Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF A SMART STREET LIGHTING SYSTEM WITH FAULT DETECTION USING IOT

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ZAREEN ZURIKA BINTI NORIZAN

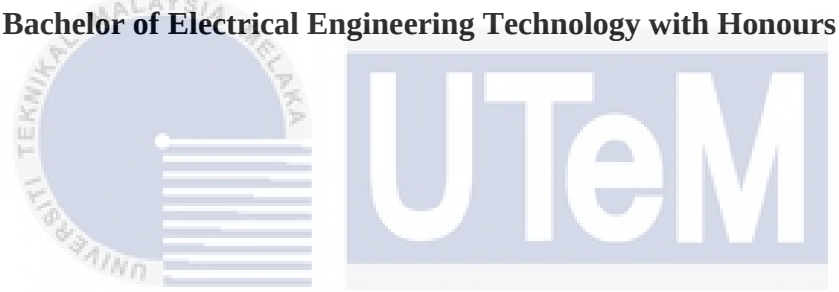
Bachelor of Electrical Engineering Technology with Honours

2021

DEVELOPMENT OF A SMART STREET LIGHTING SYSTEM WITH FAULT DETECTION USING IOT

ZAREEN ZURIKA BINTI NORIZAN

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



Faculty of Electrical and Electronic Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this project report entitled “Development Of A Smart Street Lighting System With Fault Detection Using Iot” 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 : ZAREEN ZURIKA BINTI NORIZAN

Date : 06/01/2022

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

APPROVAL

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

Signature : 

Supervisor Name : DR. AZHAN BIN ABD RAHMAN

Date : 11 JANUARY 2022

Signature :

Co-Supervisor :

Name (if any)

Date :

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEDICATION

My thesis is dedicated to my family and a friend. A special thank you to my loving parents, Encik Norizan bin Nasir and Puan Masrah binti Ismail, who supported me finish this project with their compassion and understanding.

This project is also dedicated to my friends, lecturers and supervisor who have been assisting and supporting me in completing this project on time.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ABSTRACT

Many factors contribute to the importance of proper street lighting, one of which is safety. When we think of safety, the first thing that comes to mind is accident prevention. In general, embedded intelligent controllers based on the Internet of Things (IoT) may be designed with fault detection to pinpoint which street lights are malfunctioning. By implementing fault detection in the street light, monitoring and the management of the street lights will become easier for the lighting technician as they can know when to do the preventative maintenance and also corrective maintenance. By doing preventative maintenance before the street light suffered more damage, the cost of the maintenance can be reduced greatly and the energy and current that flow through will not be wasted. As a result, this project examines a variety of concerns and challenges, as well as several unexpected case studies resulting from a faulty street light. Based on the researches done on this literature reviews from different researches in creating a smart street light with fault detection, most of the studies show almost similar way of construction. The way of construction differs only if the component used differs. These approaches and observations gave a lot of things to be considered while completing this project. The approach used for this project is based on the other research's observation and considered all other factors that can be done in creating a smart street lighting system with fault detection.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ABSTRAK

Banyak faktor menyumbang kepada pentingnya penerangan lampu jalan yang betul, salah satunya adalah keselamatan. Apabila memikirkan tentang keselamatan, perkara pertama yang terlintas dalam fikiran adalah pencegahan kemalangan. Secara umum, pengawal pintar tertanam berdasarkan 'Internet of Things (IoT)' mungkin dirancang dengan pengesanan kesalahan untuk menentukan lampu jalan mana yang tidak berfungsi. Dengan melaksanakan pengesanan kerosakkan di lampu jalan, pemantauan dan pengurusan lampu jalan akan menjadi lebih mudah bagi para peladang kerana mereka dapat mengetahui waktu untuk melakukan penyelenggaraan pencegahan dan juga penyelenggaraan pembetulan. Dengan melakukan penyelenggaraan pencegahan sebelum lampu jalan mengalami lebih banyak kerosakan, kos penyelenggaraan dapat dikurangkan dengan banyak dan tenaga dan arus yang mengalir tidak akan sia-sia. Hasilnya, projek ini meneliti pelbagai kebimbangan dan cabaran, serta beberapa kajian kes yang tidak dijangka akibat lampu jalan yang rosak. Berdasarkan kajian yang dilakukan terhadap tinjauan literatur ini dari kajian yang berbeza dalam membuat lampu jalan pintar dengan pengesanan kerosakkan, kebanyakan kajian menunjukkan cara pembinaan yang hampir serupa. Cara pembinaan akan berbeza jika komponen yang digunakan berbeza. Pendekatan dan pemerhatian ini memberi banyak perkara yang perlu dipertimbangkan semasa menyelesaikan projek ini. Pendekatan yang digunakan untuk projek ini berdasarkan pada pemerhatian penyelidikan lain dan mempertimbangkan semua faktor lain yang dapat dilakukan dalam membuat sistem lampu jalan pintar dengan pengesanan kerosakkan.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ACKNOWLEDGEMENTS

First and foremost, all praises and thanks be to Allah S.W.T for giving the strengths and blessing for me to complete this project despite the pandemic.

I would like to express my gratitude to my supervisor, Dr. Azhan Bin Abd Rahman for their precious guidance, words of wisdom and patient throughout this project. I am also indebted to Universiti Teknikal Malaysia Melaka (UTeM) for the financial support which enables me to accomplish the project.

My highest appreciation goes to my parents, Encik Norizan bin Nasir and Puan Masrah Binti Ismail and family members for their love and prayer during the period of my study.

Finally, I would like to thank all the fellow colleagues and classmates, the Faculty members, as well as other individuals who are not listed here for being co-operative and helpful.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

TABLE OF CONTENTS

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF TABLES

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF FIGURES

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF SYMBOLS

δ	-	Voltage angle
F	-	Force
g	-	Gravity = 9.81m/s
l	-	length
m	-	mass
r	-	radius
x	-	displacement
T	-	torque

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF ABBREVIATIONS

V	-	Voltage
IoT	-	Internet of Things
LDR	-	Light Dependenet Resistor
LED	-	Light Emitting Diode
I/O	-	Input Output
CPU	-	Central Processing Unit
IR	-	Infrared
SMS	-	Short Message Service

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 1

INTRODUCTION

1.1 Background

Street lighting is the most crucial item for workers and farmers in excluded area to ensure their safety. Street light can also be used in a farm area as to lighten the place when the farmers want to check on their crops at night time. Street lighting can gives safety benefits and more vision for the farmers as well as increase the owner safety, particularly from robber and other thieves that can appeared in midnight. These lights have the potential to keep the farm lighted. Smart Street Light can also be used across the roads. These lights must be kept in good working order because they give the required visibility on the road when driving.

Fault detection can be used as an important technology that can detect if there is any broken street light or malfunction street light anytime. The fault in street light can be detected and controlled via the Internet of Things (IoT) innovation. It is quite an appropriate solution since it can immediately notify the owner if the streetlight breaks, including when the light has tripped the circuit breaker. This gadget can also save money by reducing the cost of testing light bulb fuses on a regular basis improved lighting, as Painter, K. (1996) pointed out, is a premium way of generating a significant impact on public safety, improving the built environment, and quality of life for people on the streets after dark [1].

When there is any malfunction street light due to burnt bulb or short circuit that makes the street light to not glowing up at night, this type of technology that can detect which street lights that have fault and did not turn on accordingly will be the greatest help

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

to the local authorities and the technician to do the maintenance works. The lighting technician can save a lot of time by knowing exactly the location of the fault street light coming from. They can also save their energy by checking all the street lights to see if they all function correctly. This type of technology can make the lighting technician works in more a relax situation and can work more efficiently rather than going all over the streets to conduct the maintenance when there is no need to because the street lights are working just fine.

