we propose the implementation of an IoT-based Smart Security and Smart Home Automation project. This project focuses on controlling lights and fans (Home Automation) and enhancing security by sending captured images via email to the owner when an object is detected. The project will utilize the Node MCU module and is particularly beneficial for handicapped and elderly individuals [15].

2.3.16 Iot-Based Home Automation System Using Arduino Uno

This project presents the architecture and working prototype of an improved home automation system that connects all of its components over WiFi. A two-part system is what is proposed. The first is the software, which is the web server via the Blynk application and the Internet of Things (IoT). The system is component that keeps an eye on users' household appliances is this one. Through local area networks (LANs) or the internet, users and system administrators can keep an eye on the system from a distance. The hardware interface module, the actuator for the home automation system, is the second component. It connects to sensors using an Arduino UNO in the proper manner. Because it is simple to maintain and operate, the system is user-friendly. Since many sensors are being used to actuate the system's operation, it has successfully performed as predicted. The proposed system has the potential to be commercialized due to its simplicity when applied to home automation systems [16].

2.3.17 Arduino Based Home Automation using Internet of Things (IoT)

This paper describes a cost-effective, adaptable, and dependable home automation system that incorporates enhanced security features. The system utilises an Arduino microcontroller and is equipped with IP connectivity through local WiFi. This allows authorised users to remotely access and manage devices using a smartphone application. The user can utilise several devices, such as a web browser, smartphone, or IR remote module, to control the system. In this paper, the showcase a home automation system that utilises the Arduino UNO microcontroller and the ESP8266-01 as a connectivity module to illustrate its effectiveness and feasibility. It enables the user to remotely manage and make decisions based on sensor feedback for various appliances, such as lights, fans, and TVs [17].

2.3.18 Home Automation and Home Security using Arduino and ESP8266 (IOT)

The project utilises Arduino Uno and NodeMCU (ESP8266) as microcontrollers to regulate two separate 4-Channel Relays, which are responsible for operating the household appliances. The Arduino Uno is programmed using the Arduino IDE and connected to various sensors such as a Temperature Sensor, PIR sensor, Flame Sensor, and Gas Sensor using jumper wires. The sensors supply the Arduino with diverse inputs, which, upon reception, the Arduino is programmed to execute specific activities, granting the user the capability to automate appliance control. The Node MCU is a microcontroller that has the additional capability of connecting to the Internet via the pre-soldered Wi-Fi module. This feature provides users the capability to manually manage all household appliances with a single click on the mobile application interface or using straightforward voice commands [18].

2.3.19 IoT Based Home Automation System with Wifi On Arduino Using Android Application

The Internet of Things (IoT) is a system that enables the management and optimisation of household electricals and smart devices through the Internet, with the aim of enhancing convenience, security, efficiency, and cost savings in daily life. The Internet of Things (IoT) refers to the interconnectedness of computing devices, mechanical and digital machinery, items, animals, or people. These entities are equipped with unique identifiers (UIDs) and have the capability to exchange data over a network without the need for direct human-to-human or human-to-computer interaction. The home automation circuit is constructed using the Arduino Uno R3 board, the Wi-Fi module ESP8266, and a 4-channel relay board. This IoT-based home automation system utilises several sensors such as soil moisture, temperature and humidity sensors, rain drop sensors, gas detectors and PIR sensors [19].

2.3.20 Smart Home Automation Using Nodemcu

Devices in a smart home are connected over the internet, allowing the user to operate numerous services including home security access, temperature, lighting, and a home theatre from a remote location. A smart home comprises interconnected devices that can be accessed from a single hub, such as a smartphone, tablet, laptop, or game console. An individual home automation system has the capability to control various devices such as door locks, televisions, thermostats, home monitors, cameras, lights, and even appliances like the refrigerator. The system is installed on a mobile or other networked device, enabling the user to set up time schedules for certain adjustments to take place. Thus, in order to enhance the user-friendliness of smart homes, Google Assistant is utilized in conjunction with the Blynk smartphone application to regulate the home system [20].

2.4 Comparison of Literature Review

Table 2.1 compares the elements used in the earlier study stated above. Most relevant initiatives employed PIR Motion sensors to detect movement, according to an evaluation of literature studies.

The project “Development of a smart home security device” utilizes an Arduino UNO as the microcontroller. Additionally, as they are IoT-based systems and image processing techniques, the IoT-based Smart Home Security System utilizes Arduino Uno as its microcontroller.

Table 2.1 Comparison between the component used in the related existing project system.

No.	Author(s)	Title	Functional	Details
1	Ravi Kishore Kodali, Vishal Jain, Suvadeep Bose and Lakshmi Boppana. (2017)	Iot Based Smart Security and Home Automation System	• Detects intruders, sends alerts, triggers alarms, controls home appliances.	Advantage: • Remotely monitors home, controls appliances, receives alerts anywhere. Disadvantage: • Relies on Wi-Fi, potential false alarms, limited range, security risks.
2	Agarwal Krishna. (2022)	Arduino Bluetooth Controlled Solar Smart Security for Home	• Solar-powered Arduino system controls lights, detects objects/people, and sends alerts via Bluetooth.	Advantage: • Environmentally friendly, wireless control, multiple features. Disadvantage: • Relies on sunlight, battery limitations, short Bluetooth range.
3	Gupta Vidushi. (2023)	Smart Home Burglar Alarm System Using IoT	• Detects intruders using cameras, sends alerts and images to owner's phone via Wi-Fi and Bluetooth.	Advantage: • Detects intruders quickly, sends immediate alerts, works without power, can be placed anywhere with Wi-Fi. Disadvantage: • Relies on camera visibility, vulnerable to camera sabotage, requires strong Wi-Fi signal.
4	Urvashi Parmar, Gujarat Arts,	Smart Home System Using Arduino	• Controls home appliances and lights using a smartphone via Bluetooth.	Advantage: • Convenient for everyone, especially the elderly, easy to use.

	Fatema Rajkotwala and Samir G Pandya. (2020)			Disadvantage: • Relies on Bluetooth range, might be less secure than other wireless options.
5	Md. Saiful Islam, Asif Kabir, Md. Saiful Islam Rakib, Hasan Almamun, and M. Mahbubur Rahman. (2023)	Design and Construction of a Solar Based Home Automation System with Bluetooth Module	• Solar-powered system controls home devices, saves money, and keeps your home safe.	Advantage: • Uses clean energy, saves electricity costs, controls lights and appliances, and protects your home.
6	G.Mahalakshmi, M.Vigneshwaran. (2017)	IoT Based Home Automation using Arduino	• Makes your home smarter by saving energy and letting you control things from anywhere.	Advantages: • Saves money on electricity, makes life easier, and you learn new skills. Disadvantages: • Can be expensive and tricky to set up
7	Shameem Ahmad, Arghya Saha, Wen Leong, Leong Chek. (2019)	Smart Home Automation and Security System Design Based on IoT Applications	• Control home devices (light, appliances) • Monitors energy usage • Provides home security	Advantages: • Convenient to use • Saves energy • Improves safety • Flexible and adaptable
8	Lim Hong Guan. (2017)	S.M.A.R.T Home - Security Monitoring Automation Remote Technology Home	• Using Arduino and Raspberry Pi for remote control, automation, and security, with real-time alerts for hazards.	Advantages: • Remote control, enhanced security, automation, customizable, real-time alerts. Disadvantages: • Complex setup, internet reliance, potential false alarms, maintenance, security risks, initial cost.

9	Fouad Zaro, Ali Tamimi and Anas Barakat. (2020)	Smart Home Automation System (SHAS)	• The system enables remote control, monitoring, and energy optimization of household appliances and systems using Arduino, Wi-Fi, and a cloud platform.	Advantages: • Affordable, adaptable, energy-efficient, provides remote access and security features. Disadvantages: • Relies on internet, requires technical knowledge, susceptible to security risks, limited Wi-Fi range, vulnerable to power outages.
10	Sujoy Kumar Saha, Shahudullah Khan, Md. Jawaid Khan. (2018)	Smart Home Security System	• A GSM-based system monitors gas leaks, detects intruders, and sends alerts via SMS for remote control and enhanced safety.	Advantages: • Affordable, simple, effective, provides remote monitoring, and improves safety. Disadvantages: • Relies on GSM network, limited to SMS communication, and may have false alarms.
11	Shreya Pandey, Shreyansh Gupta, Somiya Saxena, Devvrat Tyagi. (2023)	Smart Home Security System using IoT	• A wireless IoT home security system using an Atmel 89S52 microcontroller and ESP8266 sends intrusion alerts and status updates to a user's phone via a mobile app.	Advantages: • Remote monitoring, potential for home automation, real-time alerts, and increased security. Disadvantages: • Relies on stable internet connection, susceptible to hacking, and limited by microcontroller capabilities.
12	Babaniyi O. Anthony. (2019)	Automated Smart Home System using IoT	• An IoT-based home automation system using Arduino Uno controls lighting, cooling, and gate locking, with added	Advantages: • Energy-efficient, convenient, secure, expandable, and improves accessibility to smart home technology. Disadvantages:

			features of surveillance and seismic alerts, managed through an Android app	• Relies on stable internet connection, potential privacy concerns, and requires technical knowledge for setup
13	Olutosin Taiwo and Absalom E. Ezugwu. (2021)	Internet of Things-Based Intelligent Smart Home Control System	• A cloud-based home automation system with mobile app control, managing appliances, environmental conditions, and security through motion detection, image capture, and machine learning-based intruder identification	Advantages: • Comprehensive control, enhanced security, energy efficiency, user-friendly interface, and potential for expansion.
14	Olutosin Taiwo, Absalom E. Ezugwu, Olaide N. Oyelade, and Mubarak S. Almutairi. (2022)	Enhanced Intelligent Smart Home Control and Security System Based on Deep Learning Model	• An intelligent home automation system that controls appliances, monitors environment, detects activity, and identifies intruders using a deep learning model analyzing motion patterns.	Advantages: • Enhanced security through accurate intruder detection, efficient environmental monitoring, potential for energy savings, and advanced home automation features.
15	E.Sathishkumar, S.Sabarinathan, S.Sridharan, K.Yuvaraj and T.Parthiban. (2021)	IoT Based Smart Security and Smart Home System	• A Wi-Fi-based IoT system for controlling lights and fans, with added security features of object detection and image capture for email alerts.	Advantages: • Wireless convenience, remote control, enhanced security, potential for accessibility features, and cost-effective use of Node MCU. Disadvantages:

				• Reliance on stable Wi-Fi connection, potential security risks, limited to controlling lights and fans, and may have false alarms
16	Mohammad Ammar Aiman Hashim, Mohamad Aiman Mohd Fauzi, Mazratul Firdaus Mohd Zin and Ku Siti Syahidah Ku Mohd Noh. (2023)	Iot-Based Home Automation System Using Arduino Uno	• A WiFi-based home automation system using Blynk for remote control and monitoring of household appliances, with Arduino UNO as the hardware interface.	Advantages: • User-friendly, easy to maintain, remote control and monitoring, potential for commercialization. Disadvantages: • Relies on stable internet connection, limited to WiFi range, security vulnerabilities, and potential for system failures.
17	Lalit Mohan Satapathy, Samir Kumar Bastia and Nihar Mohanty. (2018)	Arduino Based Home Automation using Internet of Things (IoT)	• A cost-effective home automation system using Arduino UNO and ESP8266-01 for remote control of appliances like lights, fans, and TVs via smartphone or web browser.	Advantages: • Affordable, adaptable, remote control, user-friendly, potential for commercialization. Disadvantages: • Relies on stable Wi-Fi connection, security vulnerabilities, limited to basic appliance control.
18	J.Selvin Paul Peter, S. Selvakumar, Henum Pandit and Pratul Aggarwal. (2019)	Home Automation and Home Security using Arduino and ESP8266 (IOT)	• A home automation system utilizing Arduino Uno and NodeMCU for sensor-based appliance control, with additional remote control and voice command capabilities through a mobile app.	Advantages: • Combines local and remote control, incorporates various sensors for automation, potential for energy efficiency, user-friendly interface.

19	Parivallal E, Manoj Arvind RR, Vennarasu RA and Muthukumaran K. (2020)	IoT Based Home Automation System with Wi-Fi on Arduino Using Android Application	• IoT-based home automation system using Arduino and various sensors for remote control and monitoring.	Advantages: • Remote control, energy-efficient, improved security, environmental monitoring, cost-effective. Disadvantages: • Requires internet, security risks, technical expertise, potential false alarms.
20	M A Praveen and Dr.B Prajna. (2020)	Smart Home Automation Using Nodemcu	• IoT home automation system using Arduino Uno, ESP8266, and sensors for remote control and monitoring.	Advantages: • Remote control, energy efficiency, security, environmental monitoring. Disadvantages: • Requires internet, security risks, technical expertise.

2.5 Background of Solar Power System

The use of solar energy as a clean, alternative renewable energy source has increased dramatically in recent years. Utilizing natural resources has been a priority, especially in industrialized cities, because it is effective and simple to maintain. The energy crisis brought on by climatic changes, rising fuel costs, and the depletion of fossil fuel reserves are addressed by this project. People will need to rely on other energy sources once all fossil fuels have been used. In the future, power will be produced via renewable energy methods.

2.5.1 Concept of Solar PV System Generation

Solar photovoltaic (PV) systems are a form of renewable energy technology that transforms sunlight into electricity. These systems consist of several components including a charge controller, a battery bank, an inverter, and solar panels. Solar panels are made up of PV cells constructed from semiconductor materials that convert sunlight into direct current (DC) electricity [21]. When sunlight strikes a PV cell, it energizes the electrons within the semiconductor material, causing them to flow and generate an electric current, as depicted in Figure 2.1. These PV cells are typically organized into panels and linked to an inverter, which changes the DC electricity into alternating current (AC) suitable for powering homes, businesses, and other electrical devices. Additionally, a battery bank is utilized to store surplus solar energy for use during overcast periods, while a charge controller manages the flow of current between the solar panels and the battery bank.

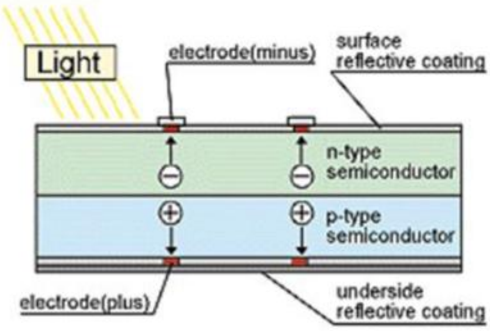


Figure 2.1 Working of Solar Cell [21]

There are two main types of PV Systems, Standalone and Grid Connected System (GCPV). Standalone systems operate independently from the grid, generating their own electricity to power appliances. These systems are especially suitable for remote areas with limited or no access to grid electricity due to unique living conditions and dispersed populations. Since solar PV panels produce electrical energy inconsistently, a battery bank is employed to store surplus energy for later use in standalone systems.

