FACULTY OF COMPUTER SCIENCE AND INFORMATION TECHNOLOGY

UNIVERSITI MALAYA

SOLAR POWERED STANDALONE CCTV SURVEILLANCE SYSTEM

ACADEMIC PROJECT 1 REPORT

WIA3002 ACADEMIC PROJECT 1

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DARRELL BECKLEY ANAK JOHNSON

17075190/2

SUPERVISOR: DR. TEY KOK SOON

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ABSTRACT

Solar energy is getting more popular as an alternative energy source for electrical appliances including closed-circuit television (CCTV). As more people are using CCTV to help monitor their properties, the need for an efficient battery system or energy storage for the system is needed. This project aims to develop a solar powered CCTV surveillance system which will be powered by the solar panel and the Lithium Ion battery pack. However, problems such as limited charging time are one of the main problems for the project. As such, an efficient system that can generate power to the system through solar energy as well as a method to create a good battery balancing to preserve the battery life of the system is researched in this project. An alert system is also proposed for security reasons. All of these are taken into consideration when developing the surveillance system for the CCTV which will be developed by using a Laravel framework.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

In recent years, the number of surveillance systems installed has increased worldwide. The use of surveillance systems by using closed-circuit television (CCTV) has become more and more popular as people can monitor their properties in real-time via the internet. This makes it more convenient for people as that eliminates the problem of having to be on-site to monitor their properties. In a network camera-based network video system, video is transported over an IP network and is recorded to a PC server. (Murdan, A.P., 2018). This ensures that the video is recorded and stored so that it can be viewed even after the event has passed.

Energy demand around the globe is increasing day by day. Therefore, an efficient energy source is being explored. One of these energy sources is solar energy. Solar energy is a promising energy source. With the solar energy readily available in nature during daytime. Aside from that, solar energy does not need a long period of time before it can be used. The potential for solar energy is enormous, since about 200,000 times the world's total daily electric-generating capacity is received by Earth every day in the form of solar energy (Ashok, S., 2021). To use solar power, Photovoltaic (PV) technology is commonly used. A PV system consists of solar panels which are used to convert the solar energy collected into electrical energy. The converted energy will then be used to power the CCTV in this project. As mentioned, solar energy is only present during the day which would cause a limited service time if CCTV would only rely on the solar power directly. Therefore power management or energy management is very important in order for the CCTV to continue operating. As such, the CCTV will also be powered by a lithium ion battery pack where the energy will be stored.

1.2 Aim and Objectives

The aim of this project is to develop a solar powered CCTV surveillance system which will be powered by the solar panel and the Lithium Ion battery pack. A system that can help users to monitor the environment through the video that was captured by the CCTV which can be accessed through the surveillance system.

The objective of this project are as follow:

1. To develop a solar powered CCTV surveillance system with battery storage using an Arduino Nano IoT 33 as a control unit.

2. To develop a server to communicate with CCTV.
3. To develop an alert system for the CCTV surveillance system.

1.3 Problem Statements

The problem statements will be described in this section.

1.3.1 Limited Charging Time

As previously mentioned, solar energy can only be collected and obtained during day-time. Therefore a charging system is crucial for this project. Although the CCTV can also be powered by the lithium ion battery pack, once the battery runs out, the battery pack would have to be replaced. This can be quite troublesome and also not effective. Therefore, to counter this, a charging system where the solar energy can be collected and stored inside the battery is needed

1.3.2 Surveillance system is unable to send signal to CCTV

CCTV is fully capable of sending the videos captured to the server. However, on the other hand, the surveillance system has limited options to send in signals or messages to the CCTV. Therefore the communication is only one-way.

1.3.3 Limited security measure for security problems

A surveillance system is only capable of monitoring the video captured through the CCTV. When a security issue arises, there are limited options for the admin to handle it. This raises a security problem where during an emergency, users will not be able to be notified.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter will focus on the study of solar power and charging systems for batteries from scholarly studies, research and articles that relate to the topics being discussed to provide in-depth understanding on the topic.