Some of the street light in Malaysia used the timer for streetlights under the council's authority is set between 7pm/7.30pm and 7am/7.30am, according to MPSJ councillor Ken Chia, who chairs the council's infrastructure committee [2]. However, because the street light uses a timer to switch on and off, the street light is switched off automatically even if the environment is still dark at 7.30 a.m. at various periods of the year. As a result, while the streets are dark, it is difficult for vehicles, cyclists, and pedestrians to access the streets early in the morning.

Malaysia's present street lighting system has been found to be inefficient and in need of constant repair. The various street lighting systems are controlled by a light sensoror timed switch that turns on the lights at night or low light intensity during the day and turns them off during the day; therefore, by implementing and utilizing the technology of the IoT-based smart street lighting system with fault detection, energy consumed for the street lighting system can be reduced and energy will not be wasted.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

1.2 Problem Statement

Currently, farmers nowadays have each have their own farm whether their farm located nearby their houses or located far away from they lived. So the farmers tend to install some street lights at their farm to have a vision when they went to visit their farm at night time. Street lights help the farmer to see their farm and to avoid thieves from insert their farm. Farmers will be much more aware as to the street light will help the farmer to notice if there is any suspicious looking stranger going to their farm at night time. The farmers will become more secured knowing that their farms are installed with street light especially those who need to visit their farm all alone in the night time frequently. Next, when there is any fault street light, bad things can happen to the farmers. The fault street light can make it harder for the farmers as to walk across those farm will not be able to see anything because it will be pitch black during the night and some incident can happen during that time.

Nevertheless, Nevertheless, the normal street light is expensive and the maintenance cost is high to test the light bulb fuse occasionally from time to time and the way to check every street light is quite inefficient. Smart streetlights that use information and communication technologies (ICT) such as the Internet of Things (IoT) can help the farm become more energy efficient. Energy will also be wasted when the current is still flowing through the street light, but the light is still not glowing. This will cause the government will still have to pay for the street light electricity so it will be inefficient for the all parties.

When the object is detected using the sensor and the lights are not turned ON consequent naturally, this is perceived as a fault has happened. Also, the message is sent as a caution and to alert the farmers. The notification massage will be sent by utilizing the Internet of Things (IoT) innovation. Consequently this system is intended to lessen the force utilization to recognize and address the flaw in the system.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

1.3 Project Objective

The objective of this paper is to design and develop a smart street lighting system that can identify faults using the Internet of Things. At the end of this project, the objectives that are going to be achieved are as follow:

a) To design and develop an IoT-based simple smart street lighting system with fault detection.

b) To test the system functionality that can alert the farmers on broken lamps.

c) To analyse time taken for the message of warning about faulty street light to be delivered to the farmers.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

1.4 Scope of Project

The project briefly described the boundaries of this project which focused on micro controller programming with Arduino Uno, circuit design and the purpose of developing the hardware. The details of the scopes of the project are explained in the following:

a) The circuit is design using Proteus to support the smart street lighting system using Arduino UNO micro controller as servers and to connect to the hardware. The platform used to configure the Arduino UNO micro controller to allow communication is Arduino IDE software.

b) The system functionality that can alert farmers and lighting technician on broken lamps willbe tested by looking if the message has been sent when the fault is detected.

c) Analyze the time taken for the message to be delivered to the farmers or lighting technician on duty by using a stopwatch when the message about gfaulty street light received and to check if the project is successful.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In today's modern society, Smart lighting systems make use of technology that helps to reduce power consumption while also conserving energy. The Light Dependent Resistor (LDR) detects light at first, and the resistance of the LDR varies depending on the brightness. During the night, the lights usually have a low intensity. An infrared sensor is used to detect any object that passes close to the sensor's operating area.

However, for this project with an upgraded smart street light system using fault detection was to innovate the embedded system with the addition of fault detection by sending messages to inform the farmers and send the alarming notification through the mobile phone telling that there has been a fault that happened to one of the smart street lights. This project utilizing GSM module to detect the faulty street light that can happen at anywhere and anytime. This procedure is carried out via the Internet of Things (IoT), which is connected to the Arduino UNO micro controller, which serves as the project's main server. The message will be sent via mobile application so the farmers will know when there is any fault happened and can go directly to the scene to do the maintenance of the faulty street light and the problem will be solved.

Other than that, these type of Smart Street light can also be implemented across the roads. According to MPSJ councilor Ken Chia, who leads the council's infrastructure committee, certain lamps in Malaysia utilize a timer for lighting under the council's jurisdiction that is set between 7pm/7.30pm and 7am/7.30am [2]. Unfortunately, because the

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

street light uses a timer to switch on and off, the street light will switch off automatically even if the environment is still dark at 7.30 a.m. at various periods of the year. As a result, while the streets are dark, it is unsafe for vehicles, cyclists, and pedestrians to cross the streets early in the morning. So by utilizing the LDR sensor, which can detect the presence of the light, the timer will not be needed and it can conserve lighting energy by glowing at the minimum intensity when the infrared sensor did not detect any motion around the street lights.

From TNB's Environmental Initiatives - Green Development, the UNITEN Putrajaya Campus has a Smart Street Light Showcase Project, which is a street lighting system with communications networks that able to perform tasks like as brightness control, monitoring, and digital street signs. Malaysia is one of the countries that has implemented an IoT-based smart street light system

2.2 Faulty Street Light

The faulty street light can happen at any time and there are many factors that can cause the street light to be broken. One of the factors that can cause the street light to be broken is the bad quality of light components such as burnt light bulb, damaged time-switch and other components in the street light. If the light bulbs burn out too often, the issue may fall under high wattage, insulation is near to light, poor wiring on the circuit and mains or more wattage on a dimmer switch [3]. According to the Tenaga Nasional Berhad portal, other than the bad quality of the light, the bad weather also can affect the good condition street light such as when there is a thunderstorm or heavy rain the possibility of the tree to fall and hit the street light is high [4]. This is because usually trees are planted closely to the street light so when the thunder struck the tree, it will cause the tree to fall and hit the nearby

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

street light. The third party also can cause a problem for street light. The examples of the third party are like damaged poles due to road accidents, damaged underground cable, etc.

So the faulty street light can happen at any time and anywhere. When the street light is not glowing, but the current is still flowing through the street lights, the energy will be wasted and it will be inefficient as the lighting technician will not know the exact location of the street light without the fault detection. By utilizing the fault detection in the street light, the lighting technician will have no difficulties to do the maintenance whenever there are any street light malfunctions.

2.2.1 Report on Faulty Street Light

In any local area, the faulty street light needs to be reported by calling the local authorized by email. The report's email address was supplied on the company's online page. Some online websites have provide a form to make the reports by the residents. The residents need to fill all the required question and provide some details of the problem street light such as the lights does not turn on, the lights does not off and other issues that related to the street light. By providing the problems, lighting technicians can do the maintenance accordingly to the report.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2.2.1.1 Common Problems with LED Lights

The term "light emitting diode" refers to a device that emits light. In comparison to incandescent light bulbs, LED lighting products produce light up to 90% more effectively. Because of its sturdy casing/housing, small components, inability to heat-up, and low energy usage, an LED light is meant to be stronger and endure longer than typical fixtures.

Among the most significant issues with modern lighting systems is purchasing and utilizing the incorrect LED bulbs. For most circumstances, low-cost LED bulbs aren't as

dependable as other lighting options. Ultimately, these components become faulty in a short period of time, exhibiting difficulties such as flickering, unusual heating, spontaneous dimming and even premature failure.