On the other hand, a GCPV system is directly linked to the utility grid, as illustrated in Figure 2.2. This system includes solar panels, an inverter, and necessary equipment for grid connection [22]. GCPV systems are versatile and can be applied in various settings, including residential areas. Unlike standalone systems, GCPV systems usually do not require battery backup, as any excess energy produced is automatically fed into the utility grid.

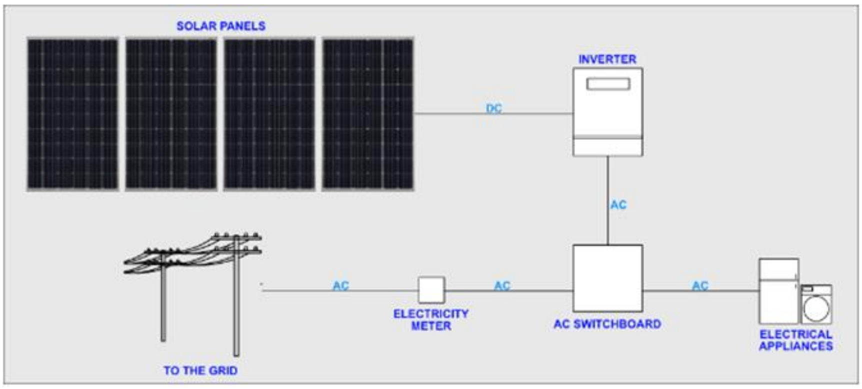


Figure 2.2 Simple Grid-ties and Off-grid System

In residential environments, rooftop solar systems connected to the grid typically have a capacity of around 10 kilowatts, effectively meeting the household's energy requirements. Any surplus energy generated is transmitted into the grid for use by other connected consumers. This excess power transfer is monitored by a metering system. Occasionally, the power output of the PV system may fall short of the household's usual consumption due to various factors, leading the consumer to rely on grid energy.

Solar PV systems are also integrated into large-scale utility projects like wind and solar farms to provide the grid with clean, renewable energy, reducing dependence on fossil fuels and addressing climate change concerns. Challenges arise when incorporating solar PV systems into the grid, including their intermittent and variable nature. However, these challenges can be addressed by implementing energy storage systems and advanced control mechanisms.

2.5.2 Component of PV System

The key components of a solar PV system are the photovoltaic (PV) modules, commonly known as solar panels. These modules are constructed from solar cells composed of silicon, which convert sunlight into electricity. Each solar cell is linked together to form larger units called modules or panels, which can further be combined to create arrays. These arrays are then connected to the electrical grid as part of a comprehensive PV system. Due to their modular nature, PV systems can be tailored to suit various sizes or levels of electricity demand.

2.5.2.1 Type of Solar Panel

There are a variety of photovoltaic modules or solar panels available on the market, including monocrystalline, polycrystalline, and thin film as shown in Figure 2.3.

Monocrystalline panels are typically more efficient than polycrystalline panels, as they are made from single silicon crystal. Meanwhile, thin-film panels offer flexibility and lighter weight compared to crystalline silicon panels [23]. When selecting PV panels for a construction project, factors such as desired rating, installation location, module technology, and datasheet specifications must be considered. Table 2.2 shows the summary of solar panels. As seen in Figure 2.4, sunshine gets turned into electricity by tiny solar cells. These cells are grouped together into solar panels, which are then combined to form a complete solar system that powers homes and businesses.

For instance, when choosing PV modules like the Q.Peak Duo BLK Series 380-400W shown in Figure 2.5, specifications such as power output within the range of 380W to 400W, voltage at Pmax, current at Pmax, open-circuit voltage, short-circuit current, and temperature coefficients of Voc and Isc are crucial. A thorough examination of all specifications is necessary to ensure optimal output [24].

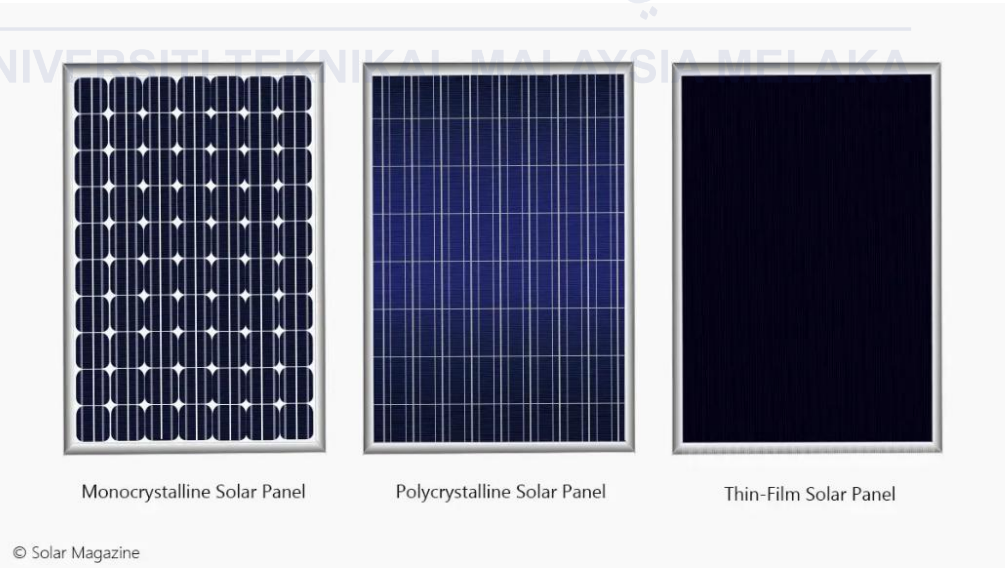


Figure 2.3 Most Common Solar Panel used in Malaysia

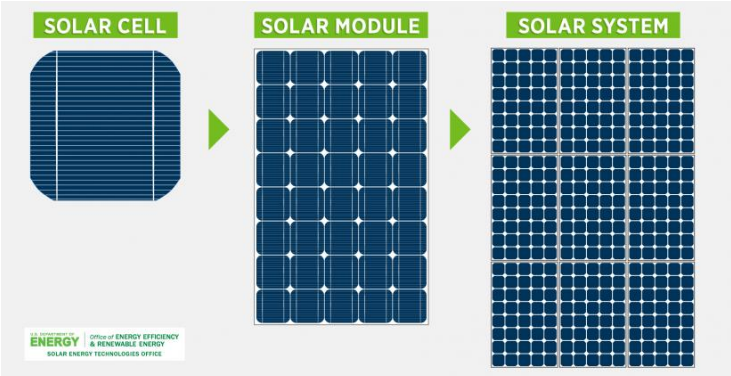
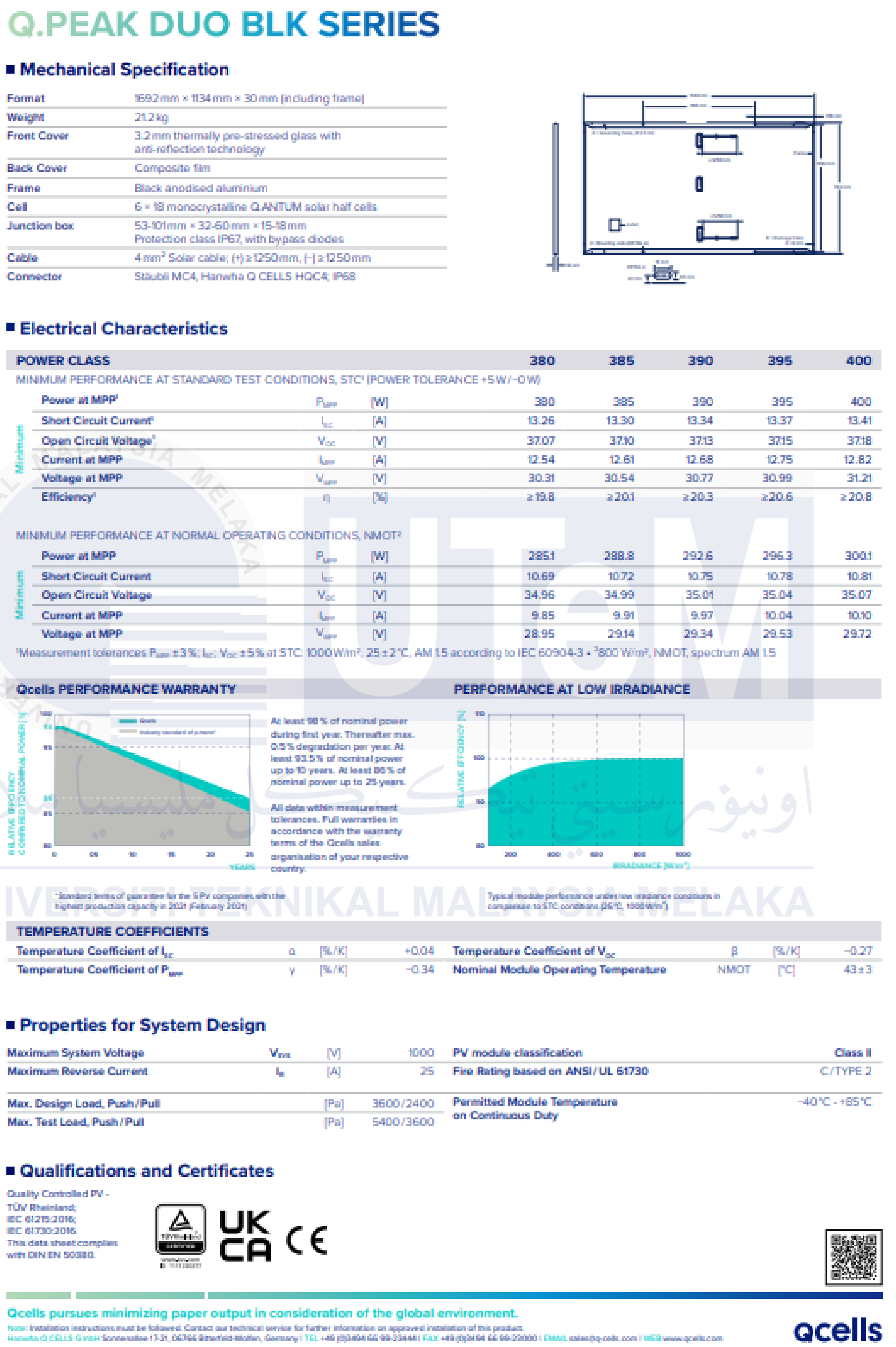


Figure 2.4 Solar Panel

Table 2.2 Summary table of the three most common solar panel types.

Solar Panel Type	Material	Efficiency	Cost	Appearance
Monocrystalline	Pure, single silicon crystal	High (18% or slightly higher)	Highest	Black or blue cells with rounded corners
Polycrystalline	Silicon fragments	Medium (15% - 17%)	High	Blue rectangular cells
Thin-Film	Various	Low (11% but may attain 15%)	Lowest	Black or blue uniform surface



Q.PEAK DUO BLK SERIES

Mechanical Specification

Format	1692 mm × 1134 mm × 30 mm (including frame)
Weight	21.2 kg
Front Cover	3.2 mm thermally pre-stressed glass with anti-reflection technology
Back Cover	Composite film
Frame	Black anodised aluminium
Cell	6 × 18 monocrystalline Q.ANTUM solar half cells
Junction box	53-101 mm × 32-60 mm × 15-18 mm Protection class IP67, with bypass diodes
Cable	4 mm² Solar cable; (+) ≥1250 mm, (−) ≥1250 mm
Connector	Stäubli MC4, Hanwha Q CELLS HQC4; IP68

Electrical Characteristics

POWER CLASS			380	385	390	395	400
MINIMUM PERFORMANCE AT STANDARD TEST CONDITIONS, STC[1] (POWER TOLERANCE +5 W / −0 W)							
Power at MPP[1]	P_{MPP}	[W]	380	385	390	395	400
Short Circuit Current[1]	I_{SC}	[A]	13.26	13.30	13.34	13.37	13.41
Open Circuit Voltage[1]	V_{OC}	[V]	37.07	37.10	37.13	37.15	37.18
Current at MPP	I_{MPP}	[A]	12.54	12.61	12.68	12.75	12.82
Voltage at MPP	V_{MPP}	[V]	30.31	30.54	30.77	30.99	31.21
Efficiency[1]	η	[%]	≥19.8	≥20.1	≥20.3	≥20.6	≥20.8
MINIMUM PERFORMANCE AT NORMAL OPERATING CONDITIONS, NMOT[2]							
Power at MPP	P_{MPP}	[W]	285.1	288.8	292.6	296.3	300.1
Short Circuit Current	I_{SC}	[A]	10.69	10.72	10.75	10.78	10.81
Open Circuit Voltage	V_{OC}	[V]	34.96	34.99	35.01	35.04	35.07
Current at MPP	I_{MPP}	[A]	9.85	9.91	9.97	10.04	10.10
Voltage at MPP	V_{MPP}	[V]	28.95	29.14	29.34	29.53	29.72

[1]Measurement tolerances P_{MPP} ±3%; I_{SC}; V_{OC} ±5% at STC: 1000 W/m², 25±2 °C, AM 1.5 according to IEC 60904-3 • [2]800 W/m², NMOT, spectrum AM 1.5

Qcells PERFORMANCE WARRANTY

At least 98% of nominal power during first year. Thereafter max. 0.5% degradation per year. At least 93.5% of nominal power up to 10 years. At least 86% of nominal power up to 25 years.

All data within measurement tolerances. Full warranties in accordance with the warranty terms of the Qcells sales organisation of your respective country.

PERFORMANCE AT LOW IRRADIANCE

Typical module performance under low irradiance conditions in comparison to STC conditions (25 °C, 1000 W/m²).

TEMPERATURE COEFFICIENTS							
Temperature Coefficient of I_{SC}	α	[%/K]	+0.04	Temperature Coefficient of V_{OC}	β	[%/K]	−0.27
Temperature Coefficient of P_{MPP}	γ	[%/K]	−0.34	Nominal Module Operating Temperature	NMOT	[°C]	43±3

Properties for System Design

Maximum System Voltage	V_{SYS}	[V]	1000	PV module classification	Class II
Maximum Reverse Current	I_R	[A]	25	Fire Rating based on ANSI / UL 61730	C / TYPE 2
Max. Design Load, Push / Pull		[Pa]	3600 / 2400	Permitted Module Temperature on Continuous Duty	−40 °C - +85 °C
Max. Test Load, Push / Pull		[Pa]	5400 / 3600		

Qualifications and Certificates

Quality Controlled PV - TÜV Rheinland; IEC 61215:2016; IEC 61730:2016. This data sheet complies with DIN EN 50380.

Qcells pursues minimizing paper output in consideration of the global environment.

Note: Installation instructions must be followed. Contact our technical service for further information on approved installation of this product.