2.2 Analysis of Power Generation by Solar Panels

Most solar panels nowadays have power output ratings ranging between 250 to 400 watts. Before calculating the power output generated by solar panels, it's important to understand the key factors which affect the power output which are: solar panel efficiency, solar panel size and environmental factors.

2.2.1 Solar Panel Efficiency

Most silicon-based solar cells can convert about 20 percent of the sunlight that hits them into usable solar energy (Aggarwal, V., 2021). There are generally two types of solar panel which are, p-type and n-type solar cells. The difference lies in the chemistry where p-type cells are positively charged due to a layer of boron, whereas n-type silicon cells are built on bases of phosphorus, giving them a negative charge (Richardson, 2021). N-type are more efficient compared to p-type as p-type suffers from light induced degradation (LID). LID occurs when oxygen impurities in the silicon wafer react with the doped boron in the first few hours/weeks of illumination of the cell. This effect can reduce cell efficiencies from 2-4% (CED Greentech, 2021).

2.2.2 Solar Panel Size

Generally, solar panels are divided into two different sizes, 60-cell solar panels and 72-cell solar panels. Usually the 60-cell solar panels outputs about 270 to 300 watts of power while the 72-cell solar panels outputs about 350 to 400 watts of power. This is due to the fact that the 72-cell solar panels have an extra row of cells. Therefore, they are able to output more power.

2.2.3 Environmental Factors

The power output is also dependent on other environmental factors such as degree of shading that the system experiences and the tilt angle and azimuth of the roof on which it's installed (Aggarwal, V., 2021). In order to maximise the power output, the tilt angle of the roof in which the solar panel is installed on is important in order to get the optimum sunlight for the solar panel. For those north of the Equator, the best direction for solar panels is south, while homes in the southern hemisphere would position solar panels on roofs with a northern facing orientation (Marsh, 2022). Shade is also an important factor to consider when calculating the power output of a solar panel. The degree of which a shade is covering the solar panel can hinder the performance of the solar panels based on the degree of shading. As shown in the figure below, the higher the degree of shading, the lower the power output of the solar panels.

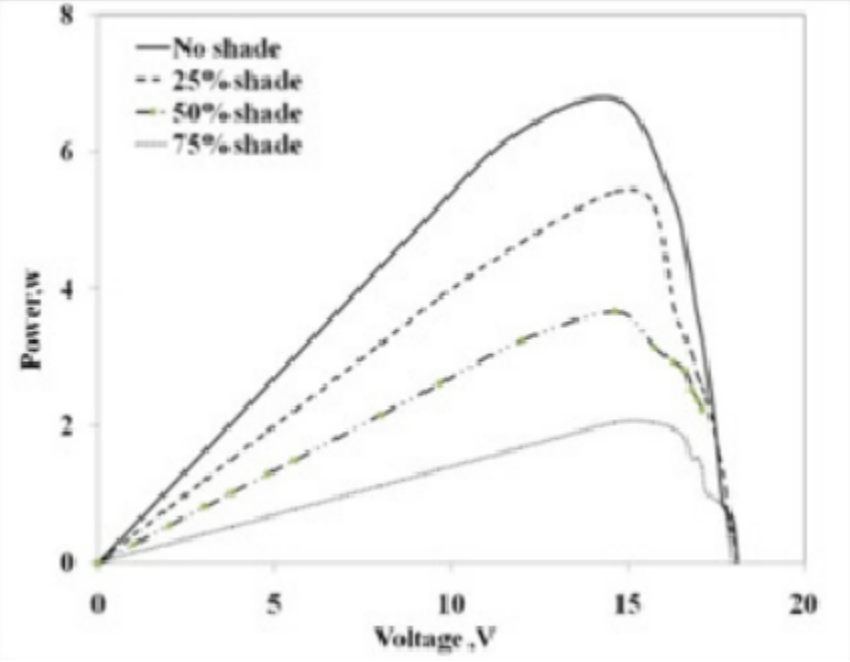

Figure 1: P-V Characteristics of the module under uniform shading

2.3 Charging System for Lithium Ion Battery

There are quite a few different types of batteries. The one chosen for this project is the lithium ion battery. There are a few advantages to using the lithium ion battery. According to Leakeem (2021), there are the benefits of lithium ion batteries compared to nickel-metal hydride. Firstly, lithium ion batteries can be charged in about 1 to 3 hours while nickel-metal hydride batteries take 10–12 to recharge. Secondly, they can better withstand extreme temperatures such as very high temperatures or very low

temperatures compared to nickel-metal hydride batteries. Lastly, lithium ion batteries have higher energy density where they carry more charge per gram than a nickel-metal hydride battery.