A lot of the problems LED light fixtures usually exhibit are as a result of poor installation. A faulty lighting system connection might cause plenty of issues such as short-circuits can be caused by loose or exposed cables, poor light distribution, breakdowns on a regular basis, and so forth.

2.3 Case Studied of Street Lighting

2.3.1 Case studies

Kee, K. K., Lau, S., & Affandi, M. H. [5] stated that the street lighting systems in Malaysia must follow the regulations and rules that have been set up by the Public Works Department that according to the Malaysian standard in 2020. It is also include the specification for the street lighting brightness. According to the MS852 Part I, the street light is not allowed to turn OFF in any situation, even in low condition. From the studies, it stated that by using the LED, the potential energy saving can go up to 48% compared to the conventional street lighting system. Pubic lighting, on the other hand, has been proven in tests to reduce crime by up to 20% and traffic accidents by up to 35%. When compared to more energy-efficient systems utilized in developed nations, many existing street lighting systems in Malaysia have comparatively high energy consumption and power costs. To automate the switching procedures, the system still use an ON/OFF switch, a timer, or a light-activation sensor.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2.3.2 Harmful Effect of Faulty Street Light

There are some researches related to real cases which occurred in recent years in Malaysia and other country. Only a quarter of all car travel is done between the hours of 19.00 and 08.00, but it is during this time that 40 percent of fatal and serious injuries are sustained. This means that driving at night is more likely to result in death or serious injury than driving during the day [6].

Other than that, Some examples have been gathered from various case reports, journals, and newspapers, including one in which a woman was strolling alone on a dimly lighted street at 8.30 p.m.. This case occurred in Bangalore, India where a woman almost get raped by a cab driver [7]. The perception of poorly lit streets is that they are dangerous. Fear would be reduced if the street was well lit. Women and everyone else, even the elderly, would feel more welcome on the street as it can ensure their safety.

There is also a case occurred in Johor Baru, Malaysia, the street lights that located along Jalan Persisiran Danga Sutera have created discomfort because for three to six months, respectively, they were not in a good condition to function accordingly. The witness of the accidents that happened there said that the complained had been made to the relevant authorities but the fault lights still not repaired as soon as possible [8].

Accident prevention and better security are two major advantages of street lighting. It is better to have awareness of that this type of cases can happen to anyone that uses the street a lot such as the walkers and the driver. When the residents take the initiative to call or email the local authorized, sometimes it will take quite a while for lighting technicians to come and do the maintenance.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2.3.2.1 Example of Smart Street Lights

Cities that invest in smart lighting get a return on their investment. While Smart Poles helped Los Angeles generate income by offering Long-Term Evolution (LTE) reception while also conserving energy, a four-year plan to replace 270,000 street lights with LEDs and smart controllers may save Chicago $10 million per year in energy expenses. With the introduction of the Eolgreen turbine lamppost, which is powered by wind, cities in Spain have also invested in green street lighting.

Sensor-enabled smart streetlights have been placed in San Diego to assist driversin finding accessible parking places and to alert traffic enforcement officers about unlawfully parked vehicles. These smart lights might be linked to technologies that can detect which intersections are the most dangerous and need to be adjusted automatically. Sensors linked to streetlights might detect gunshots, smashed glass, or a car accident, perhaps aiding authorities in traffic signal management by monitoring intersections and recording when traffic backs up.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

While in Malaysia, In the first phase of the project, 92 streetlights in the Malaysian state of Penang's Bayan Lepas Free Industrial Zone will be upgraded. Weather- proof 6LoWPAN wireless mesh network modules have been installed in the street lights, which will replace the existing sodium vapour bulbs with considerably more energy- efficient and dimmable light-emitting diodes (LEDs).

2.3.2.2 Energy-efficient streetlight

Due to faulty design, most street lighting nowadays wastes a lot of electricity. A smart city's key aims in street light management are energy conservation and simplicity of maintenance with minimum physical work. Kee, K. K., Lau, S., & Affandi, M. H. stated that street lighting systems in Malaysia must follow the regulations and rules that have been set up by the Public Works Deparment that according to the Malaysian standard in 2020. It is also include the specification for the street lighting brightness. According to the MS852 Part I, the streeet light is not allowed to turn OFF in any situation, even in low condition [5].

The energy-efficient LED lighting is utilised in this system, and the intensity of the brightness may be controlled automatically using the LDR. According to their characteristics, LED light sources have a long lifespan and require less energy. According to some research done to identify the possibility of energy savings, LED lighting findings reveal a potential energy savings of up to 48 percent when compared to standard street lighting systems.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Type of Lamp	Lumens per watt	Average lamp life in Hours
Incandescent	8-25	1000-2000
Fluorescent	60-600	10000-24000
High Pressure Sodium (HPS)	45-110	12000-24000
Low Pressure Sodium (SON)	80-180	10000-18000
Metal halide	60-100	10000-15000
LED	28-79	25000-100000

Table 2.1 shows each lamp efficiency and also the service life of the lamp

2.4 The application of the fault detection in Street Light

It is difficult to maintain the same level of urban living due to the consequences of faster development. However, the IoT's which is the Internet of Things developing technological advancement is driving a transition to a more dynamic approach to dealing with future difficulties. An arduino application is used to operate street lights and detect faults with a cloud storage system. By using the coding program software which is Arduino IDE, the level of intensity can be set to indicate if there is any fault happens to thestreet light automatically. The street lamps are now operated through manually.

The street light control and fault detection utilizing the cloud storage system, on the other hand, automatically turns the street lighting on and off and detects street lighting faults. For the street lights ON/OFF, the system monitors the environment. To check the time, an LDR (light dependent resistor) is utilised. LDR's function is to detect if the environment is light or dark.

The street lights should have been turned on during the day. However, some of the faulty lights are not turning on. The system detects that the lights are not glowing at the moment. As a result, some fault occurs in the light, which we may detect using the LDR readings. As a result, the system uses the GSM module to transmit the alarm message to the authorised man's mobile phones to give them the alert massage. The faulty street light can be found using the fault detection in the exact location.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

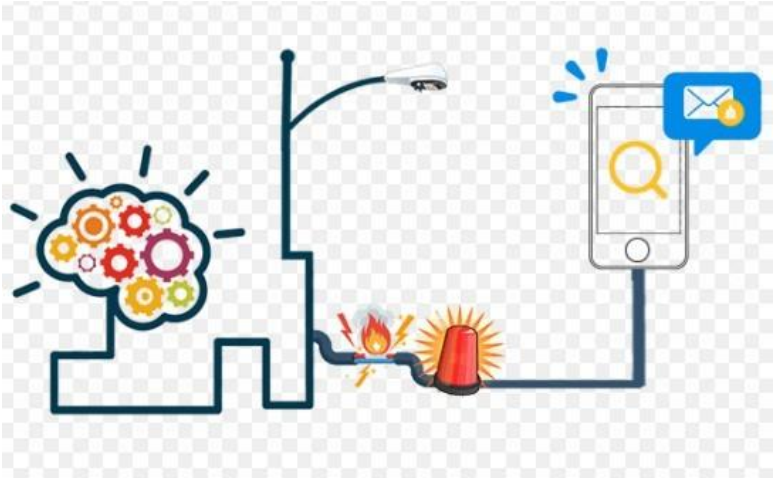


Figure 2.1 shows a diagram of when the fault happens and an alert message is sent to the mobile phone

2.5 Preventative and Corrective Maintenance of Street Light

Preventive maintenance, often known as preventative maintenance, is the process of preventing resource and gear breakdowns. This management approach is conducted on a regular basis, which means that even though there are no indications of breakdown, the equipment is examined. This way, any component failure is minimised as much as possible, ensuring the resources' efficient functioning and welfare. Corrective maintenance is a series of technical actions and decisions taken when equipment fails which has to be repaired or replaced. This form of management is used to repair faults in equipment that will have to be maintained in order to return to its original state [9].