Hanwha Q CELLS GmbH Sonnenallee 17-21, 06766 Bitterfeld-Wolfen, Germany | TEL +49 (0)3494 66 99-23444 | FAX +49 (0)3494 66 99-23000 | EMAIL sales@q-cells.com | WEB www.qcells.com

Figure 2.5 Datasheet of Q.Peak Duo BLK Series 380-400W

2.5.2.2 Solar Inverter

In a PV system, the inverter plays a crucial role by converting the direct current (DC) generated by solar panels into alternating current (AC), which can be utilized by the electrical grid or local off-grid electrical systems. A block diagram of the solar panel inverter is depicted in Figure 2.6. It ensures that the PV modules consistently operate at their maximum power point, monitors the overall energy yield of the PV system, and alerts users to any potential issues. Additionally, the inverter keeps a close watch on the power grid it's connected to and, as a safety measure, disconnects the PV system from the grid if any problems arise [25]. Various types of inverters are employed in PV systems, including string inverters, microinverters, power optimizers, and central inverters. String inverters, shown in Figure 2.7, are the most common type and connect multiple panels to a single inverter. Microinverters, as illustrated in Figure 2.8, are smaller inverters installed on each panel, known for their simplicity in system design, reduced amperage wires, efficient stock management, and enhanced safety. Large-scale PV systems typically utilize central inverters, engineered to manage a vast number of panels. In off-grid systems where the inverter derives its DC energy from batteries charged by photovoltaic arrays, standalone inverters are utilized.

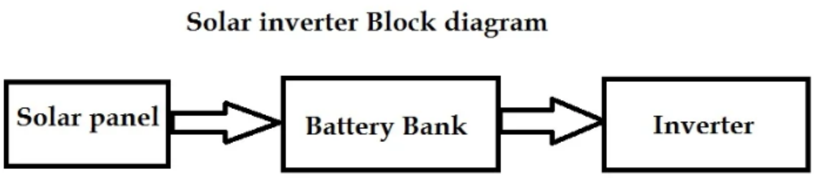


Figure 2.6 Block Diagram Of Solar PV

Figure 2.7 SMA Sunny Boy 7-US 700 String Inverter

Figure 2.8 Enphase IQ7 Microinverter(MC4)

2.5.2.3 Wiring Configuration

Wiring plays a crucial role in PV system design, requiring outdoor-rated wiring capable of handling the system's amperage. Three main wiring configurations are utilized for PV modules: series, parallel, and series parallel. Central to solar panel wiring is the concept of the "solar panel string," where multiple PV modules are interconnected in series or parallel. Solar panels are equipped with positive and negative terminals for series connection. In Figure 2.9, the process of wiring solar panels in series is demonstrated by linking the positive terminal of one module to the negative terminal of the next, boosting the output voltage measurable at the terminals. Alternatively, when solar panels are wired in parallel, the output current increases while voltage remains constant, with the total output current being the sum of currents generated by all modules in the string. Series-Parallel Connection combines both series and parallel connections, illustrated in Figure 2.10, by wiring solar panels in parallel and series to increase voltage. It's essential for all parallel-connected solar panel strings to maintain consistent voltage. To ensure optimal system performance, modules must be of the same model throughout.

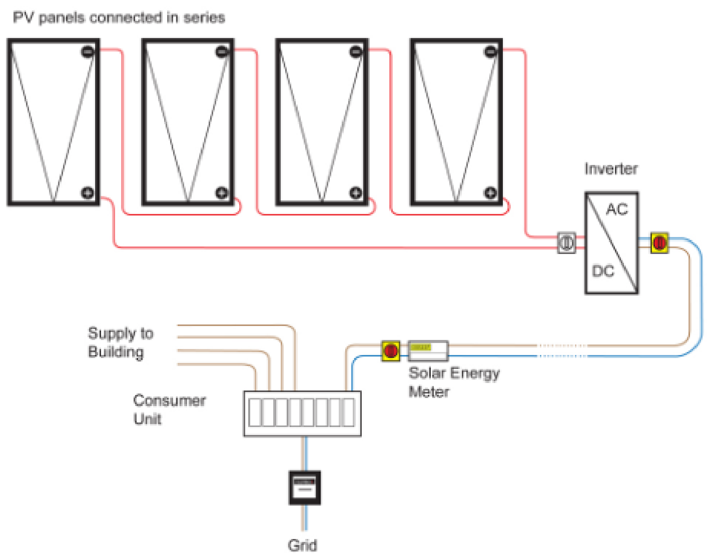


Figure 2.9 PV Panels Connected In Series For Grid-Tied Installation

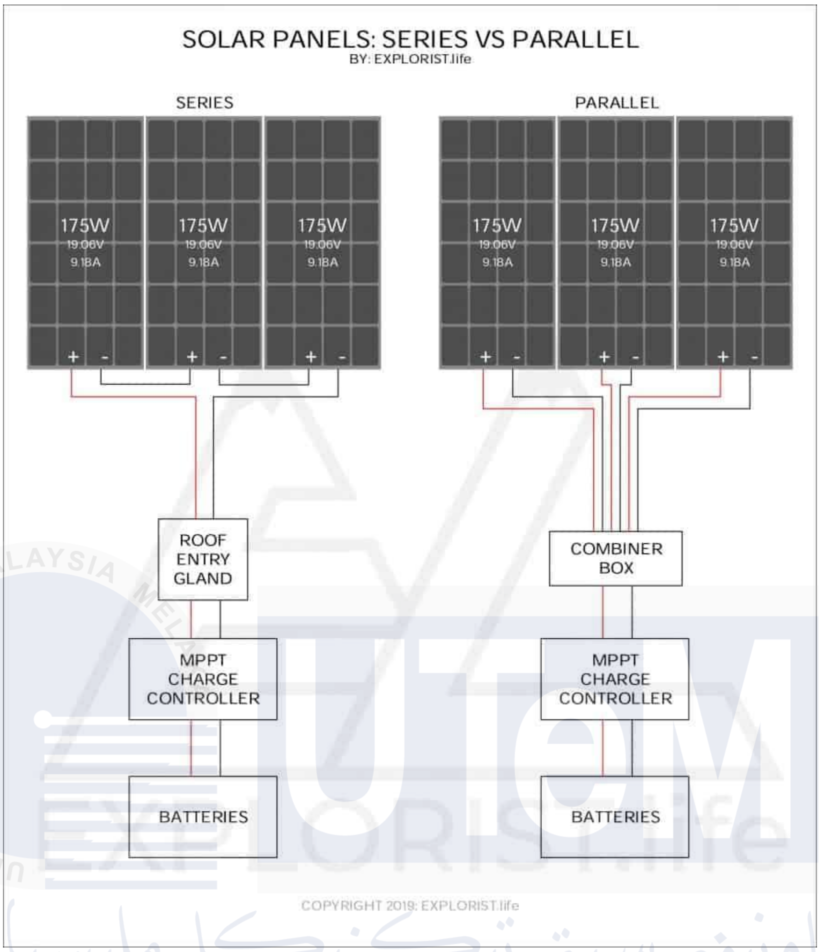


Figure 2.10 Series And Parellel Solar Panel Wiring

2.5.2.4 Comparison between BIPV and BAPV

Mounting plays a crucial role in PV system design, requiring sturdy structures capable of enduring years of exposure to various environmental elements. A range of mounting options exists for PV arrays, including building applied photovoltaics (BAPV), ground-mounted racks, pole-mounted racks, building integrated photovoltaics (BIPV), and tracking systems. Mounting surfaces for PV components must be robust and sufficient to support the array's weight. Building applied photovoltaics (BAPV) are the most common type of mounting structure, typically installed a few inches above the roof surface in parallel. They are often found in large-scale utility PV stations, secured by ground-based supports and racks. In situations where space is limited, pole-mounted racks with panels attached to a single pole are utilized. Building integrated photovoltaic (BIPV) systems are directly integrated into building materials like roofing, windows, and facades. Tracking systems optimize energy production by adjusting the angle of the PV array to track the sun's movement. Figure 2.11 provides a comparison between BIPV and BAPV [26].

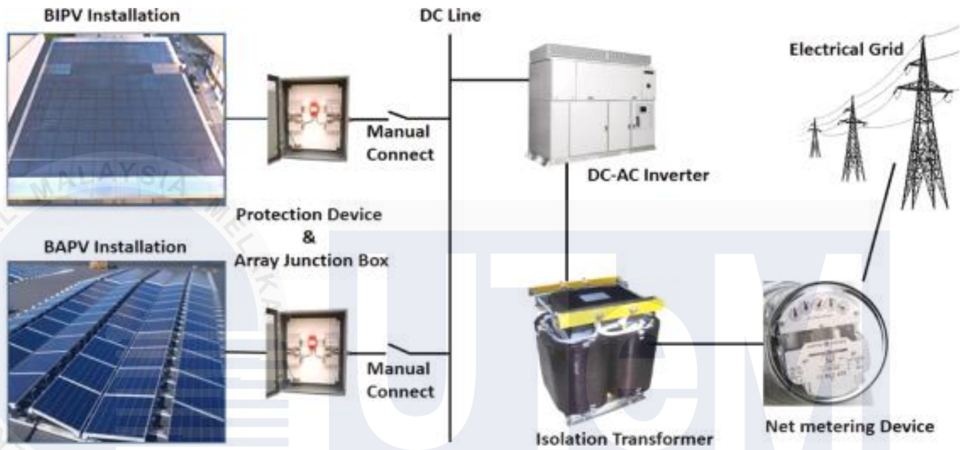


Figure 2.11 Classification of Bipv and Bapv

Cabling is a critical element in PV system design, essential for transferring DC solar energy within the system and linking solar panels and arrays in a solar power network. These cables, equipped with suitable connectors, are often pre-installed in the panels. Typically, three types of solar cables are used in a PV system: DC solar cables, Solar DC main cables, and solar AC connection cables. Solar main DC cables, favored for outdoor installation, typically come in sizes like $2mm^2$, $4mm^2$, and $6mm^2$. Various types of cables are necessary to complete a solar power project. Figure 2.12 depicts a DC $6mm^2$ cable for solar panel systems. DC cables connect PV panels and inverters, including junction boxes, while AC cables link inverters and substations. To mitigate grounding and short circuit risks, it's advisable to lay cables with opposite polarities separately.

Figure 2.12 6DC 6mm² Solar PV Cable For Solar Panel System

2.5.2.5 Battery Bank

A crucial element of a solar PV system is the battery bank, which stores excess energy generated during daylight hours for later use during nights or overcast days. Lead-acid batteries are the most used type in such systems. Table 2.3 provides a comparison of available battery banks in the market. In case of power disruptions, battery storage can serve as a backup power source. Selecting the right battery bank for a solar PV system involves determining the system's watt-hour consumption. Additionally, investing in high-quality batteries is vital to uphold system reliability and minimize the likelihood of performance decline.

Table 2.3 Comparison of available battery banks in the market.

Specification	Lead-Acid	Lithium-Ion
Specific energy (Wh/kg)	30-50	90-12
Internal resistance	Very low	Very low
Life cycle (80% Depth of Discharge)	200-300	1000-2000
Charge time	8-16 hours	1-2 hours
Overcharge tolerance	High	Low
Self-discharge/month (room temperature)	5%	<5%
Cell voltage (nominal)	2V	3.2V-3.3V
Maintenance requirement	36-months	Free
Cost	Low	High
Safety requirement	Thermal stable	Protection circuit mandatory
Environmental	Not eco-friendly	Eco-friendly

2.5.2.6 DC to DC Converter

The DC-to-DC converter, sometimes referred to as a power optimizer, is created to maximize the ability of solar and wind turbines to capture energy. It is important to raise or lower the input panel voltage until the desired battery level is reached. The three main components of the DC-to-DC converter circuit are the inductor, the capacitor, and the MOSFET.

2.6 Microcontroller

A microcontroller is an integrated circuit (IC) designed to manage different aspects of an electronic system. It achieves this by incorporating memory, peripherals, and a microprocessor unit (MPU). Microcontrollers are tailored for embedded applications, providing computational power and precise, efficient interaction with electronic, digital, or analog components.

2.6.1 Arduino UNO

Modern microcontrollers are available in a wide range of types, with one of the most popular and user-friendly development boards being the Arduino. There are numerous kinds and models of Arduinos, each offering distinct computing capabilities and interface features. The Arduino UNO's construction is seen in Figure 2.13.

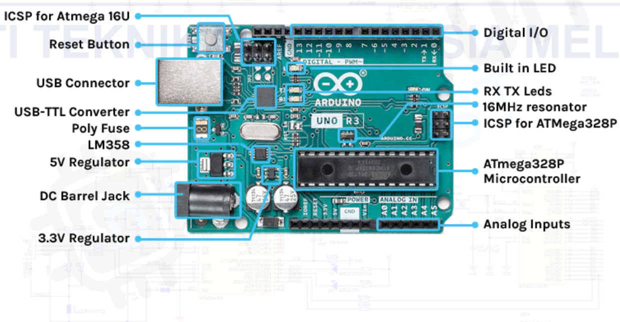


Figure 2.13 The Structure of Arduino UNO

The Arduino UNO is a microcontroller board based on the ATmega328P. It features 6 analog inputs and 14 digital input/output pins, 6 of which can be used as PWM outputs. Additional features include a 16 MHz quartz crystal, a USB port, a power connector, an ICSP header, and a reset button. It has everything needed to support the microcontroller, requiring only a USB connection to a computer, an AC-to-DC adapter, or a battery to operate.

2.6.2 NodeMCU ESP8266

The NodeMCU (Node MicroController Unit) is an open-source platform built on the affordable ESP8266 System-on-a-Chip (SoC). Developed by Espressif Systems, the ESP8266 integrates all essential computer components, including a CPU, RAM, WiFi networking capabilities, and even a modern operating system and software development kit (SDK). This all-in-one design makes the ESP8266 an ideal choice for various Internet of Things (IoT) projects. Figure 2.14 illustrates the structure of ESP8266.

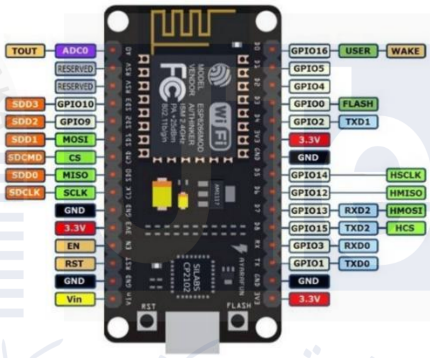


Figure 2.14 The Structure of ESP8266

2.6.3 Raspberry Pi

The Raspberry Pi is a compact and affordable computer, roughly the size of a credit card, which can connect to a display or television and be used with a standard keyboard and mouse. This powerful little device allows people of all ages to learn about computing and programming in Python and Scratch. It can perform typical desktop tasks such as browsing the internet, watching high-definition videos, creating spreadsheets, word processing, and even playing games. The Raspberry Pi board includes a CPU, a graphics chip, and RAM. It also features an Ethernet port, GPIO pins, an Xbee socket, a UART, and a power connection, along with multiple interfaces for various external devices. Mass storage is provided by an SD flash memory card, allowing the Raspberry Pi to boot from the SD card similarly to how a traditional computer boots from its hard drive. Figure 2.15 illustrates the structure of the Raspberry Pi.