The battery management system is important as it helps protect the battery system from getting damaged. The battery management system carries out various tasks and one of them is the measuring of the state-of-charge (SOC) of the battery system. A balancing system is essential in a battery management system. In research from Daowd (2011), without the balancing system, the individual cell voltages will differ over time, and battery pack capacity will decrease quickly. That will result in the failure of the total battery system. Thus cell balancing acts an important role in battery life preservation.

The methods for battery balancing can be categorised in two categories, which are passive and active balancing. The passive balancing method works by removing the excess charge from a fully charged individual battery until the charge is equal to the charge in those of the lower battery. The charge is released to the surrounding area in the form of heat. Some of the advantages to this method is that it has a simple architecture and is easy to implement. Besides that, this method is also cheap to implement. However, the disadvantage of this method is that it might overcharge the battery and thus damage the battery. Figure 2 shows an example of a passive balancing method.

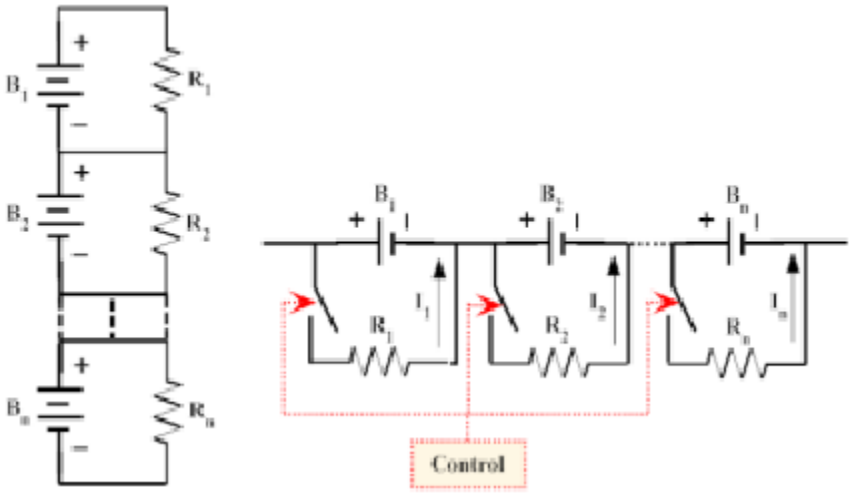

Figure 2: Example of Passive Balancing Method

Active balancing method on the other hand works by removing the charge from a higher energy battery or batteries and transferring it into lower energy battery or batteries. The advantage of this method is that it is more efficient compared to passive balancing methods. Less energy is wasted as the energy is transferred between the batteries.

However, this method has a more complex design and is more expensive to implement. Figure 3 shows an example of an active balancing method.

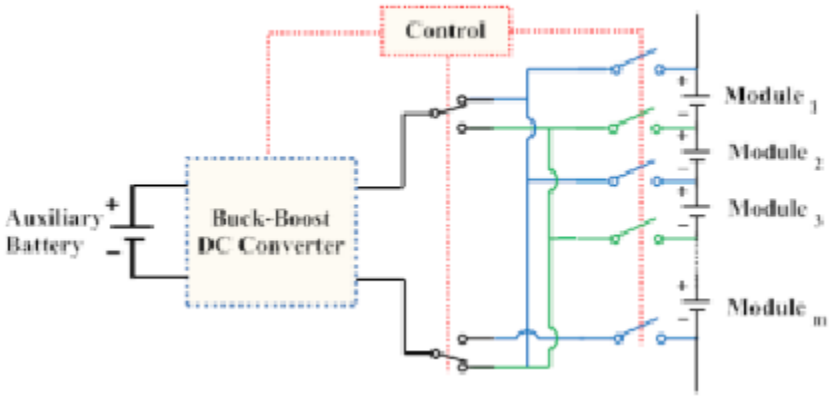

Figure 3: Example of Active Balancing Method

2.4 Existing Web Server - Grafana

Grafana is an open source data-visualisation platform which allows users to see their data in the form of graphs and charts in one or more dashboards. As such, users are able to monitor the data obtained from the solar panel and arduino and visualise it in the form of graphs or charts.