Preventative maintenance before the light burnt is much more efficient as to it will save a lot of cost than have to repair and replaced back all the components that needed for the street light to operate back to its original state. The preventative maintenance can be done by lighting technicians when they received the message from the GSM module that has been used to detect the fault in the street light to the location of the street light and observe the fault in the street light. Compared to the corrective maintenance when the bulbs have burnt

or any obvious damages to the street light and have to replace all the components, it will cost a lot more that the preventative maintenance which will only to prevent the street light from having bad damage and can still operate in its original state. By using the fault detection, the preventative maintenance is possible if the lighting technicians received the message earlier to prevent the street lights from badly damage.

2.6 Previous Relateed Work

The referenced work includes a summary of past projects on the smart lighting system by a variety of researchers. The system's methodology as well as the purposeful application of numerous communication technologies are briefly explained.

Guilherme H. Costa, Anderson S. dos, and Marco A.D. Costa [10] in 2009, LEDs, solar energy, and batteries were used to create an automated street lighting system. In this method, LEDs are utilised to represent a light source for the system. Despite being difficult to develop, the system is extremely effective due to all of the DC-DC power stages. The battery's price will be quite costly is the cause behind this. If the batteries are costly, the system will be far more pricey, and the batteries would have a shorter lifespan.

Yeu-Torng Yau, Po-Yen Chen and Hung-Chun Lee, Yi-Hua Liu [11] in 2009, have previewed a street lighting system that includes LED, digital control LED operating circuit, LED lamps, and Ethernet connectivity. Nevertheless, the system became inefficientas the number of accidents increased, according to its use of ethernet.Ethernet was also inappropriate for real-time applications because to its non-deterministic properties.

In order to construct a street light control system, Hengyu Wu, MinliTang [12] a single-chip microprocessor, the AT89S52, contains a power circuit, a fault detection circuit, a photosensitive detection circuit, an infrared detection circuit, an LCD display circuit, a street light control circuit, an alarm circuit, and a pressed key control circuit. This technology

can regulate switches and turn lights on and off based on road activity. The fundamental issue in the system is that it does not explain how this works. It stated that when a fault detection circuit is broken, the voltage is will become zero, producing a problem, according to the report. This is a theoretic evidence that only exhibits simulation findings, not real-world experiments.

Kee, K. K., Lau, S., & Affandi, M. H. [5] used the microprocessor ATMEGA328 as the controller device to control the specific tasks programmed. The difference in this project is the utilizing of the rain/water sensor, current sensor and also the wireless Network Module. The project's goal is to design and create a smart street lighting system that uses wireless sensing network technologies to save energy and make maintenance easier. The LED light source ensures optimum energy efficiency in brightness, while an adaptive control system based on environmental data is used to significantly improve energy savings.

Other than that, there are also some researches and studies that related to energy efficiency for the street lighting system which is by implementing the different type of lamps, which the researchers used Metal Helide, fluorescent, and High Pressure Sodium (HPS) [13]. There is also about implementing the usage of photovoltaic (PV) solar as their power source [14]. The purpose of this project study is to save energy by using a kinetic sensor to regulate the system such as infrared sensor. LEDs are being used to replace HPS lamps, and dimming the street light is a way recommended throughout the project for achieving great energy efficiency.

The differences between the other researches and this project can be seen from the components this project used. This project used LDR (light-dependent resistor) to detect the presence of light in the daytime and nighttime. This project utilised the GSM module as the medium from Arduino UNO as the main server to connect to the mobile phone and that way it can alert the authorities and to inform about the fault of the street light. That way the

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

maintenance of the street lights can be done faster and the energy from the current flowing through the street light will not be wasted.

2.7 Summary

Throughout this aspect, embedded intelligent controllers based on the Internet of Things (IOT) may be designed with fault detection to pinpoint which street lights are malfunctioning. By using the GSM module, lighting technicians or local authority will get alert of the fault that happens to the street light. Many factors contribute to the importance of proper street lighting, one of which is safety. When we think of safety, the first thing that comes to mind is accident prevention. Poor visibility is a major cause of accidents, as drivers are unable to see where they are going and drivers are unable to see oncoming traffic or roadside obstacles. As a result, this chapter examines a variety of concerns and challenges, as well as a number of unexpected case studies resulting from a faulty street light.

Based on research done on this literature review from different research in creating a smart street light with fault detection, most studies show almost similar construction methods. The way of construction differs only if the component used differs. These approaches and observations gave a lot of things to be considered while completingthis project. The approach used for this project is based on the other researchers' observations and considered all other factors that can be done in creating a smart street lighting system with fault detection.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 3

METHODOLOGY

3.1 Introduction

In general, the two most significant criteria for this defective system street lighting are accuracy and performance. The term "accuracy" relates to how the system determines which street lights are broken. Meanwhile, efficacy refers to the system's capacity to operate properly by delivering an alarm message to a mobile phone, as well as the time it takes for the message to arrive.

3.2 Methodology

This thesis shows the about how the project flow from the beginning until the end. The project is about to detect the fault in the smart street light. This project will first begin with the identification of the problem of this project and by collecting some informations from other researchers so that this project can flow accordingly.

After that, the software that was used in this project are Proteus and Arduino IDE is used to design the circuit and to do the program development which is the coding neededfor the project. After the simulation is done, if the result is as expected then it can proceed to the test of the functionality and the result of this project can be analysed but if the simulation is failed then it will loop to the design of the circuit. The result of this project can be analysed by using a stopwatch when the system detects the fault.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

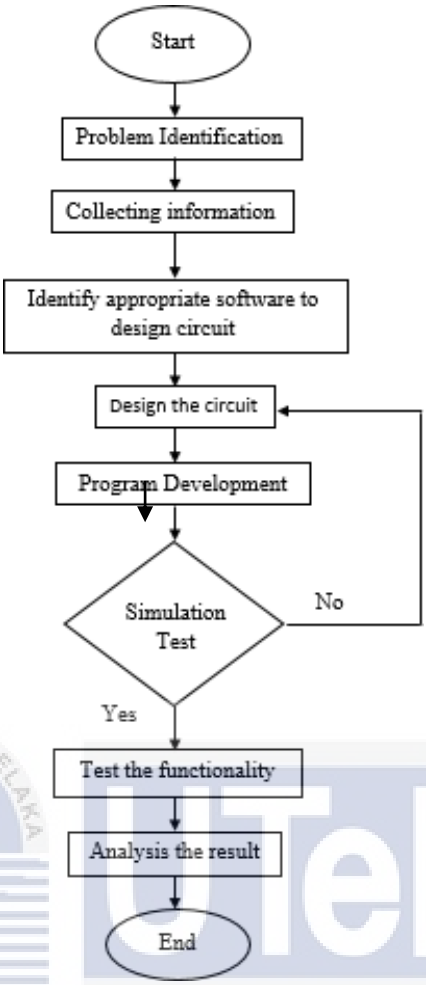


Figure 3.1 show estimation general process flow

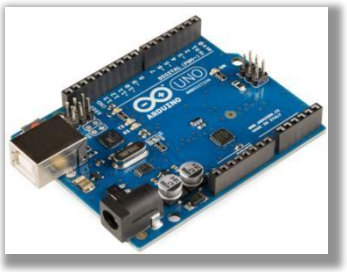
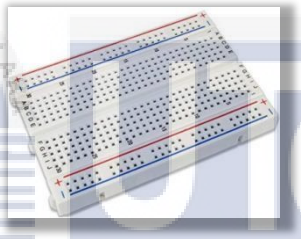
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

3.2.1 Experimental setup

This thesis presents an integrated analytical approach in creating a smart street light with fault detection utilizing IoT (Internet of Things). The essence of the approach used in this project is centered on the main server used which is Arduino UNO micro controller as the brain of this project. The chosen strategy is based on the issue description and other relevant techniques, with the goal of developing an IoT-based smart street light with failure detection that uses a GSM module to send an alarm message to a relevant authority. By simulation and the test of functionality of the project then the result can be analyzed. Subsequently, Figure 3.1 shows the research design of this thesis.