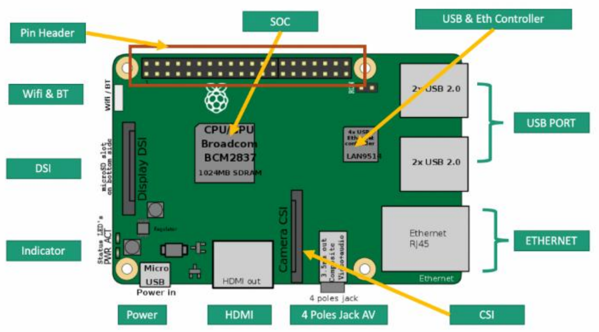


Figure 2.15 The Structure of Raspberry Pi

2.7 Summary

This chapter discusses the previous related studies. The focus of this research is on smart home security devices. Extensive research has been conducted to ensure that all components selected are suitable for use in Malaysia. Various types of solar panels have been investigated to determine the most efficient ones for power generation. Additionally, different types of charge controllers have been explored to identify the most suitable option for this project. Based on previous research, it was found that modern sealed lead acid batteries are commonly used for storing electricity.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter highlights the methodology of the project. The development of the hardware and software for this project is split into two separate phases. For the project to succeed and to produce the required results, the technique is crucial. For a better understanding of the process, flowcharts and block diagrams are used in this chapter to define and illustrate the project's development process.

3.2 Methodology

This project will use a variety of techniques to accomplish the goals, including reading materials, the creation of a standalone solar PV, and a smart home security device. The system is created in stages, starting with the search for the project title, the identification of the problem statement, project goals, and scope, followed by a literature search, the creation of the hardware and software, and finally the gathering of data. In this part, all the applied techniques, tools, and software utilized for this project are described. The whole project development flowchart is shown in Figure 3.1.

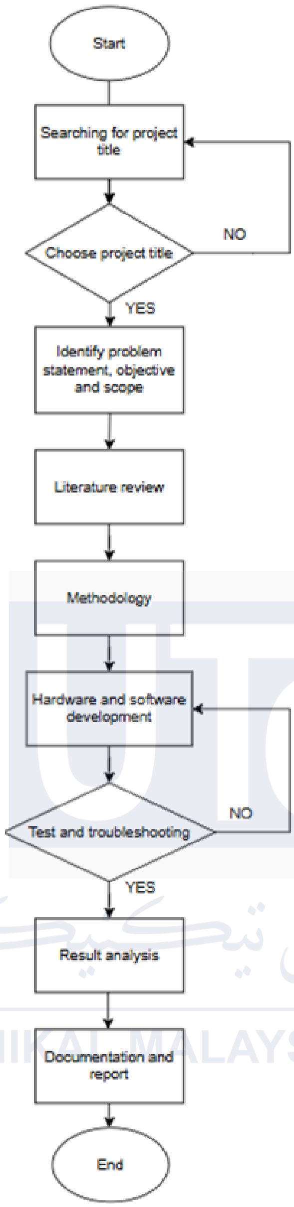


Figure 3.1 The Flowchart of The Overall Project

3.3 Project System Flowchart

The objective of the project system flowchart, illustrated in Figure 3.2, is to represent the operational mechanics of the system. A motion sensor in this home security system generates notifications that are transmitted to your phone through Blynk app. Live camera footage can be accessed using a mobile application, which will notify you upon detecting movements using PIR sensor. The app enables a remote control of the lights, contingent upon the user's desire to activate them or trigger an alert in reaction to an intruder. The system also includes an MQ2 sensor for gas leak detection. When petrol levels surpass 50%, a warning notification is dispatched to the Blynk app, and the exhaust fan and buzzer are instantly engaged. These components will become inoperative when the gas level falls below 45%. Additionally, a DHT11 sensor is incorporated to measure temperature and humidity in the bedroom, with real-time data presented on the Blynk app for remote monitoring and control.

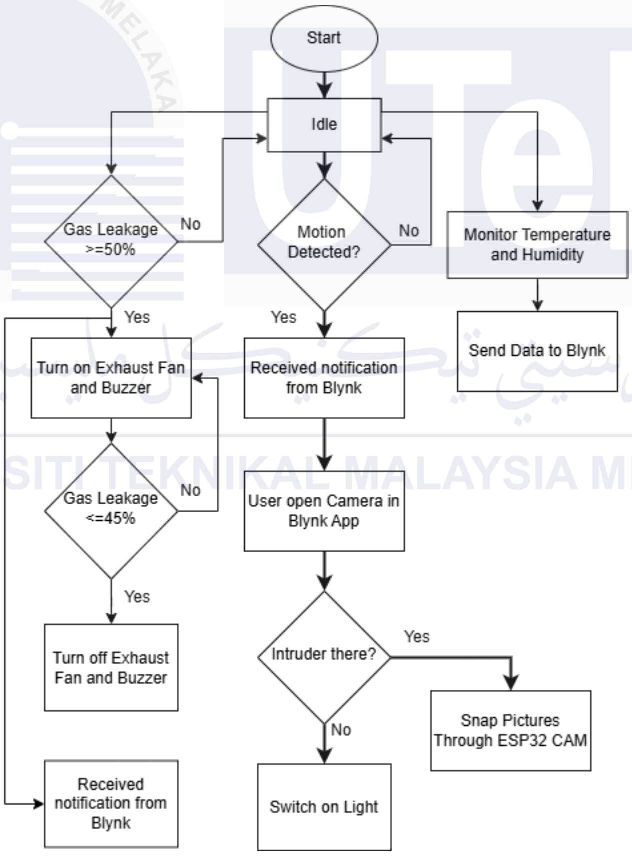


Figure 3.2 The Flowchart of Smart Home Security Device

3.4 Block diagram of standalone PV solar

As illustrated in Figure 3.3, photovoltaic (PV) solar panels use sunlight from the sun to create direct current (DC) electricity. The batteries will be charged by the charge controller so that the load can have electricity during the day or at night.

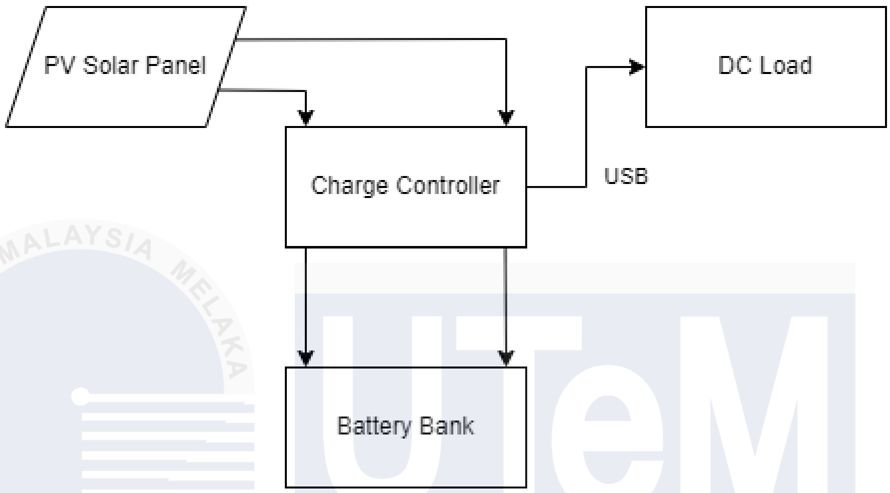


Figure 3.3 Block Diagran of Standalone PV Solar

3.5 Block Diagram of Overall System

Figure 3.4 presents a block diagram of an independent smart home security system powered by a photovoltaic (PV) solar array. The system incorporates multiple sensors, such as a PIR motion sensor, a DHT11 temperature and humidity sensor, and an MQ2 gas sensor, to assess ambient conditions and identify potential hazards. The sensor readings are relayed to an ESP8266 microcontroller, which processes the data and interfaces with the Blynk cloud platform. Blynk facilitates remote surveillance and management, permitting users to get alerts and modify system configurations from a distance. The system integrates actuators, including an exhaust fan, LED lamp, and buzzer, which are controlled by the microcontroller according to sensor data and user inputs. This integrated method, utilizing renewable solar energy, offers a thorough and sustainable solution for improving home security and environmental awareness. illustrated in Figure 3.4, the standalone PV solar supplies power to the Arduino UNO to operate it. When the PIR sensor detects the movement, it will transmit the data to the Blynk. Blynk will process the data and transmit the output to ESP8266 which will send a notification to the user.

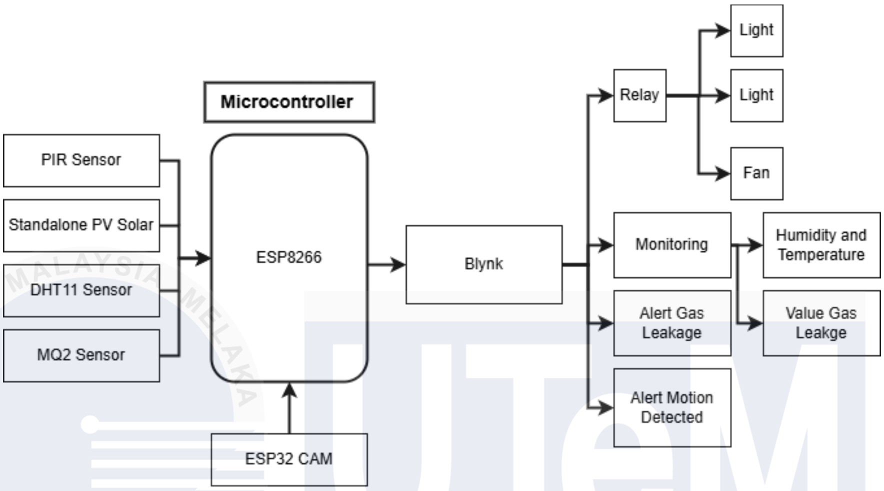


Figure 3.4 Block Diagram of Smart Home Security Device

3.6 Software Development

The software used to build this project, including Arduino IDE, Proteus 8 Professional, and Blynk, will be covered in this part. These programs are used for coding, simulation, and circuit design.

3.6.1 Arduino IDE

Most Arduino modules can be programmed, assembled, and uploaded with the help of the open-source Arduino IDE application. There is software available for the Arduino Leonardo, Arduino UNO, Arduino Mega, Arduino Micro, and other Arduino boards. Using the primary code often referred to as a sketch created on the IDE platform, a Hex File can be uploaded to the board's controller.

Furthermore, the two essential components of the IDE environment are the Editor and the Compiler. After the pertinent code is written in the Editor, it is compiled and uploaded to the Arduino Module by the Compiler. This software supports the C and C++ programming languages. Figure 3.5 shows the software for the Arduino IDE.

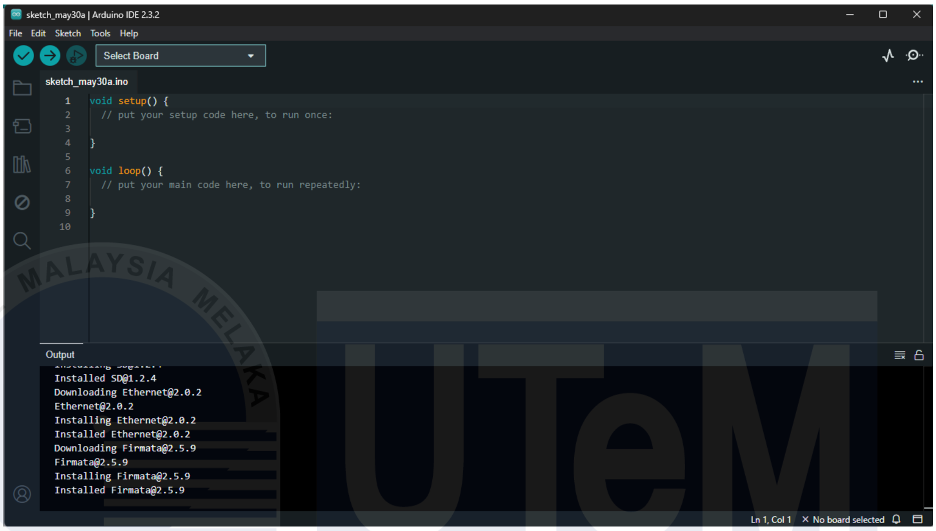


Figure 3.5 Arduino IDE Software Interface

3.6.2 Proteus 8 Professional

The main uses for Proteus, also referred to as Proteus 8 Professional, are schematic simulations and PCB layout design. This software is particularly helpful for creating and testing programming programs because of its many microcontroller libraries. In this project, Proteus is used to design and simulate the circuit before it is attached to the hardware. In Figure 3.6, the Proteus 8 Professional software is shown.

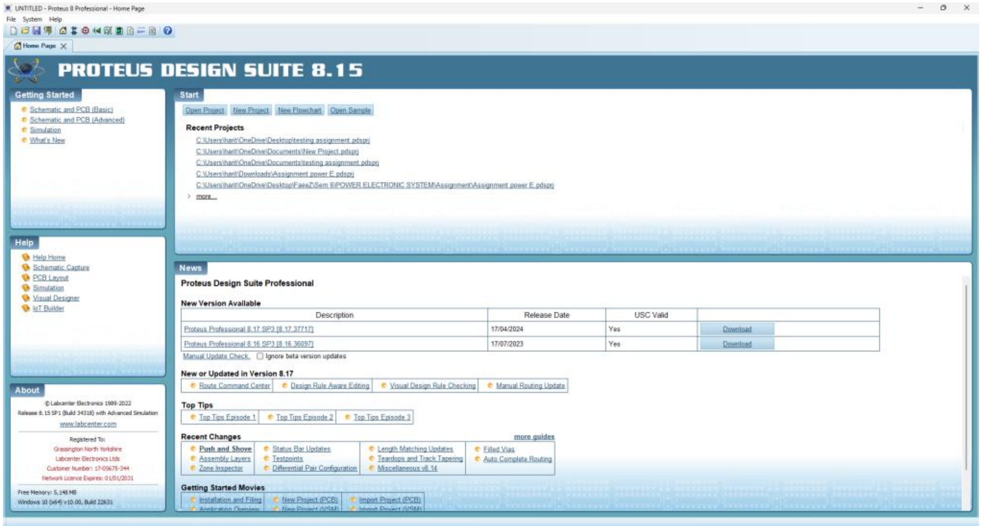


Figure 3.6 Proteus 8 Professional Software Interface

3.6.3 Blynk Application

One popular platform for building smartphone apps to control Internet of Things (IoT) devices is called Blynk. It provides an easy-to-use interface in addition to a few tools and frameworks that simplify the process of creating mobile applications for managing hardware such are the ESP8266, Arduino, Raspberry Pi, and numerous more. Using Blynk, you may develop original mobile apps that establish an online connection with your physical devices. You may customize the app's user interface and add buttons, sliders, graphs, and other UI components to manage and display data from your connected devices using the platform's drag-and-drop interface.