Figure 4: Example of Grafana Interface

Some of the advantages of using grafana is that it is cloud agnostic. This ensures that the web server can run seamlessly in any cloud environment. Besides that, it also provides a diverse integration options where it can connect with different types of databases such as MySQL, InfluxDB or Splunk. Grafana also offers various visualisation options to help visualise your data in accordance with your organisation's requirements. However, the options for the data visualisation is limited to only the one that are designed and released by Grafana Labs which limits the flexibility of the data visualisation. Another disadvantage to using Grafana is that it mostly supports only time-series data. Therefore, the data that can be presented is limited.

CHAPTER 3: METHODOLOGY

3.1 Defining Components

In this step, the components for the project are defined before proceeding with the project. Firstly, the CCTV used for the project is the 4 MP Outdoor AcuSense Fixed Bullet Network Camera by Hikvision.

Figure 5: CCTV by Hikvision

The system consists of two subsystems which are the power generation and storage, and the client-server communication. The two subsystems will be managed by a control unit, Arduino Nano IoT 33 which will be configured using the Arduino IDE as the development tool. The power generation and storage subsystem is made up of four components, which are Photovoltaic panel, DC to DC converter, cell balancer and a lithium ion battery pack. As for the client-server communication, the client will use built

in modules in the Arduino Nano IoT 33 which is used to connect to the wireless network and communicate with other devices meanwhile the server side will use MySQL database.

3.2 Information Gathering

For information gathering, the power generation and storage will be used to measure through the voltage and the current recorded from the PV panel. A voltage divider will be used to ensure that the voltage does not exceed the operating voltage of the Arduino Nano IoT 33 so that it would not damage the control unit. The operating voltage of the control unit is 3.3V. For the client-server communication subsystem, for wireless communication purposes, the Arduino will use the WiFiNINA library for data transmission to the network using the User Datagram Protocol (UDP). Aside from that, the data transmission protocol used will be the Message Queuing Telemetry Transport (MQTT) protocol which will send the data to the server.

CHAPTER 4: ANALYSIS AND DESIGN

4.1 Introduction

This chapter will cover collaborators for the project and the proposed system architecture and system design for the project. Diagrams are used to illustrate the system's requirements and process.

4.2 Stakeholders Collaboration Initiative

The solar powered standalone cctv surveillance system is a project that is being done in collaboration with Universiti Malaya (UM) as part of a grant from the UM Living Labs Grant Programme - SUS (Sustainability Science). The product of this project will then be deployed and used in UM.

TITLE :	***Iot Based Smart Solar Powered Standalone Cctv Surveillance System***	**PROJECT NO :**	***RUU2022-LL005***
		GRANT :	***UM Living Lab Grant Programme - SUS (Sustainability Science)***

Figure 6: Collaboration Details

4.3 Requirements

In order to achieve the objectives for the project, several requirements need to be fulfilled in order for the system behaviour to be in line with stakeholder's requirements. The requirement for the system are as follows:

1. To use an Arduino Nano IoT 33 as the system's control unit.
2. To develop a CCTV surveillance system powered by the solar panel and the Lithium Ion battery pack.
3. To create a server where to upload the information such as battery status, solar voltage for analysis
4. To link the CCTV to the server

4.4 System Design for Client Side

The Arduino Nano IoT 33 will act as a control unit to control the power generation and storage system to measure, monitor and control the voltage and current for the system.The connection for the system is shown in the figure below:

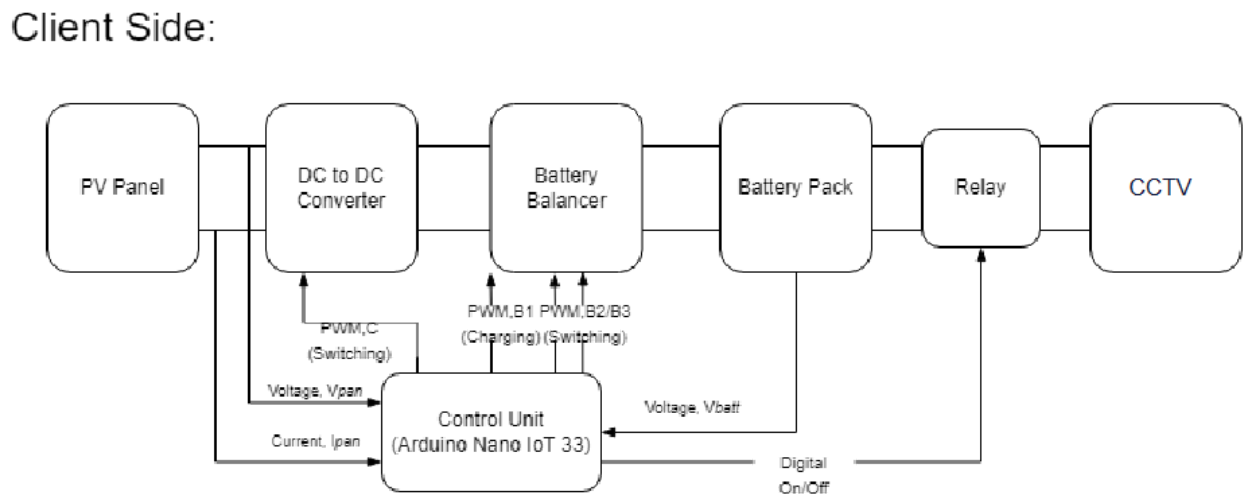

Figure 7: Connection between Arduino and Power Generation and Storage System

4.5 System Design for Client-Server Connection

The control unit which is the Arduino will connect to the internet using the UDP protocol and will then communicate with the database by using the Message Queuing Telemetry Transport (MQTT) protocol. The database will then send the data to the web server where the data will be analysed and presented.

Client-Server Connection:

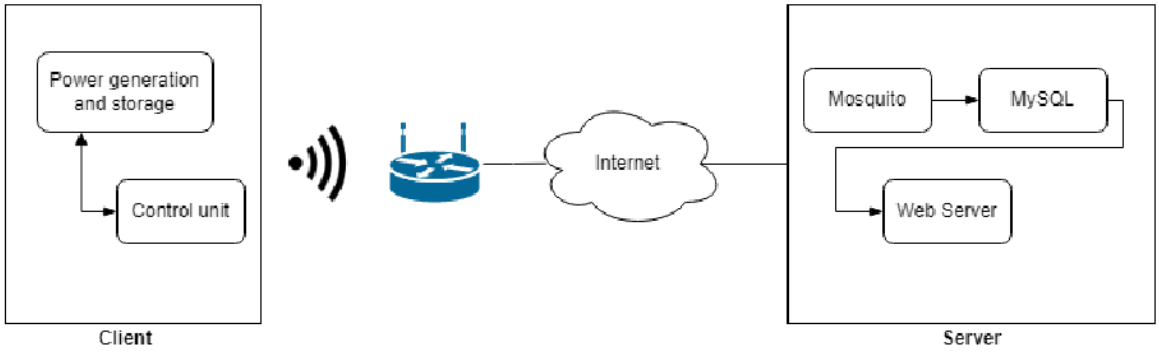

Figure 8: Client-Server Connection

4.6 Use Case Diagram

The system's use case diagram will describe the behaviour of the surveillance system web server. The use case consists of 4 actors that interact with the surveillance system.

Figure 9: CCTV Surveillance System Use Case Diagram

CHAPTER 5: SYSTEM DEVELOPMENT

5.1 Introduction

This chapter details the technical implementation for the project as well as the demonstration of the mock user interface.