3.2.1.1 Selection of Materials

According to the study done for this project, the appropriate materials or components that will be employed for this project are as follows.

MATERIALS	PICTURE
Arduino UNO	
Breadboard	
LED	
Resistor 10k Ohm	

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

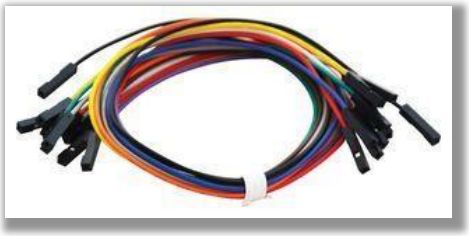
LDR	
Jumper Wires	
IR sensor	
GSM SIM 900A MODEM	

Table 3.1 shows the components used in the project

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

3.2.1.2 Material Specification and Function

Every components have their own function that have been considered deliberately as to matches the aims for this project.

Component	Input/Output	Control	Function
Arduino Uno x 1	-	Automatic	The micro controller which integrates the other component with coding
Breadboard x 1	-	-	To build test circuitsbefore finalizing anycircuit design
Jumper Wires	-	-	The wires carry the electric current to various parts of the electric or electronic system
LED x 3	Output	Automatic	When current runs througha semiconductor light source, it emits light.
Resistor 10k Ohm x1	-	-	As a circuit element, it involves electrical resistance.
LDR x 1	Input	Automatic	The most used devicesfor detecting the presence or absence oflight, as well as estimating light intensity.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

IR sensor x 3	Input	Automatic	An electrical gadget that detects and monitors infrared radiation in its surrounding environment.
GSM SIM 900A MODEM	Input/Output	Manual	This module is used to implement the Internet of Things (IoT) Embedded Applications.

Table 3.2 shows the function of the selected componenets

3.3 Main Components of This Project

3.3.1 Infrared Sensor

Infrared sensors are Infrared-emitting electrical sensors that detect individual elements in their surroundings. An infrared sensor detects motion and measures the heat of an object. The phrase "passive IR sensor" refers to sensors are used to detect rather than emits infrared radiation. In the infrared spectrum, almost all substances emit some type of heat emission. These radiations are unnoticeable to the naked human eye, but an infrared sensor would capture them. A conventional infrared LED serves as the emitter, while a photodiode serves as the detector, detecting infrared light of the same wavelength as the IR LED.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

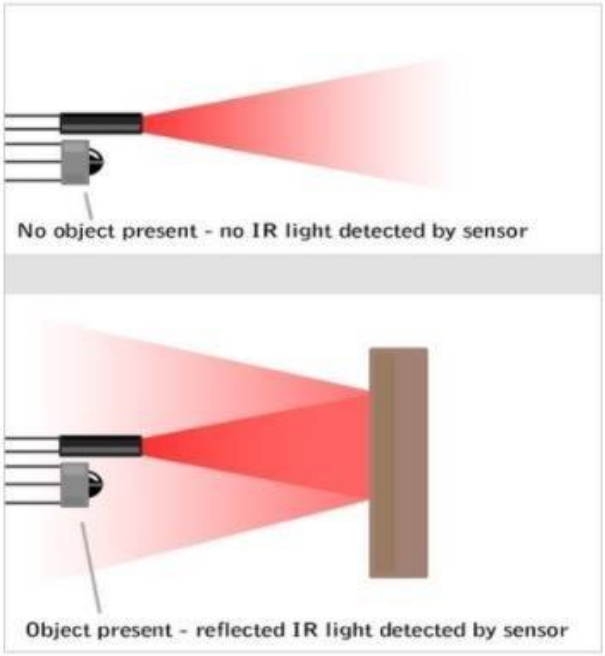


Figure 3.2 shows the reflected IR detected by the sensor

In electrical devices, the infrared sensor circuit is one of the most basic and commonly used sensor modules. This sensor works in the same way that a human's visionary senses do, one of the most common real-time implementations is to identify the obstacles. The following elements comprise this circuit:

- LM358 IC 2 IR transmitter and receiver pair.
- Resistors of the range of kilo ohms.
- Variable resistors.
- LED (Light Emitting Diode).

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

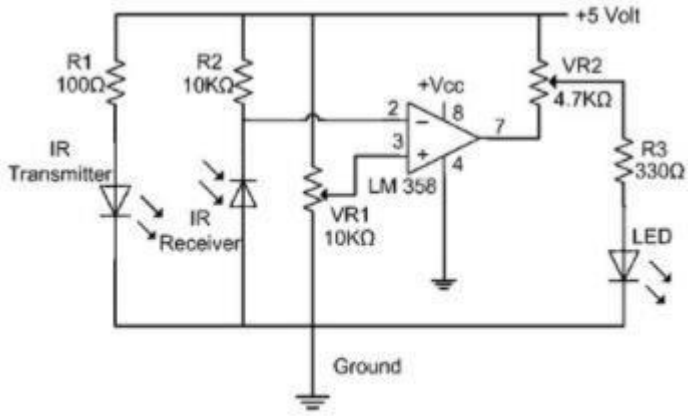


Figure 3.3 shows Infrared Sensor Diagram

3.3.2 Light Dependent Resistor (LDR)

Light-sensitive devices, often known as photo resistors or light dependent resistors (LDR), are light-sensitive devices that really can detect the occurrence of light as well as evaluate the light intensity. Their resistance is quite high in the dark, sometimes up to 1M, but when exposed to light, depending on the strength of light, the resistance decreases fast, maybe to a few ohms. LDRs are nonlinear devices whose sensitivity varies depending on the wavelength of light used. They're used in a number of applications, however, comparable devices like photodiodes and phototransistors can make them redundant at times. Some nations have prohibited lead or cadmium-based LDRs due to environmental concerns.

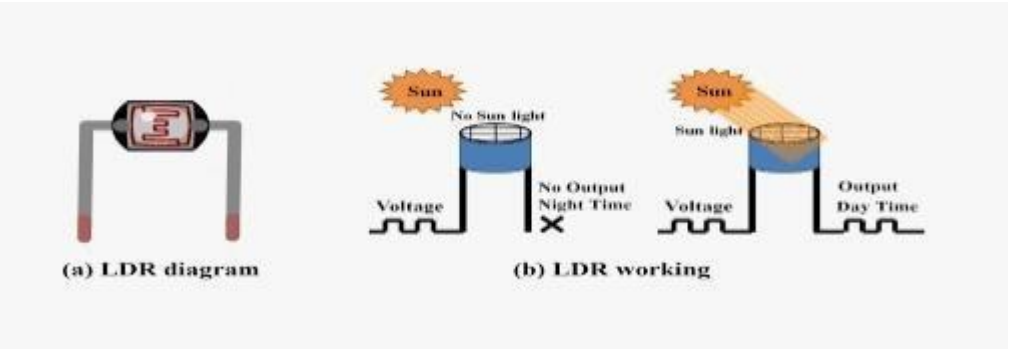


Figure 3.4 shows how the LDR working by detectting the presence of light

As the wavelength of light changes, so does the sensitivity of a photo resistor. The device's resistance has no effect if the wavelength is outside of a specific range. The LDR can be regarded insensitive in that light wavelength range. The wavelength spectral response curves against sensitivity of various materials are different. Longer wavelengths of light are commonly used to make extrinsic light-dependent resistors, with infrared wavelengths being preferable (IR). It's crucial to remember that when working in the infrared, heat can affect readings by raising the device's resistance due to thermal effects. Figure 3.5 shows the working temperature in K is indicated in parentheses, and the spectrum response of photoconductive detectors built from various materials is shown.