Blynk provides a cloud-based architecture to manage the connection between your mobile app and the hardware. It uses a simple protocol that allows for instantaneous communication with the devices. Sensors or other source data may be used to program and update the hardware. In Figure 3.7, the Blynk program is displayed.

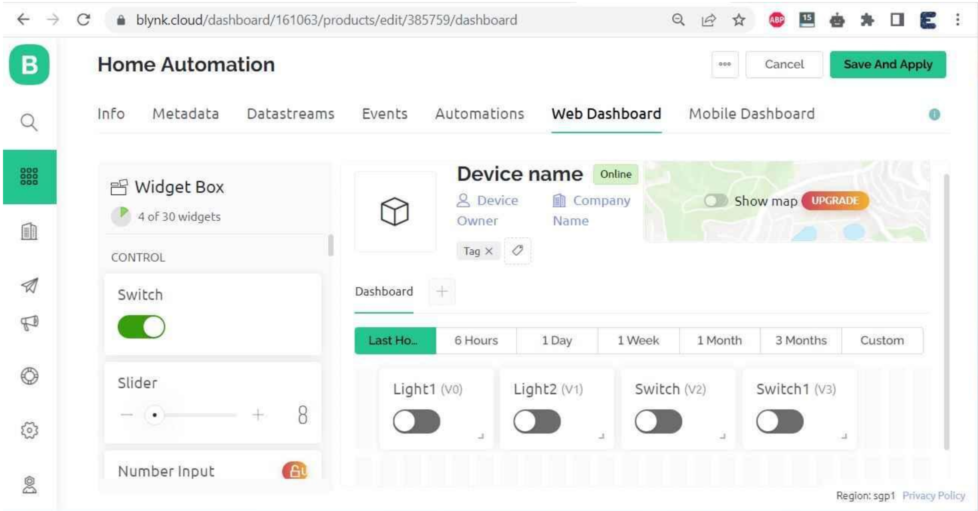


Figure 3.7 Blynk Website Interface

3.7 Hardware Development

Any project requires hardware, but technology and engineering projects especially require hardware. The project's hardware is in charge of carrying out its essential functions. An idea or concept would be all that the project would be without hardware. Hardware is needed to convert theoretical notions and ideas into feasible, real implementations, even while software is crucial for managing and programming the simulation. It makes it possible to put the project's features and functionality through real-world testing, validation, and demonstration.

3.7.1 ESP8266

As shown in Figure 3.8, ESP8266 is a 32-bit MCU that can connect wirelessly to microcontroller-based applications thanks to a variety of peripherals and Wi-Fi capabilities. It supports IEEE 802.11 b/g/n standards and may be programmed using the Arduino IDE or other platforms. The ESP8266 is widely used in IoT applications and is perfect for home automation, environmental monitoring, and remote-control systems because of its low cost, compact size, and Wi-Fi connectivity.

Figure 3.8 ESP8266 Board

3.7.2 PIR Sensor

As shown in Figure 3.9, the infrared (IR) radiation that objects within the field of view of a passive infrared (PIR) sensor emit is measured in for the purpose of identifying mobility. The sensor detects a change in infrared levels when an object, like a human, moves inside its detection range. After that, the sensor signals a linked microcontroller, such as an Arduino, to initiate a suitable action, like turning on a light, sounding an alert or sending a notification to the smartphone. Because of its low power consumption, dependability, and simplicity of integration, PIR sensors are frequently employed in autonomous lighting and security systems.

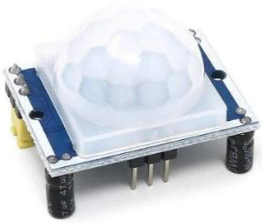


Figure 3.9 Passive Infrared Sensor (PIR Sensor)

3.7.3 Relay Module

A relay module as shown in Figure 3.10, functions as an electrically actuated switch on a microcontroller, such as an Arduino, to provide control over high-voltage devices. Relays, transistors, diodes, and optocouplers are commonly found in the module, which offers electrical isolation between the high-voltage load and the low-voltage control circuit. The relay is triggered by a low-voltage signal from the microcontroller to the relay module, which closes the circuit and permits current to go to the high-voltage device. Using the low-power signals from the microcontroller, this configuration permits safe control of appliances such as lights, motors, and other heavy-duty electrical devices.

Figure 3.10 Relay Module

3.7.4 Buzzer

A buzzer is a small sound signaling device that is frequently utilized in games shows, sports, electronics, and other fields. A buzzer is shown in Figure 3.11. It creates a continuous or sporadic buzzing sound by converting electrical signals into sound. Buzzers are employed in electronics as timers, alerts, and notifications. Contestants on game shows press a buzzer to signal when they're ready to respond to a question. Buzzers signal the end of a time limit or period in sports. In this project, buzzers are used to warn an intruder in the house.

Figure 3.11 Buzzer

3.7.5 Camera

The ESP32-CAM is an economical, Wi-Fi-capable microcontroller board featuring an integrated camera module, rendering it an optimal selection for smart home security systems. Its principal application in these systems is for real-time video surveillance, wherein it takes live video or still images and sends them via a Wi-Fi network. This allows homeowners to remotely oversee their property through cellphones or computers, ensuring continuous awareness of activity surrounding their residence. The ESP32-CAM can also be programmed for motion detection and artificial intelligence integration. Utilising tools such as TensorFlow Lite or OpenCV enables the identification of motion and the initiation of particular activities, including issuing alerts, triggering alarms, or recording footage. Figure 3.12 is feature boosts security by targeting suspicious activity and optimises power consumption by functioning only when required.

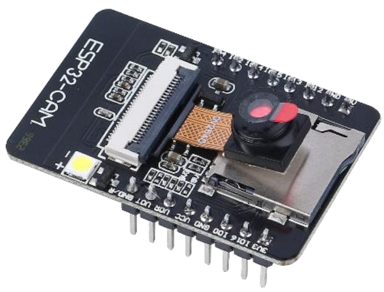


Figure 3.12 ESP32 CAM Board

3.7.6 MQ2 Sensor

The MQ2 sensor is a gas detector utilized for identifying smoke, combustible gases, and vapours such as LPG, methane, and hydrogen, rendering it extremely appropriate for smart home security systems as shown in Figure 3.13. In these systems, the MQ2 sensor is employed for fire and gas leak detection, continually monitoring air quality and activating alarms or notifications upon the discovery of hazardous gases or smoke, thereby ensuring occupant safety. Furthermore, it can be combined with IoT platforms to transmit real-time notifications to smartphones or other devices, enabling homeowners to respond promptly to situations, such as gas leaks or probable fires, thereby improving overall home safety.

Figure 3.13 MQ2 Sensor

3.7.7 DHT11 Sensor

The DHT11 sensor is a device for measuring temperature and humidity, specifically utilised for monitoring environmental conditions in smart home systems, as illustrated in Figure 3.14. The DHT11 sensor is positioned in the bedroom to monitor temperature and humidity, with real-time data presented on the Blynk application. This enables users to remotely oversee and sustain ideal indoor conditions, guaranteeing comfort and a healthy living environment. The integration with Blynk improves ease and accessibility, facilitating efficient climate management straight from a smartphone or other connected device.

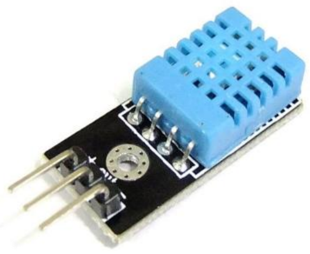


Figure 3.14 DHT11 Sensor

3.8 Component of Standalone PV solar System

The solar photovoltaic system is the most important component of the project since it will provide the electricity needed to run the flood monitoring apparatus. The development of PV solar requires the use of several components, including battery banks, charge controllers, and solar panels.

3.8.1 Monocrystalline Solar Panel

A monocrystalline silicon solar panel consists of a single, continuous silicon crystal, generating greater efficiency (18-22%) and a refined black aesthetic. In contrast, polycrystalline panels, composed of multiple fused silicon crystals, exhibit lower efficiency (15-18%) and a mosaic blue appearance. Monocrystalline panels are costlier yet exhibit superior longevity and efficiency in low-light conditions, whereas polycrystalline panels are more economical but offer diminished performance and reduced lifespans. The solar panel for this project, characterised by Isc = 0.6A, Voc = 22.28V, and a peak power of 10W, is a standard monocrystalline panel capable of producing a maximum power output of 10 watts in ideal sunlight conditions. Figure 3.15 illustrates a monocrystalline solar panel.

Figure 3.15 Monocrystalline Solar Panel

3.8.2 Sealed Lead Acid Battery

A sealed lead-acid (SLA) battery is a rechargeable battery that employs an electrolyte solution and lead plates for the storage and discharge of electrical energy. In contrast to conventional lead-acid batteries, SLA batteries need minimal maintenance, making them suitable for applications such as backup power systems and emergency lighting. They can withstand numerous deep discharges without considerable harm and are offered in diverse sizes. An illustration is the GP Back Up Battery 12V 7.2 AH Rechargeable Sealed Lead Acid VRLA Battery, including a voltage of 12V, a nominal capacity of 7.2AH, dimensions of 151 x 65 x 94mm, and a weight of 2.2kg. Although SLA batteries are reliable, they include toxic substances such as lead and sulphuric acid, necessitating careful handling and responsible disposal. Figure 3.16 illustrates a sealed lead-acid (SLA) battery.

Figure 3.16 Sealed Lead-Acid (SLA) Battery

3.8.3 Intelligent Charge Controller

The charge controller uses the battery to connect the solar panel to the storage batteries. To avoid overcharging, which could damage the battery, it controls the amount of power coming from the solar panel. The charge controller also guards against possible harm to the system and guarantees effective power transfer. The maximum solar wattage requirements for the model utilized in this project are 10A, 12V 120W, 24V 240W, and a 5V 3A USB output for external device powering. Figure 3.17 shows the solar charge controller for the photovoltaic system.

Figure 3.17 Solar Charge Controller

3.9 Solar and Battery Configuration

Configuring solar and battery systems so that the battery can act as a backup power source in the event of nocturnal solar activity is essential to ensuring the achievement of project goals. For the load to operate and function properly, this arrangement of solar panels and batteries is essential. Consequently, a series of calculations has been carried out to increase the accuracy of the photovoltaic and battery setup.

1. **Load details:**

Pir Sensor: 0.05mW × 24h = 1.2mW

2 LED: 6W × 6h = 36W

Fan: 3.6W × 0.25h = 0.9W

MQ2 Sensor: 0.8W × 24h = 19.2W

ESP32 Cam: 33.5mW × 24h = 0.804W

ESP8266: 0.231W × 24h = 5.54W

Total Load = 1.2mW + 36W + 0.9W + 19.2W + 0.804W + 5.54W

= 62.45W

2. System specific requirement:

Energy usage (per day) = 62.45Wh

Depth of Discharge (DoD) = 50%

Days of Autonomy (DoA) = 2 days

Battery Bank Temperature Multiplier (BBTM) = 1

Peak Sun Hour (PSH) = 4 Hours

3. System specific requirement:

The output power of solar panel

= Energy usage (per day) ÷ PSH ÷ system efficiency

= 62.45Wh ÷ 4 hours ÷ 0.85

= 18.37W

Monocrystalline solar panel size = 10W

Therefore, 18.37W ÷ 10W = 1.837 ≈ 2 Solar panels

4. Battery Bank Capacity:

= (Daily Average × DoA × BBTM) / DoD

= (62.45 × 1 × 1.05) / 0.5

= 141.65Wh

5. Battery Bank:

= (Battery bank capacity) / (Battery voltage)

= 141.65 / 12

= 11.80Ah

= 11.80Ah / Battery Ah = 11.80Ah / 7.2Ah

= 1.64 ≈ 2 Battery

The estimate completed in the preceding section can be interpreted in two ways: the number of solar panels and batteries required for this project. It is obvious that the maximum number of solar panels to be used is two, while the maximum number of batteries used is two. To achieve the project's objectives, the two batteries will be configured in parallel to increase operating current and extend usable life (in Ah).

3.10 Cost and Bill of Materials

Table 3.1 Cost and Bill of Materials for Overall Project

No.	Material	Description	Quantity	Price (RM)
1.	12V, 10W Monocrystalline Solar Panel	1 unit = RM43.18	1	43.18
2.	12V,7.2A Sealed Lead Acid Battery (SLA) GP	1 unit = RM36.44	1	36.44
3.	NodeMCU ESP8266 (LoLin V3) + Board USB	1 unit = RM19.90	1	19.90
4.	DC 12V 2pin Brushless Fan	1 unit = RM9.90	1	9.90
5.	HC-SR501 PIR Sensor	1 unit = RM5.90	1	5.90
6.	DHT11 Sensor	1 unit = RM4.90	1	4.90
7.	Breadboard (Large)	1 unit = RM3.90	1	3.90
8.	Active Buzzer Tone	1 unit = RM1.50	1	1.50

9.	Relay Module (4Way/5V)	1 unit = RM13.40	1	13.40
10.	MQ2 Sensor	1 unit = RM6.50	1	6.50
11.	ESP32 Cam	1 unit = RM29.90	1	29.90
12.	Solar Panel Controller	1 unit = RM15.88	1	15.88
13.	Male to Female Jumper (40pcs)	1 unit = RM4.60	1	4.60
14.	Male to Male Jumper (65pcs)	1 unit = RM5.60	1	5.60
15.	Female to Female Jumper (40pcs)	1 unit = RM3.36	1	3.26
16.	FTDI – USB to TTL Serial (TX/RX) Converter	1 unit = RM7.88	1	7.88
17.	12V LED	1 unit = RM2.30	2	2.30
Total (RM)				**214.94**

3.11 Project Design and Installation

Figure 3.18 provides insight into the project's installation procedure, particularly emphasizing the use of polyplastic board. The first image illustrates the preliminary phase of material preparation, presumably entailing the measurement and cutting of polyplastic board sheets to the specified dimensions for the enclosure. The second illustration illustrates the next phase of enclosure assembly, in which the cut polyplastic board segments are being organized and presumably joined to create the housing for the smart home security equipment. The assembly procedure will be succeeded by the integration of electronic components within the polyplastic shell, encompassing wiring and interconnections.

Figure 3.18 Cutting process of the polyplastic to the first step of model Smart Home Security Device

Figure 3.19 illustrates the second phase of the project, which entails the assembly and integration of components within the polyplastic shell. The interior components include an MQ2 sensor (presumably for gas detection), a PIR sensor (for motion detection), a DHT11 sensor (for temperature and humidity measurement), an exhaust fan for ventilation, an LED bulb and a buzzer for alarms. The electrical components are interconnected by wires, and the wiring harness is discernible within the container. This step illustrates the amalgamation of diverse sensors and actuators to establish a working smart home security system.