5.2 Technical Implementation

The tools used for the implementation of the surveillance system will be described here.

5.2.1 WiFi connectivity

For the WiFi connection, the WiFiNINA module will be used to connect to the network. WiFiNINA is a module that is readily available in the Arduino Nano IoT 33. The code for the WiFi connection is as shown in the figure below:

```
int status = WL_IDLE_STATUS;
while (status != WL_CONNECTED) {
  Serial.print("Connecting to ");
  Serial.println(WIFISSID);
  status = WiFi.begin(WIFISSID, WIFIPASS);
  delay(5000);
}
```

Figure 10: Connecting to WiFi

```
void wifiReconnect() {
  while (status != WL_CONNECTED) {
    Serial.print("WiFi disconnected. Reconnecting to ");
    Serial.println(WIFISSID);
    status = WiFi.begin(WIFISSID, WIFIPASS);
    delay(5000);
  }
}
```

Figure 11: Reconnecting to WiFi

5.2.2 Web Server Framework

The framework that is used for the web server is Laravel. Laravel is an open-source PHP framework that is robust and easy to understand. Laravel has a variety of compatible packages and extensions which helps developing the web server become more structured and easier. Despite being a PHP framework, Laravel can also use other languages to help with system development such as HTML, CSS, JavaScript and many more.

Laravel has a built-in authentication and authorization function which makes the development for login and register modules much more simpler. Besides that, Laravel also uses a Model-View-Controller (MVC) architecture. For example, a model represents data that is stored in the database, while the view is an interface where the user can interact and view the data. The controller would be the conduit in the middle between the model and view which handles the request for the data and then processes it before returning the view to the user. Laravel also has a built-in object-relational mapper (ORM) which allows easy interaction with databases.

Figure 12: Laravel Logo

5.2.3 Database

The Surveillance System will use MySQL as the database for the project. MySQL is a relational database management system that uses SQL (Structured Query Language).

Figure 13: MySQL Logo

5.3 User Interface

In this section, the user interface for the surveillance system is displayed. Disclaimer, this is not a fully functional prototype yet and is still being developed at the moment.

5.3.1 Login Page

The figure below shows the login page where users will login to the system by using valid login credentials.

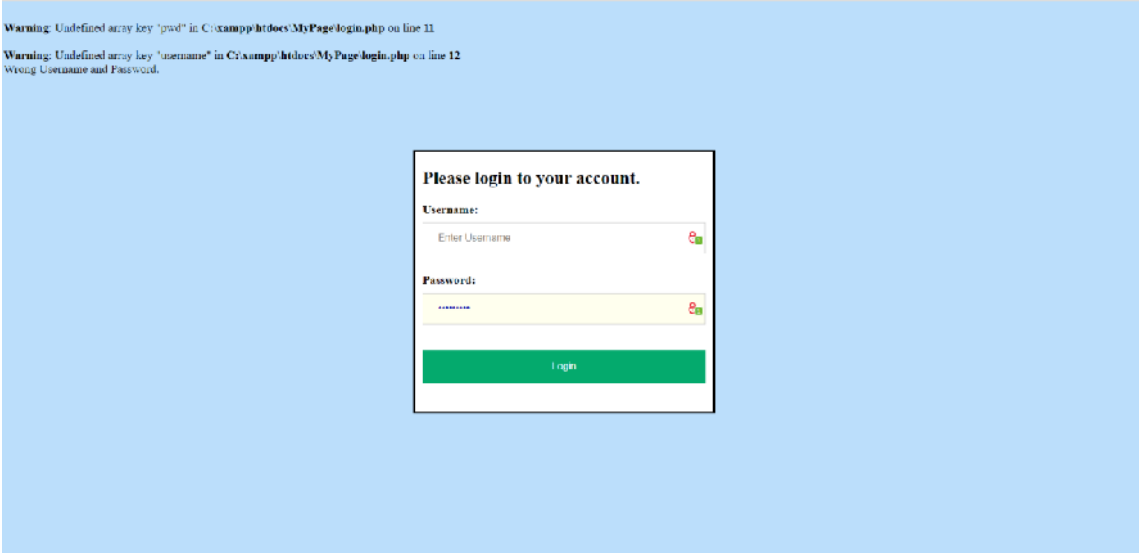

Figure 14: Login Page

5.3.2 Dashboard

In the dashboard, users will be able to view the data such as the voltage and power output in the form of graphs to display the condition of the hardware.