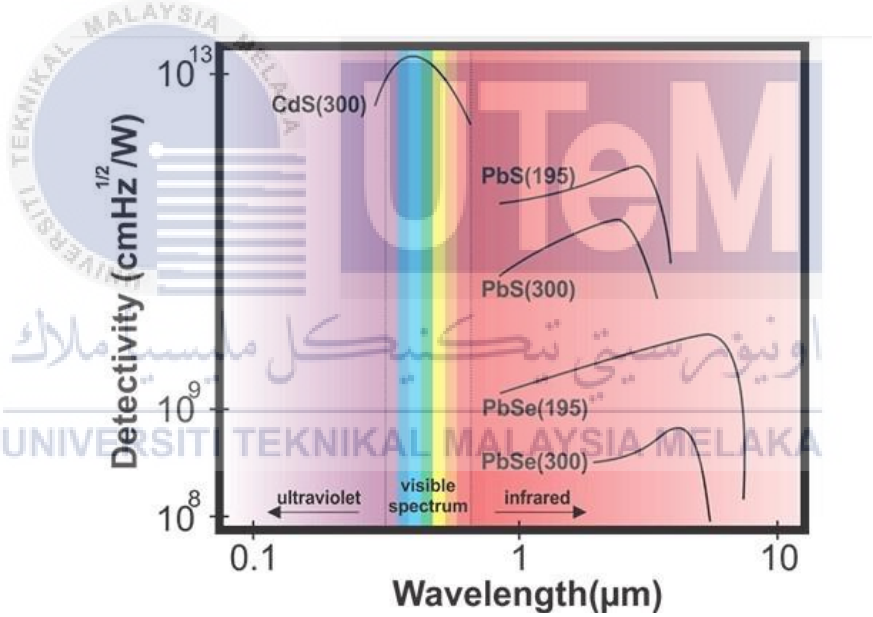


Figure 3.5 shows the working temperature in K is indicated in parentheses

3.3.3 Arduino Uno Microcontroller

The Arduino/Genuino Uno micro controller board is based on the ATmega328P micro controller (datasheet). On the board, there are 14 digital input/output pins (six of which are PWM outputs), a USB connection, six analogue inputs, a power connector, a 16 MHz quartz crystal, an ICSP header, and a reset button.

The term "uno" means "one" in Italian, and it was chosen to mark the release of the Arduino Software (IDE) 1.0. The Uno board and Arduino Software (IDE) version 1.0 were the reference versions of Arduino, and subsequent versions have since been released.

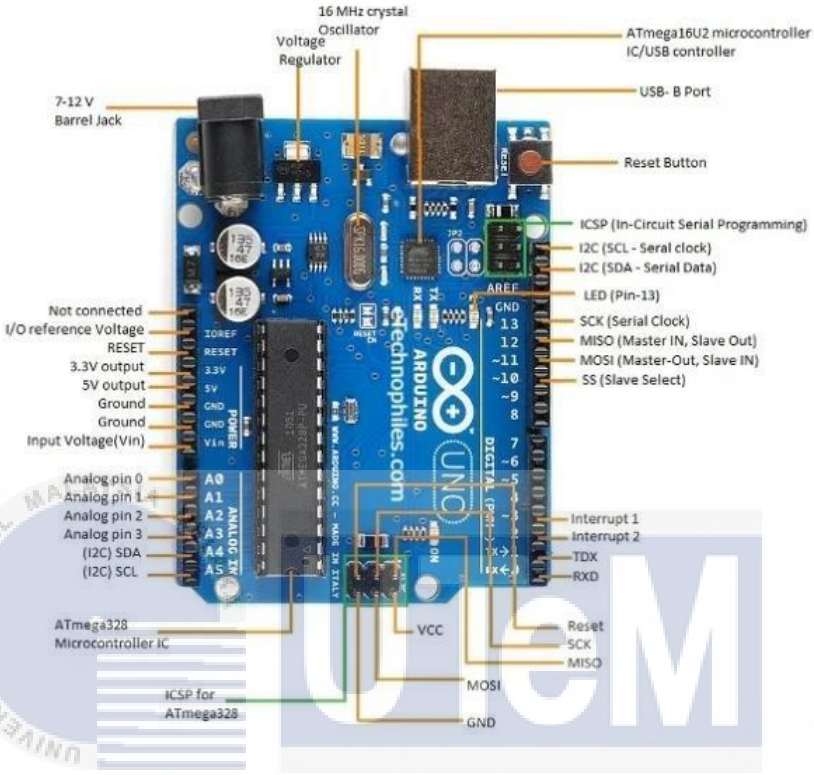


Figure 3.6 shows the pin diagram for the Arduino Uno board

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

The Arduino Uno may be powered by an external power supply or a USB connection. A battery or AC to DC converter are the most common external power source. The Arduino Uno may be linked to the adapter by inserting it into the Arduino board's power port. Additionally, the battery leads can be connected to the Vin and GND pins of the POWER connection. 7 to 12 volts are the recommended voltage range.

A fibreglass reinforced the poly fuse on the Arduino Uno board protects the PC's USB port from over-voltage. The fuse provides an extra layer of protective mechanism to many PCs, which already had their own supplementary protection. If more than 500mA is supplied to the USB port, the fuse will sometimes disconnect the connection until the over-voltage is discharged.

The length and breadth of an Arduino board are the most important physical qualities. The Arduino Uno printed the circuit board is 2.7 X 2.1 inches in length and breadth, although the power jack and USB connector will extend the outside of these measurements. Otherwise, the casing with the screw holes can be used to bind the board to the surface.

3.3.4 GSM SIM 900A MODEM

The SIM900A is a GSM/GPRS module that is common and may be found in a variety of mobile phones and PDAs. The Internet of Things (IoT) and Embedded Apps modules may also be utilized to develop IoT and Embedded Apps. The SIM900A is a dual- band GSM/GPRS engine that runs at EGSM 900MHz and DCS 1800MHz. SIM900A includes GPRS multi-slot class 10/class 8 and supports GPRS coding schemes CS-1, CS-2, CS-3, and CS-4 (optional). Figure 3.7 shows SIM900A GSM Module pin out. Even though SIM900A has a total of 68 pins, employing these pins help in the development of applications. However, if we utilise a module to interface with Arduino, we will just need a few pins. [15].

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

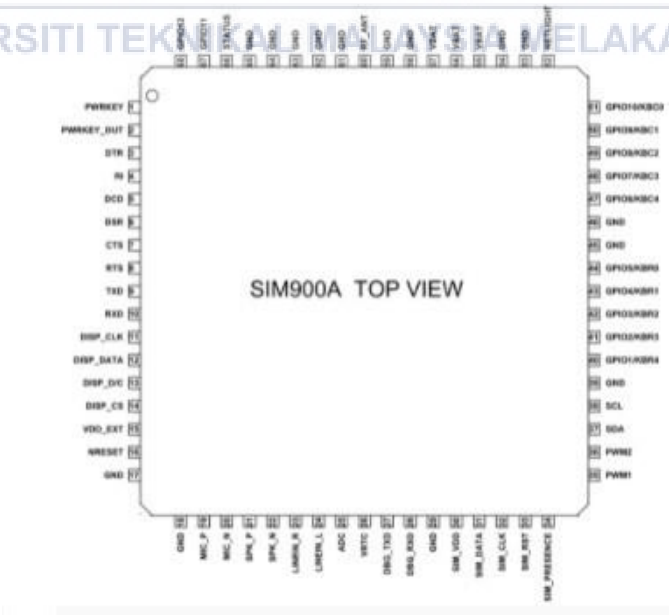


Figure 3.7 shows SIM 900A GSM Module pin out.