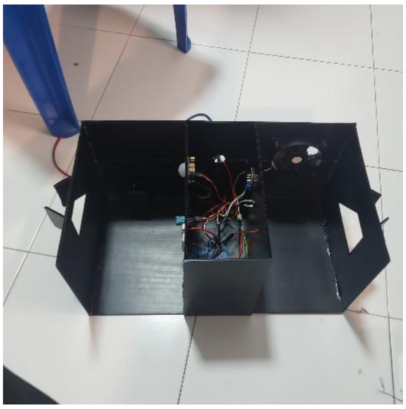


Figure 3.19 The second phase of assembly process with connection sensors and component

Figure 3.20 illustrates the final assembly phase of the smart home security device project, which integrates a solar photovoltaic (PV) system for energy generation. The left figure depicts the system's internal components, comprising a solar charge controller, a battery, and electrical connections. The image on the right displays the entire assembly with the solar panel affixed to the enclosure. The incorporation of the solar PV system allows the gadget to function autonomously from grid power, rendering it a sustainable and dependable solution. This last assembly phase signifies the successful culmination of the project and the incorporation of renewable energy technology.

Figure 3.20 Final model of the project Smart Home Security Device

3.12 Circuit Design for Project Smart Home Security Devices

The circuit design for the smart home security device, simulated with Proteus, employs a NodeMCU ESP8266 microcontroller as the central processing unit. The integrated components comprise a buzzer, MQ-2 gas sensor, PIR motion sensor, DHT11 sensor, ESP32 CAM, a relay module for managing high-current devices, and actuators including an exhaust fan and LED lamp. The microcontroller acquires data from sensors, processes the information, and regulates actuators according to programmed logic. Figure 3.21 shows the complete circuit of the project without circuit solar Photovoltaic system.

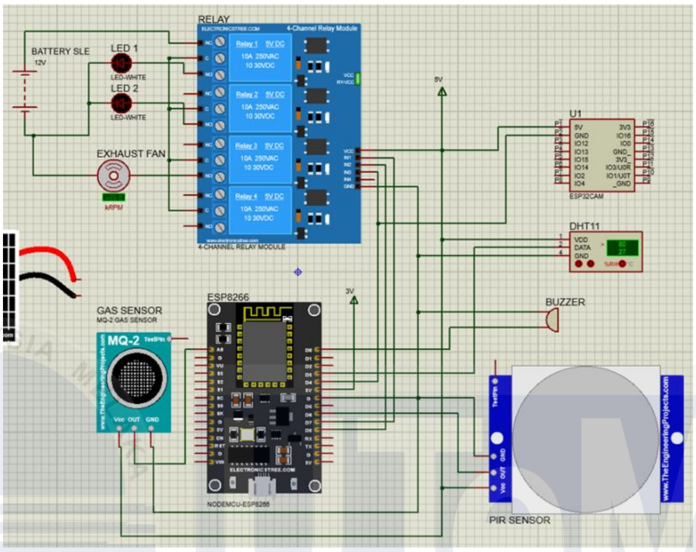


Figure 3.21 Circuit of the Smart Home Security Devices without a solar circuit system

3.13 Summary

This chapter outlines the methods utilized in the development of photovoltaic solar energy-powered smart home security equipment. It defines a combination of hardware and software elements, encompassing the NodeMCU ESP8266 microcontroller, sensors, and the Blynk application. The design of the system is illustrated by flowcharts and block diagrams, demonstrating the standalone photovoltaic solar system's capacity to energize the security device. The chapter additionally discusses the hardware components, including the MQ2 gas sensor, DHT11 temperature and humidity sensor, PIR motion sensor, and ESP32-CAM, as well as the solar power configuration. The combination of Arduino IDE, Proteus 8 Professional, and the Blynk application for programming, simulation, and monitoring guarantees uninterrupted functionality. The chapter finishes with a summary of the system design, cost assessment, and installation procedure.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter explains the project’s hardware and software development as well as the outcome and analysis of the Smart Home Security Device Using Photovoltaic Solar development. Every test has been completed in the period given to complete this project. It is very successful in terms of how well the equipment worked as well as how easily the software has been installed and uploaded to ESP8266 and ESP32 CAM. Even if there were lots of accidents that occurred during testing, it is very satisfying when the project has finished and prepared for presentation.

4.2 Project Testing Result

Over the course of four consecutive days, from December 24, 2024, to December 27, 2024, tests were conducted to assess the system's performance and collected more accurate data. In addition, the data collection process has been carried out every two hours for a total of twelve hours between 8 a.m. and 6 p.m. By following this procedure, the solar panel was able to receive the maximum amount of sunshine and function as planned. An output side load has also been attached to verify the battery bank's efficiency based on the computation.

$$P = VI \qquad \text{(Eq 1)}$$

Where P = Solar panel power (W)

V = Solar panel voltage (V)

I = Solar panel current (mA)

T=C/R (Eq 2)

Where T = Battery bank charging time (Hours)

C = Battery bank capacity (mAh)

R = Charging current (mA)

The electrical power formula calculates the power produced by the solar panel during data collection. Equation 4.1 delineates the correlation between power, voltage, and current in a solar panel. Simultaneously, Equation 4.2 has been employed to obtain data concerning battery charging durations.

4.2.1 PV Solar System Data Day 1

Table 4.1 shows the data obtained from the standalone PV solar system on 24 December 2024. The weather recorded on that day was hot in the morning and cloudy in the evening.

Table 4.1 The result of data collection for day 1.

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)
8am	12.3	0.15	1.845	12	48
10am	12.7	0.41	5.207	12	17.56
12pm	13.1	0.49	6.419	12	14.69
2pm	13	0.47	6.11	12	15.32

4pm	13	0.12	1.56	12	60
6pm	12.8	0.15	1.92	12	48

According to Table 4.1, the solar panel produced the least power at 4 p.m., with a value of 1.56W as the sun was getting set. In comparison, the power generated by the solar panel at 12 p.m. was the highest recorded, at 6.419W. The power dropped by noon as the weather started to be cloudy in the evening.

4.2.2 PV Solar System Data Day 2

Table 4.2 shows the data obtained from the standalone PV solar system on 25 December 2024. The weather recorded on that day was cloudy in the morning and rainy in the afternoon.

Table 4.2 The result of data collection for day 2.

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)
8am	12.6	0.12	1.512	12	60
10am	13.4	0.16	2.144	12	45
12pm	13.7	0.25	3.425	12	28.8
2pm	13.6	0.39	5.304	12	18.46
4pm	13.4	0.18	2.412	12	40
6pm	13.3	0.08	1.064	12	90

According to Table 4.2, the solar panel produced the least power at 6 p.m., with a value of 1.064W as the sun was getting set. In comparison, the power generated by the solar panel at 2 p.m. was the highest recorded, at 5.304W. The power dropped at noon as the weather started to be cloudy and rainy in the evening.

4.2.3 PV Solar System Data Day 3

Table 4.3 shows the data obtained from the standalone PV solar system on 26 December 2024. The weather recorded on that day was rainy and cloudy all day.

Table 4.3 The result of data collection for day 3.

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)
8am	12.8	0.13	1.664	12	55.38
10am	13	0.24	3.12	12	30
12pm	13.3	0.34	4.522	12	21.18
2pm	13.3	0.3	3.99	12	24
4pm	13.1	0.21	2.751	12	34.29
6pm	13	0.16	2.08	12	45

According to Table 4.3, the solar panel produced the least power at 8 p.m., with a value of 1.664W as the sun was getting set. In comparison, the power generated by the solar panel at 12 p.m. was the highest recorded, at 4.522W. The power was maintained from morning to evening as the weather was rainy and cloudy.

4.2.4 PV Solar System Data Day 4

Table 4.4 shows the data obtained from the standalone PV solar system on 27 December 2024. The weather recorded on that day was sunny all day.

Table 4.4 The result of data collection for day 4.

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Charging Time (Hours)
8am	12.7	0.18	1.89	12	40
10am	13.1	0.35	3.885	12	20.57
12pm	13.9	0.49	6.321	12	14.69
2pm	13.7	0.45	5.715	12	16
4pm	13.4	0.38	4.636	12	18.95
6pm	13.2	0.19	2.508	12	80

According to Table 4.4, the solar panel produced the least power at 8 a.m., with a value of 1.89W as the sun was getting set. In comparison, the power generated by the solar panel at 12 p.m. was the highest recorded, at 6.321W. The power was maintained from morning to evening as the weather was sunny all day.

4.3 Standalone PV Solar System Average Data Analysis

The average data value has been determined by analyzing and computing the results from days one to four. The data in Table 4.5 below displays the average output of the solar panel voltage, current, power, battery voltage, and charging time over the course of four days.

Table 4.5 The average output of data collection for four days.

Day	Average				
	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Battery Bank Voltage (V)	Solar Panel Voltage (V)
1	12.82	0.298	3.844	12	24.08
2	13.33	0.197	2.646	12	36.55
3	13.08	0.23	3.021	12	31.30
4	13.33	0.323	4.159	12	22.29

According to Table 4.5, the average solar panel generated the lowest power on the second day with a value of 2.646W. In comparison, the average power generated by the solar panel on the fourth day is the highest recorded, with the value of 4.159W.

The average current and power production of a solar panel throughout a four-day experimental period are shown in Figure 4.1. There are variations in current, peaking on Day 1 and then declining on Day 2. Since power is proportional to current, this variation in current has a direct impact on the power output. The variations in both metrics imply that the performance of the solar panel is susceptible to outside influences, including variations in the weather. For example, compared to sunny conditions, periods of cloud cover or decreased sunlight intensity are likely to result in lower current and power outputs.

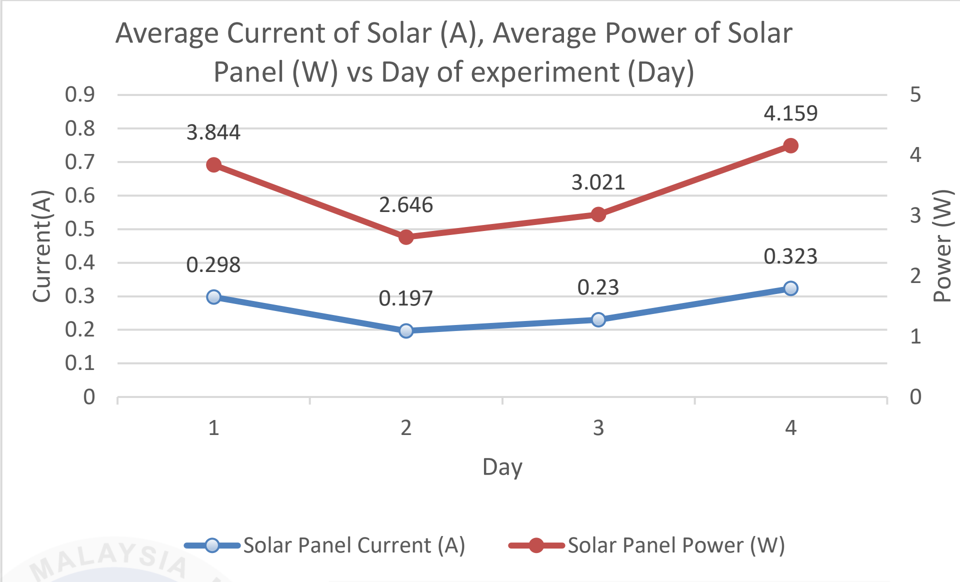


Figure 4.1 Graph of the relationship between average solar panel current and average solar panel power

During the prototype testing at the end of the year, which is during the rainy season in Malaysia, the amount of sunlight for the solar panel was not ideal. The 5-day average intensity of solar radiation was low because the weather was mostly gloomy and rainy. This caused a significant difference in the daily data collected. Additionally, the recommended size of the solar panel for this project was another factor contributing to its low output current. The calculations for the solar panel size assumed a peak sun hour of 4 hours on a bright sunny day. However, during the actual testing week, the weather was consistently cloudy, affecting the solar panel's output. On a sunny day, the proposed 10W, 22.28V(Voc) PV solar panel could produce a maximum current output of 600mA (Isc). Unfortunately, due to the overcast weather during testing, the panel could not reach its maximum output, resulting in a small current. This mismatch with the panel specifications led to a diminished ability to convert sunlight into electricity. The highest average power output observed during the experiments was only 4.159W, with an average output current of 323mA.

Moving on to the charge controller, a crucial component for charging Sealed Lead Acid (SLA) batteries, it regulates the charging current to protect the battery from overcharging and over-discharging. However, based on the experimental data in Table 4.5, the battery bank took more than 20 hours to fully charge. The low output current from the solar panel caused the charge controller module to function incorrectly.

The inverse relationship between the average current produced by the solar panel and the amount of time needed to fully charge a device is shown in Figure 4.2. The charging time reduces as the average current rises. This is consistent with basic electrical principles, which state that faster energy transfer results from higher current flow. It's crucial to remember that weather conditions probably have an impact on this relationship. Shorter charging periods are anticipated due to increased current outputs under sunny situations. On the other hand, overcast weather may cause lower current outputs and, as a result, lengthier charging times.

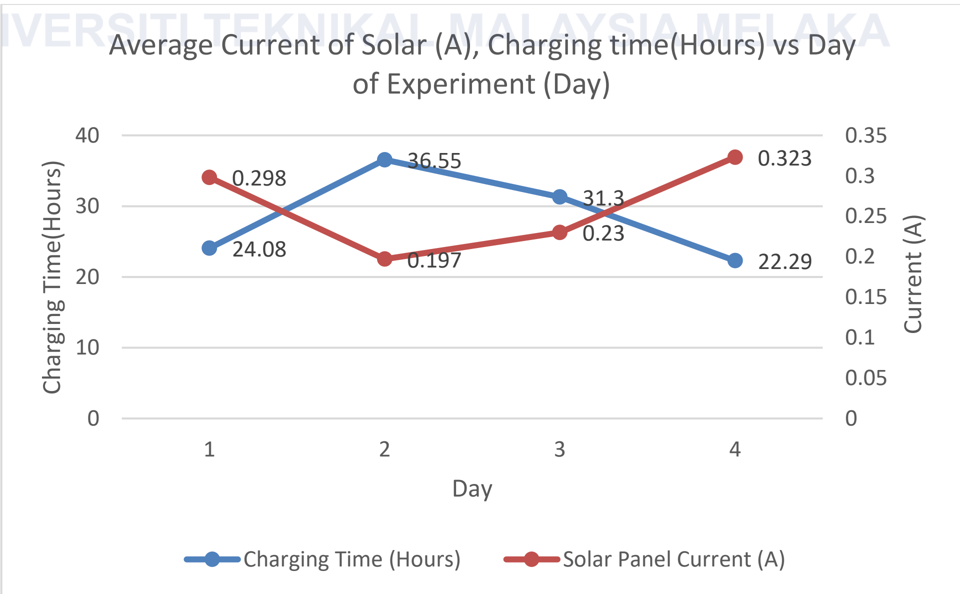


Figure 4.2 Graph of the relationship between the average battery bank charging time and average solar panel current

4.4 Smart Home Security Device Performance Analysis

The Smart Home Security Device is an innovative system that utilizes renewable solar energy as its main power source, offering a sustainable and effective option for home security and surveillance. The system operates continuously, utilizing a 10W photovoltaic solar panel and a 12V 7.2Ah SLA battery, even in low sunshine situations. The apparatus integrates many elements to improve domestic security and environmental surveillance.