Figure 15: Dashboard

5.3.3 Alert System and Video Broadcast

In this section, the user should be able to watch the videos captured from the CCTV and send an alert message to related parties should there be any emergency.

Figure 16: Alert and Video Section

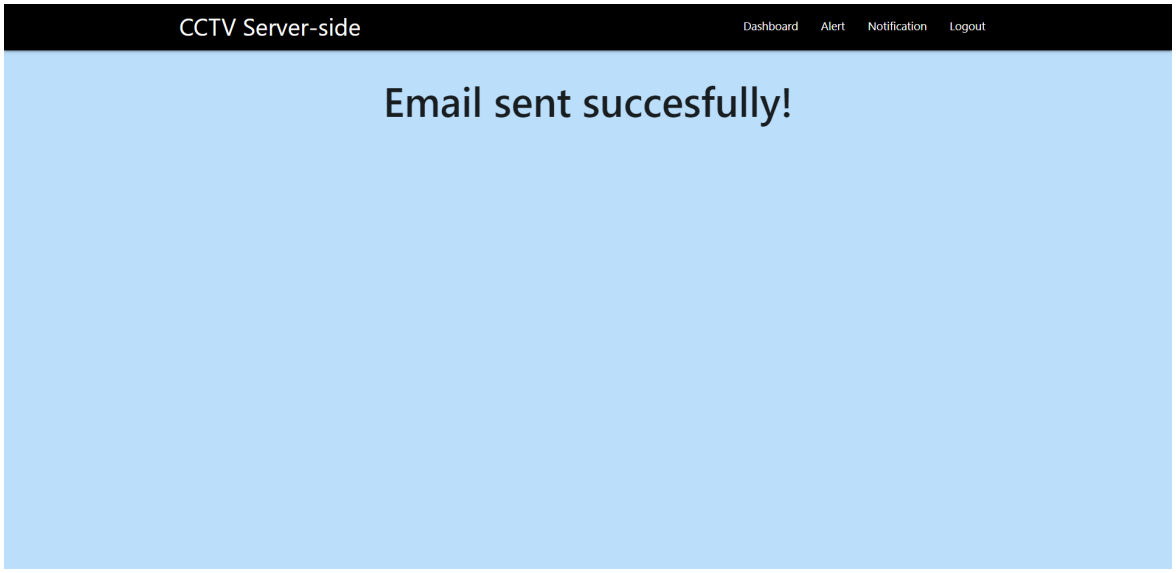

Figure 17: Alert Message Successfully Sent

CHAPTER 6: CONTRIBUTION

It is believed that the Solar Powered Standalone CCTV Surveillance System would be able to help Universiti Malaya in monitoring the area around the campus. The implementation of the system will also help the Universiti Malaya security team to react more efficiently with the alert system. This will be able to help decrease the occurrence of worst-case scenarios where the reaction would be delayed without the alert function.

CHAPTER 7: CONCLUSION

In conclusion, the solar powered standalone CCTV surveillance system is developed to help in the monitoring process around the campus of Universiti Malaya. With the use of the power generation and storage system, the problem of having limited charging time could hopefully be solved. With the proposed development of the web server, a two-way communication between the server and CCTV is hopefully can be achieved which can help users to control the CCTV more easily. And finally, the alert system in the web server will be able to dill in the gap of the security problems where it will be able to alert the related individuals on any security emergencies that occurred during the deployment of the CCTV.

The gap found in the first part of the project is that the development on the server communication with the CCTV where the video will be sent to the database. As of now, there is yet any video captured by the CCTV therefore, it is hard to finalise on the database to send the video captured by the CCTV. The idea of sending the video to be kept in the cloud sounds like a likely and plausible method to store the database. Therefore, this will be taken into consideration in the development of the system in the future along with the development of the system.

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