3.4 Block Diagram and Flow Chart

3.4.1 Block Diagram

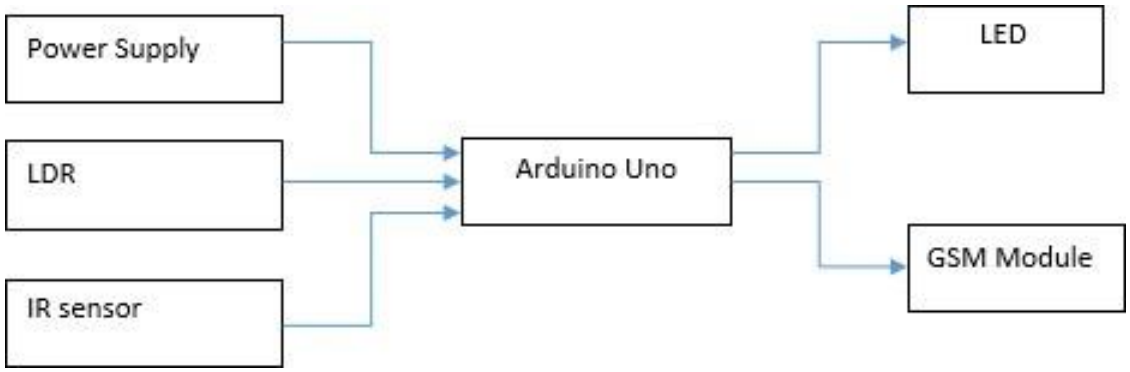


Figure 3.8 shows the Block Diagram of this project

Figure 3.8 The power supply that will be linked to the system, the LDR (Light-Dependent Resistor) sensor, and the infrared sensor (IR sensor) that will be used to detect the presence of sunlight and motion that passes through the infrared sensor sensor are shown as inputs for this project. All the input will be connected to Arduino Uno as the brain and let it run to get the output of the LEDs and finally got the massage from the GSM Module to notify and alert the authorised person when the fault happen.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

3.4.2 Flow Chart

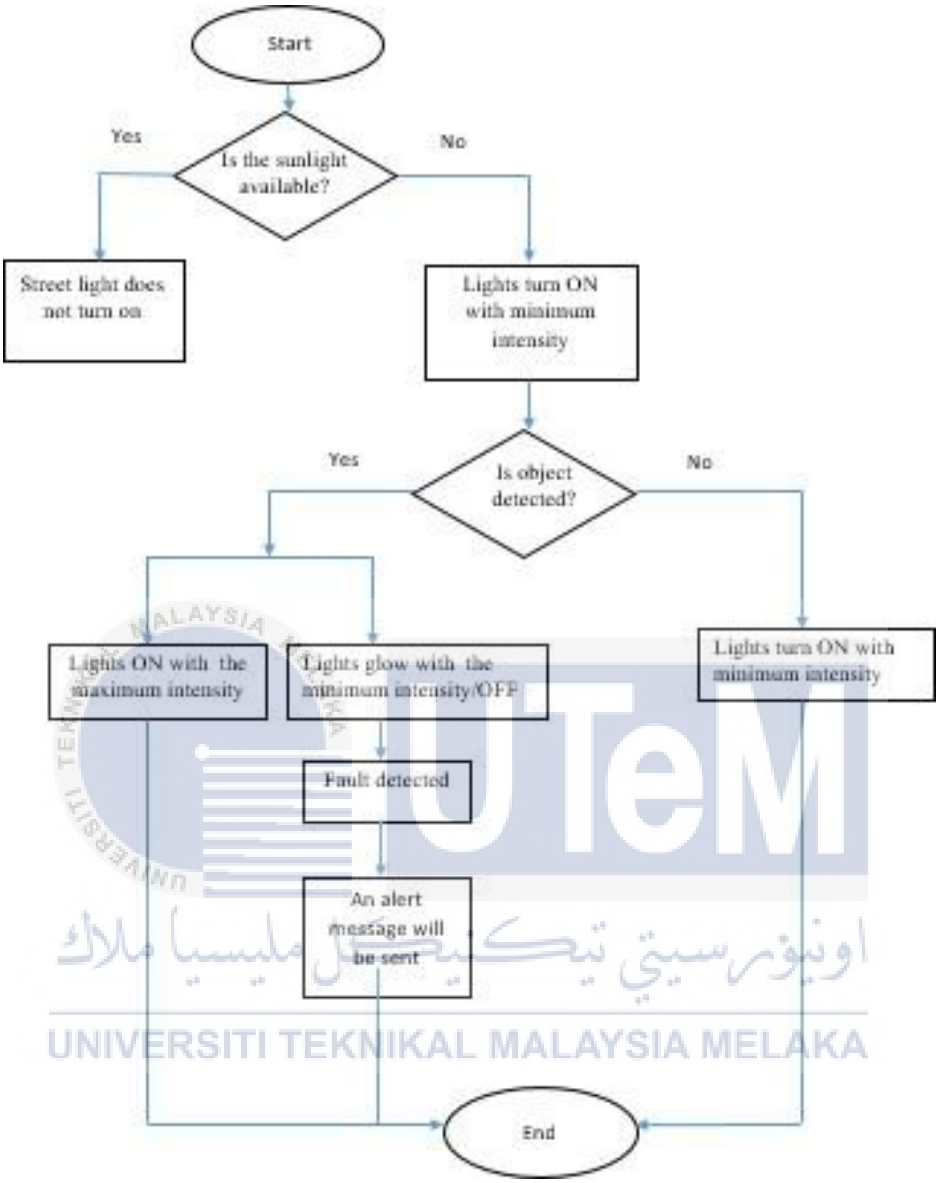


Figure 3.9 shows the flow chart of this project.

Firstly, to start the project, power source contain of 5V will be connected to the project and the project were left outside where it can reach the sunlight. After that the LDR will detect the presence of the light the LED will turn ON with low intensity when there were no light, and turn OFF when it detect the presence of the light. The when the IR sensor detect any movement nearby the street light, then the LED will turn ON with its full

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

brightness. When there were any fault detected then an alarming message will be send to the corresponding mobile phone to give the information which street light is at fault.

3.5 Summary

This chapter outlines the technique that will be used to create a new, more effective, and integrated way to building a smart street lighting system with IoT-based defect detection. The suggested methodology's main goal is to achieve a simple, less rigorous, and effective estimation that does not result in a substantial loss of accuracy in the findings. The techniques were also designed to create a basic yet effective project. The method's ultimate goal isn't to produce a tough and complicated design and development project, but to be efficient, easy to use and modify, and accessible on a wide scale.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the initial result of what we got in this project. Firstly, the preliminary result that has been done is the simulation result. The simulation is done using the software Proteus. Meanwhile, for the program development, Arduino IDE is used to find the right coding for the result. After the right coding is done according to the circuit design from the Proteus, the simulation can be done. The simulation shows the location of the faulty street light by utilizing the intensity of the LDR.