4.4.1 Functionality of MQ2 Sensor

The MQ-2 sensor in the kitchen identifies gas leaks and, with concentrations surpassing 50%, activates the ESP8266 microcontroller to transmit an alert notice to the Blynk application, as depicted in Figure 4.3. The exhaust fan and buzzer are concurrently triggered to alleviate the hazard. When gas concentrations fall below 45%, the fan and buzzer deactivate automatically, guaranteeing safe and efficient functioning.

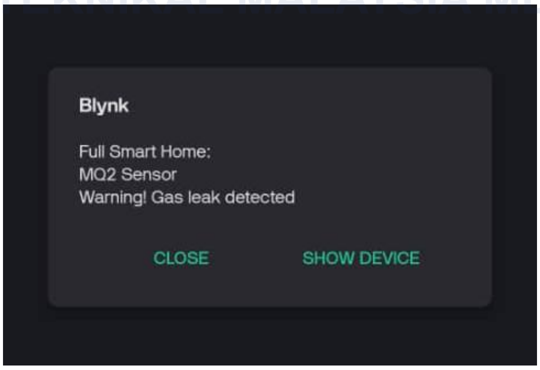


Figure 4.3 The notification from the Blynk Application is sent

4.4.2 Testing of Triggered PIR Sesnor and ESP32 CAM For Real Time Live Streaming

The PIR (Passive Infrared) sensor is very important for keeping the bedroom safe because it can successfully detect motion. Placed in a smart way, it keeps an eye on the room for any unauthorized movement or strange behavior. The PIR sensor used has a detection range of 6–10 meters, making it ideal for indoor setups. It is mounted at an optimal height to ensure reliable performance while minimizing false triggers from heat sources or obstructions. When the PIR sensor detects movement, it transmits a signal to the NodeMCU ESP8266 microcontroller. The microcontroller then sends a message to the Blynk app right away, as depicted in Figure 4.4. This real-time alert lets users know about possible attacks and act quickly, no matter where they are. The addition of the ESP32-CAM makes this feature even better by letting you stream live video through a special website. This function lets users see where the motion is coming from in real time, which adds an extra layer of security by letting them tell the difference between a false alarm and a real break-in. The PIR sensor and ESP32-CAM work together to make a full monitoring system that sees motion and gives you live video input to make things safer as illustrated in Figure 4.5.

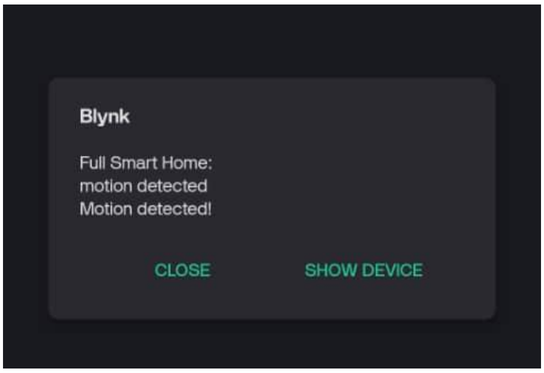


Figure 4.4 The notification from blynk application is sent went the PIR Sensor detect some motion in the bedroom

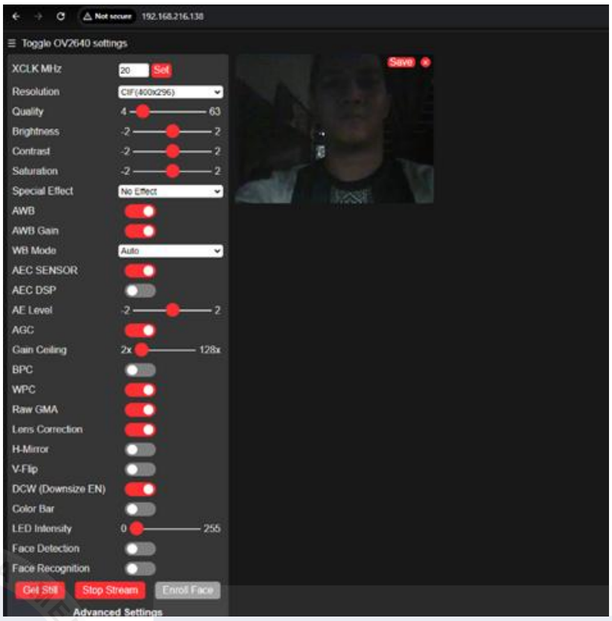
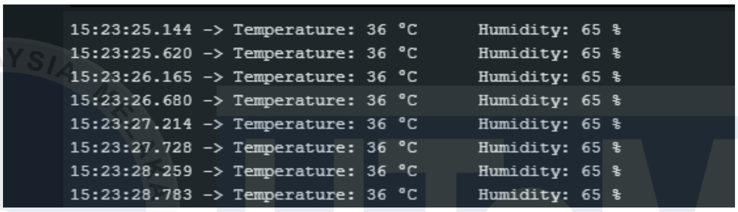


Figure 4.5 The interface from website that uses the ESP32 CAM

4.4.3 Functionality of DHT11 Sensor

The DHT11 sensor is an important part of keeping an eye on the bedroom's surroundings. It keeps track of the temperature and humidity inside, so users always know what's going on with the surroundings. This information is sent by the monitor to the Blynk app, where users can see both current events and patterns from the past. This feature is especially helpful for health and comfort because it lets users keep an eye on changes in the bedroom's temperature or humidity and act on them. For instance, when it's hot or humid outside, users can keep the perfect temperature inside by doing things like changing the air or turning on cooling devices. So, the DHT11 sensor is an important part of making the living space better, which means the system is more than just a security measure. Figure 4.6 shows the real time of temperature and humidity from sensor DHT11 through Blynk and serial monitor Arduino IDE.

(a)



(b)

Figure 4.6 (a) The interface in Blynk Application and (b) Serial Monitor from Arduino IDE

Figure 4.7 and Table 4.6 illustrate the variations in temperature and humidity in a bedroom over a 9-hour interval from 3:00 PM to 12:00 AM. Humidity displays a clear trend, initially increasing suddenly from around 60% to 80% between 3:00 PM and 4:00 PM, subsequently stabilizing at this level until 8:00 PM. A significant drop in humidity occurs, reaching approximately 60% by 9:00 PM, succeeded by a phase of relative stability. The temperature exhibits a progressive increase from 31.5°C at 3:00 PM, peaking at around 35°C between 4:00 PM and 7:00 PM. Subsequently, the temperature declines consistently, reaching approximately 32°C by midnight. These fluctuations can be ascribed to a confluence of elements including anthropogenic activities, meteorological conditions, sun radiation, and airflow patterns. Additional study, incorporating external meteorological data and occupancy patterns, is required to get more conclusive insights into the observed behaviors.

Table 4.6 The data from DHT11 Sensor that collect in bedroom.

Time	Humidity (%)	Temperature (°C)
3:00 PM	73	34
3.30 PM	66	35
4:00 PM	65	35
4.30 PM	69	35
5:00 PM	69	35
5.30 PM	69	35
6:00 PM	71	35
6.30 PM	73	35
7:00 PM	73	35
7.30 PM	76	34
8:00 PM	79	34
8.30 PM	77	34
9:00 PM	70	34
9.30 PM	68	34
10:00 PM	67	33
10.30 PM	68	33
11:00 PM	72	32
11.30 PM	74	33
12:00 AM	74	33

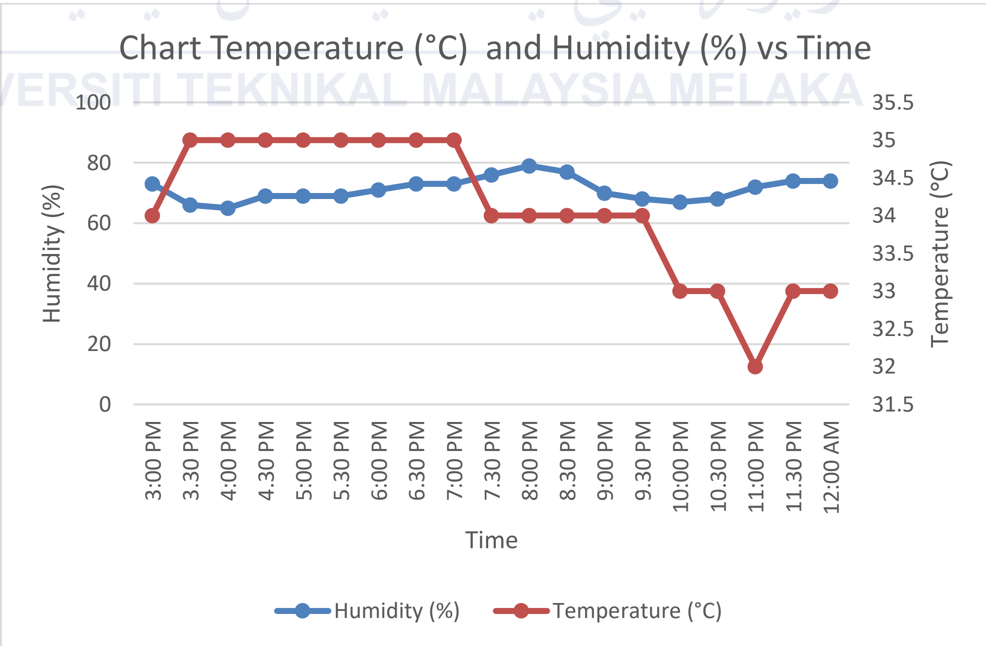


Figure 4.7 Graph of the relationship between Temperature (°C) and Humidity (%) vs Time

4.4.4 Switching of LED Testing Using Blynk

The incorporation of two LED lamps enhances both functionality and convenience inside the smart home system, with one lamp located in the bedroom and the other in the kitchen. Both bulbs are entirely managed through the Blynk application, allowing users to remotely activate or deactivate them as required. The capacity to control these lights remotely increases user convenience in multiple situations, including returning home late at night or neglecting to switch off the lights before leaving. LED lighting enhances home security by enabling users to simulate occupancy in the bedroom and kitchen, so deterring prospective burglars. The strategic positioning of the lighting enhances the whole system, integrating energy efficiency, ease, and improved security throughout various regions of the home. Figure 4.8 and Figure 4.9 are testing of switch on the lamp using Blynk Application.

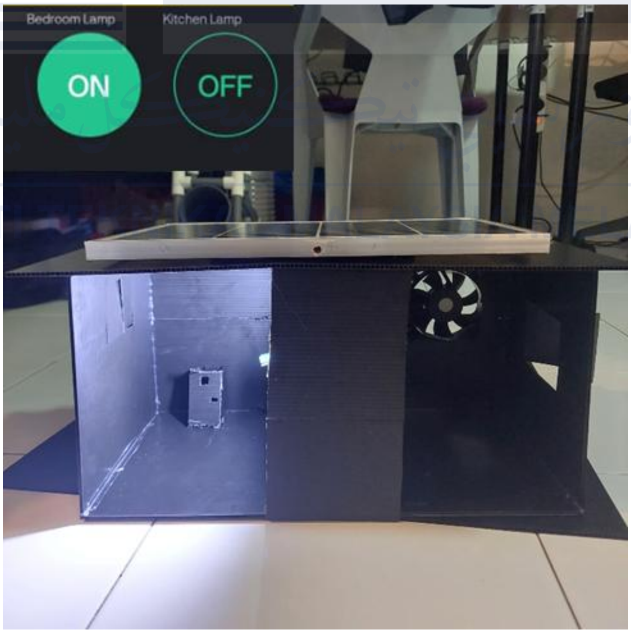


Figure 4.8 LED 1 (Bedroom) Turn ON

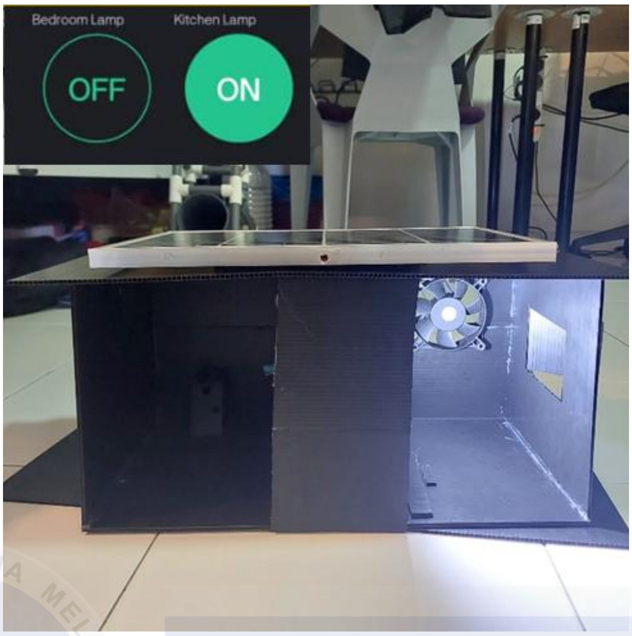


Figure 4.9 LED 2 (Kitchen) Turn ON

4.5 Summary

This chapter effectively summarizes the findings derived from a series of experiments conducted to achieve the specified objectives. The ongoing experiment possesses the ability to fulfill a certain objective associated with the project. The experiment conducted should serve as a reference for any future methods or alterations required for the undertaking.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This chapter outlines the development of a smart home security device powered by an independent solar photovoltaic (PV) system. The project aims to evaluate the feasibility of standalone photovoltaic solar components in independently energizing the smart home security system. The system comprises two primary components: the photovoltaic solar system, which transforms solar energy into electricity to operate the security device and recharge the battery bank during daylight, and the smart home security device, which incorporates various sensors and components for improved safety and convenience.

The components comprise the MQ2 gas sensor, PIR motion sensor, DHT11 temperature and humidity sensor, LED lighting, and an ESP32-CAM for real-time surveillance. The advanced mechanism guarantees continuous functioning by transitioning to stored battery power in the absence of sunlight. This project represents a substantial advancement in home security via sustainable energy solutions, providing consumers with a dependable, energy-efficient, and autonomous system for real-time monitoring and response to potential threats.

5.2 Project Objective

All three main goals of this project have successfully been achieved. They are briefly revisited and discussed as follows:

5.2.1 To Design A Smart Home Control System That Integrates Iot Technology And Solar Energy

As detailed in Chapter 3, the project successfully developed a smart home security system powered by a photovoltaic solar system. This technology was engineered to function independently from traditional electricity grids, guaranteeing sustainability and energy efficiency. Section 3.3 outlines the hardware design, including the NodeMCU ESP8266 microcontroller, ESP32-CAM, and an array of sensors, such as the MQ2 gas sensor, PIR motion sensor, and DHT11 temperature and humidity sensor. In total, these elements constituted a resilient, interlinked system adept at tracking and reducing various security and environmental issues.

The photovoltaic solar system, detailed in Section 3.4, powers the smart home security device and charges a 12V 7.2Ah SLA battery for dependable operation in low sunshine settings. This integration illustrates the viability of merging IoT technology with renewable energy, achieving the project's main goal of creating a sustainable and efficient home security system.

5.2.2 To Develop A System That Can Control And Monitor Through BLYNK Application On Phone While Away From Home

The ability for remote system monitoring and control was a crucial goal, accomplished by the implementation of the Blynk application, as outlined in Section 3.6.3: Blynk Application. This program enables users to obtain real-time notifications, manage devices like LED bulbs and exhaust fans, and access live video streaming via the ESP32-CAM. Testing and performance analysis, detailed in Chapter 4: Results and Discussions, demonstrated the effectiveness of the Blynk application in facilitating smooth engagement with the system. The MQ2 sensor immediately informs the Blynk app when gas loss is above 50%, while the PIR sensor alerts users to detect motion. These attributes guarantee that consumers remain informed and in command, enhancing both convenience and security.

5.2.3 To Evaluate The Performance Of The Remote Activation And Deactivation Of The Smart Home Security Device

The system's performance was carefully tested and evaluated, as detailed in Section 4.4: Smart Home Security Device Performance Analysis. The findings confirmed the system's capacity to function independently and effectively across various conditions. The MQ2 sensor consistently triggered the exhaust fan and buzzer during gas leak incidents, thereby reducing potential threats. Likewise, the PIR sensor accurately identified motion, activating messages to inform users of possible invasions. The DHT11 sensor consistently monitored temperature and humidity, maintaining a comfortable indoor environment, while the ESP32-CAM delivered clear, real-time video feeds for improved security.

The photovoltaic solar system proved its ability to consistently power the complete arrangement, with the battery offering sufficient backup during low sunshine conditions. The results, along with the system's responsiveness and reliability, confirmed its efficacy in achieving the project's objectives.

5.3 Project Limitation

During the prototype development and data collection phase, various limits and problems came up, affecting the experimental output data. Due to the project testing occurring near the year's end during Malaysia's rainy season, the average intensity of solar radiation was comparatively low, and the peak sun hours were decreased. The recommended dimensions of the PV solar system were originally designed for deployment on a sunny day, based on the sizing calculation indicating a peak sun hour of 4 hours. Therefore, implementing the suggested photovoltaic solar system on a cloudy day is impractical, as the efficiency of the solar panels in converting solar energy to electricity decreases. Furthermore, selecting sealed lead-acid batteries for battery banks has introduced complexity to the charging system, requiring numerous charge controller modules to accelerate the charging process of the battery bank.

5.4 Recommendations

This study aims to investigate the compatibility of the components employed in the assembly of the smart home security device and the independent photovoltaic solar system. To ensure that the smart home gadget receives sufficient power from the standalone photovoltaic solar system during both sunny and overcast conditions, the most critical elements are the dimensions of the solar panel, charger controller, and battery bank.

Several components have been studied, including battery bank durability, charge controller performance, and solar panel effectiveness. Consequently, this project can be enhanced in several ways. The further recommendations are as follows:

1. Utilize an advanced charge controller to streamline the charging circuit and speed battery charging.
2. Enlarge the photovoltaic solar panel to enhance the conversion of solar energy into electricity, even during cloudy conditions.

3. Upgrade the project's camera to a high-resolution model equipped with night vision capabilities to improve real-time surveillance and guarantee optimal operation in low-light settings.

5.5 Project Potential of Commercialization

The project has significant potential for commercialization within the expanding market for smart homes and sustainable energy technology. The increasing desire for environmentally sustainable and automated home systems makes solar-powered smart home security devices particularly attractive. Consumers, especially eco-conscious homeowners and developers of sustainable residential projects, are increasingly attracted to these solutions, particularly in areas with ample sunlight and governmental incentives for renewable energy. Cost reductions can be obtained by mass production and the utilization of less expensive materials for non-essential components. Moreover, subscription-based models for software updates and remote monitoring can diminish initial expenses while producing consistent revenue. Collaborations with property developers and governmental entities can enhance uptake by integrating the system into sustainable housing initiatives and providing subsidies to mitigate early expenses. These tactics establish the project as a viable and commercially available alternative for sustainable living.

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APPENDICES

Appendix A Gantt Chart for BDP1 and BDP 2

NO.	Task	PSM 1														PSM 2													
	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 Registration		■																										
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	Submission Report to the Panel												■																
14	Presentation of BDP1													■															
15	Drafting Chapter 4: Analyze Data and Result															■	■												
16	Data Analyze 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	Finalize the Report																								■	■			
22	Presentation of BDP2																										■		

Appendix B Full coding in NodeMCU ESP8266

```
/*
Full home automation with the New Blynk app
Home Page
*/
#define BLYNK_TEMPLATE_ID "TMPL6xXLkMKmv"
#define BLYNK_TEMPLATE_NAME "MQ2 Sensor"
//Include the library files
#define BLYNK_PRINT Serial
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
#include <DHT.h>

char auth[] = "r-slxNoO3rz5EnLsupcnpKMBYAaW-EDX"; // Enter your Auth token
char ssid[] = "CikuCakk"; // Enter your WIFI name
char pass[] = "0987654321"; // Enter your WIFI password

DHT dht(D3, DHT11); // (sensor pin, sensor type)
BlynkTimer timer;
bool pirMotionDetected = false;

// Define component pins
#define Buzzer D0
#define MQ2 A0
#define Fan D4
#define PIR D6
#define relay1 D7
#define relay2 D8

void setup() {
  Serial.begin(115200);
  Blynk.begin(auth, ssid, pass, "blynk.cloud", 80);
  pinMode(Buzzer, OUTPUT);
  pinMode(Fan, OUTPUT);
  pinMode(D6, INPUT);
  pinMode(D7, OUTPUT);
  pinMode(D8, OUTPUT);

  dht.begin();

  // Call the functions
  timer.setInterval(1000L, gassensor);
  timer.setInterval(1000L, DHT11sensor);
  timer.setInterval(1000L, checkMotion);
```

```
}

// Get the MQ2 sensor values
void gassensor() {
  int value = analogRead(MQ2);
  Serial.println(value);
  value = map(value, 0, 1024, 0, 100);
  if (value <= 49) {
    digitalWrite(Buzzer, LOW);
    digitalWrite(Fan, LOW);
  } else if (value > 49) {
    Blynk.logEvent("mq2_sensor","Warning! Gas leak detected");
    digitalWrite(Buzzer, HIGH);{
    digitalWrite(Fan, HIGH);    // Turn on the fan
    delay(10000);               // Keep the fan on for 10 seconds
    digitalWrite(Fan, LOW);     // Turn off the fan after delay
    }
  }
  Blynk.virtualWrite(V1, value);
}
// Get the DHT11 sensor values
void DHT11sensor() {
  float h = dht.readHumidity();
  float t = dht.readTemperature();

  if (isnan(h) || isnan(t)) {
    Serial.println("Failed to read from DHT sensor!");
    return;
  }
    Serial.print("Temperature: ");
    Serial.print(t);
    Serial.println("°C");

    Serial.print("Humidity: ");
    Serial.print(h);
    Serial.println("%");

  Blynk.virtualWrite(V2, t);
  Blynk.virtualWrite(V3, h);
}
// Get the PIR sensor values
void checkMotion() {
  long state = digitalRead(D6);  // Read PIR sensor state

  if(state == HIGH) {
    // Motion detected
    Serial.println("Motion detected!");
```

```
    Blynk.logEvent("motion_detected", "Motion detected!"); // Log event to
Blynk
  }
  else {
    // No motion detected
    Serial.println("Motion absent!");
  }
}
BLYNK_WRITE(V4)
{
  int value = param.asInt();
  Serial.println(value);
  if(value == 1)
  {
    digitalWrite(D7, LOW);
    Serial.println("LED 1 ON");
  }
  if(value == 0)
  {
     digitalWrite(D7, HIGH);
     Serial.println("LED 1 OFF");
  }
}


BLYNK_WRITE(V0)
{
  int value = param.asInt();
  Serial.println(value);
  if(value == 1)
  {
    digitalWrite(D8, LOW);
    Serial.println("LED 2 ON");
  }
  if(value == 0)
  {
     digitalWrite(D8, HIGH);
     Serial.println("LED 2 OFF");
  }
}


void loop() {
  Blynk.run(); // Run the Blynk library
  timer.run(); // Run the Blynk timer
}
```

Appendix C Coding in ESP32 CAM

Coding in ESP32 CAM

```
#include "esp_camera.h"
#include <WiFi.h>

//
// WARNING!!! PSRAM IC required for UXGA resolution and high JPEG quality
//            Ensure ESP32 Wrover Module or other board with PSRAM is
selected
//            Partial images will be transmitted if image exceeds buffer
size
//
//            You must select partition scheme from the board menu that has
at least 3MB APP space.
//            Face Recognition is DISABLED for ESP32 and ESP32-S2, because
it takes up from 15
//            seconds to process single frame. Face Detection is ENABLED if
PSRAM is enabled as well

// ===================
// Select camera model
// ===================
//#define CAMERA_MODEL_WROVER_KIT // Has PSRAM
//#define CAMERA_MODEL_ESP_EYE  // Has PSRAM
//#define CAMERA_MODEL_ESP32S3_EYE // Has PSRAM
//#define CAMERA_MODEL_M5STACK_PSRAM // Has PSRAM
//#define CAMERA_MODEL_M5STACK_V2_PSRAM // M5Camera version B Has PSRAM
//#define CAMERA_MODEL_M5STACK_WIDE // Has PSRAM
//#define CAMERA_MODEL_M5STACK_ESP32CAM // No PSRAM
//#define CAMERA_MODEL_M5STACK_UNITCAM // No PSRAM
//#define CAMERA_MODEL_M5STACK_CAMS3_UNIT  // Has PSRAM
#define CAMERA_MODEL_AI_THINKER // Has PSRAM
//#define CAMERA_MODEL_TTGO_T_JOURNAL // No PSRAM
//#define CAMERA_MODEL_XIAO_ESP32S3 // Has PSRAM
// ** Espressif Internal Boards **
//#define CAMERA_MODEL_ESP32_CAM_BOARD
//#define CAMERA_MODEL_ESP32S2_CAM_BOARD
//#define CAMERA_MODEL_ESP32S3_CAM_LCD
//#define CAMERA_MODEL_DFRobot_FireBeetle2_ESP32S3 // Has PSRAM
//#define CAMERA_MODEL_DFRobot_Romeo_ESP32S3 // Has PSRAM
#include "camera_pins.h"

// ===========================
// Enter your WiFi credentials
// ===========================
```

```
const char *ssid = "CikuCakk";
const char *password = "0987654321";

void startCameraServer();
void setupLedFlash(int pin);

void setup() {
  Serial.begin(115200);
  Serial.setDebugOutput(true);
  Serial.println();

  camera_config_t config;
  config.ledc_channel = LEDC_CHANNEL_0;
  config.ledc_timer = LEDC_TIMER_0;
  config.pin_d0 = Y2_GPIO_NUM;
  config.pin_d1 = Y3_GPIO_NUM;
  config.pin_d2 = Y4_GPIO_NUM;
  config.pin_d3 = Y5_GPIO_NUM;
  config.pin_d4 = Y6_GPIO_NUM;
  config.pin_d5 = Y7_GPIO_NUM;
  config.pin_d6 = Y8_GPIO_NUM;
  config.pin_d7 = Y9_GPIO_NUM;
  config.pin_xclk = XCLK_GPIO_NUM;
  config.pin_pclk = PCLK_GPIO_NUM;
  config.pin_vsync = VSYNC_GPIO_NUM;
  config.pin_href = HREF_GPIO_NUM;
  config.pin_sccb_sda = SIOD_GPIO_NUM;
  config.pin_sccb_scl = SIOC_GPIO_NUM;
  config.pin_pwdn = PWDN_GPIO_NUM;
  config.pin_reset = RESET_GPIO_NUM;
  config.xclk_freq_hz = 20000000;
  config.frame_size = FRAMESIZE_UXGA;
  config.pixel_format = PIXFORMAT_JPEG;  // for streaming
  //config.pixel_format = PIXFORMAT_RGB565; // for face
detection/recognition
  config.grab_mode = CAMERA_GRAB_WHEN_EMPTY;
  config.fb_location = CAMERA_FB_IN_PSRAM;
  config.jpeg_quality = 12;
  config.fb_count = 1;

  // if PSRAM IC present, init with UXGA resolution and higher JPEG quality
  //                      for larger pre-allocated frame buffer.
  if (config.pixel_format == PIXFORMAT_JPEG) {
    if (psramFound()) {
      config.jpeg_quality = 10;
      config.fb_count = 2;
      config.grab_mode = CAMERA_GRAB_LATEST;
    } else {
```

```
      // Limit the frame size when PSRAM is not available
      config.frame_size = FRAMESIZE_SVGA;
      config.fb_location = CAMERA_FB_IN_DRAM;
    }
  } else {
    // Best option for face detection/recognition
    config.frame_size = FRAMESIZE_240X240;
#if CONFIG_IDF_TARGET_ESP32S3
    config.fb_count = 2;
#endif
  }

#if defined(CAMERA_MODEL_ESP_EYE)
  pinMode(13, INPUT_PULLUP);
  pinMode(14, INPUT_PULLUP);
#endif

  // camera init
  esp_err_t err = esp_camera_init(&config);
  if (err != ESP_OK) {
    Serial.printf("Camera init failed with error 0x%x", err);
    return;
  }

  sensor_t *s = esp_camera_sensor_get();
  // initial sensors are flipped vertically and colors are a bit saturated
  if (s->id.PID == OV3660_PID) {
    s->set_vflip(s, 1);          // flip it back
    s->set_brightness(s, 1);     // up the brightness just a bit
    s->set_saturation(s, -2);    // lower the saturation
  }
  // drop down frame size for higher initial frame rate
  if (config.pixel_format == PIXFORMAT_JPEG) {
    s->set_framesize(s, FRAMESIZE_QVGA);
  }

#if defined(CAMERA_MODEL_M5STACK_WIDE) ||
defined(CAMERA_MODEL_M5STACK_ESP32CAM)
  s->set_vflip(s, 1);
  s->set_hmirror(s, 1);
#endif

#if defined(CAMERA_MODEL_ESP32S3_EYE)
  s->set_vflip(s, 1);
#endif

// Setup LED FLash if LED pin is defined in camera_pins.h
#if defined(LED_GPIO_NUM)
```

```
  setupLedFlash(LED_GPIO_NUM);
#endif

  WiFi.begin(ssid, password);
  WiFi.setSleep(false);

  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
  Serial.println("WiFi connected");

  startCameraServer();

  Serial.print("Camera Ready! Use 'http://");
  Serial.print(WiFi.localIP());
  Serial.println("' to connect");
}

void loop() {
  // Do nothing. Everything is done in another task by the web server
  delay(10000);
}
```