4.2 Results and Analysis

4.2.1 Exposure To The Sunlight

4.2.1.1 Street Lighting Turned OFF

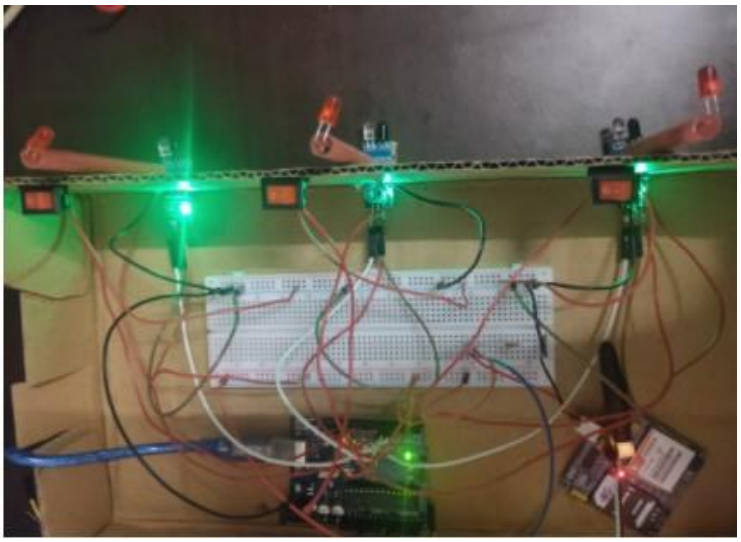


Figure 4.1 shows smart street lighting turned OFF

Figure 4.1 showed the street lighting were turning OFF. The analysis of this case is when the project of Smart Street light is being exposed to the outside world and the light shows that it turned off because the luminance intensity detected by the LDR is more than 500lx. So the LED will turned OFF according to the coding uploaded to the Arduino UNO. Figure 4.2 showed the interfacing between the hardware project that connected to the Arduino UNO. The serial monitor will show the reading for the LDR when the project is connected to the power source.

Figure 4.2 shows LDR reading when there is sunlight

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LDR Reading	Condition of the LED Smart Street Light
>500	OFF

Table 4.1 shows the LDR reading and the condition of the LED

4.2.1.2 Street Lighting Turned ON

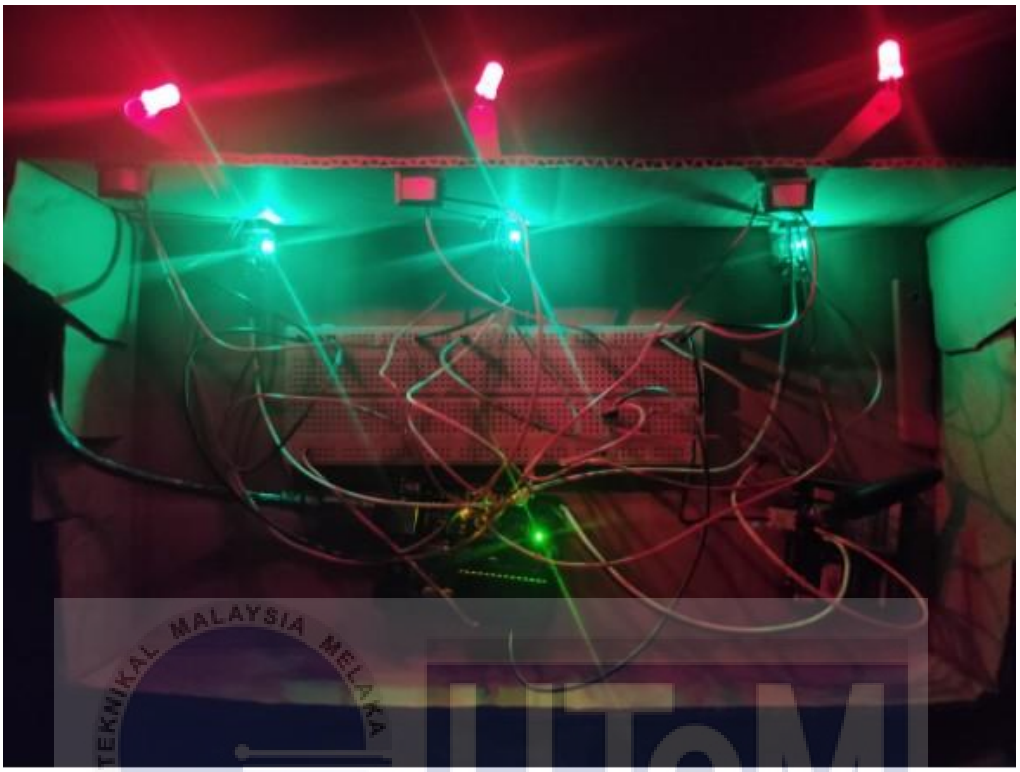


Figure 4.3 shows Smart Street Light Turn ON

Figure 4.3 showed the street lighting were turning ON. This shows that the LDR detected that there were no presence of luminance in the area and the information were send to the processer which is Arduino UNO and thus the LED were turned ON. The LED will be turned on when the LDR detected that the luminance intensity were below than 500lx. The LED will be turned ON when the time is around 7.00pm when the sun is about to set.

The LED will be turned ON as dimmed when there were no movement that can be detected by the IR sensor. This way will save the cost of electricity when there is no usage of the street lighting. Figure 4.6 showed the interface when the LED were dimmed when the LDR did not sense the luminance of the sunlight. The IR sensor will detect any of the movement that were located near the street light and when there were any presence detected by the IR sensor, the LED will be turned on in full intensity.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

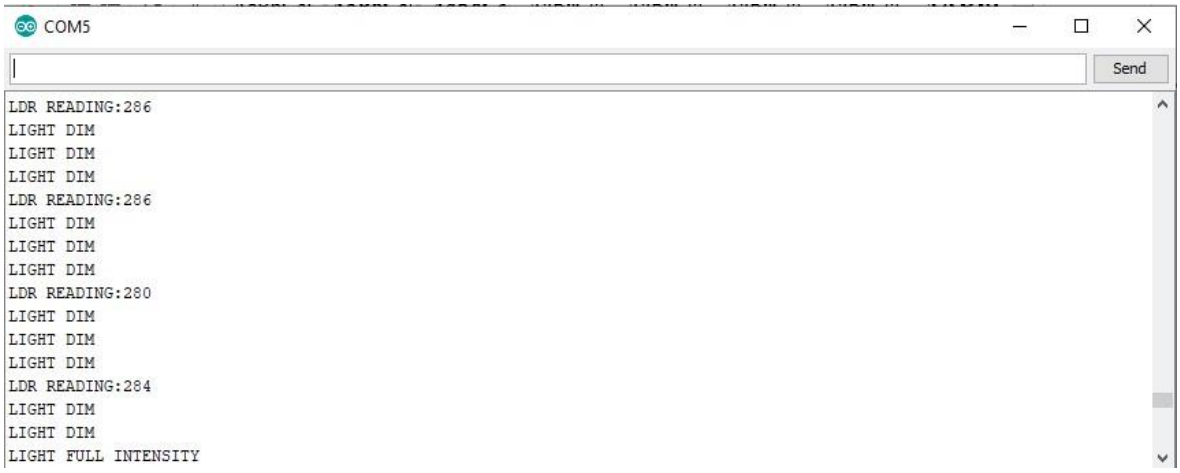


Figure 4.4 shows the LDR reading when there is no sunlight

LDR Reading	The Condition of LED Smart Street Light
<500	Turn ON with Low Intensity

Table 4.2 shows the condition when there is no sunlight

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

4.2.2 Faulty Street Light and Time Taken to Receive the SMS

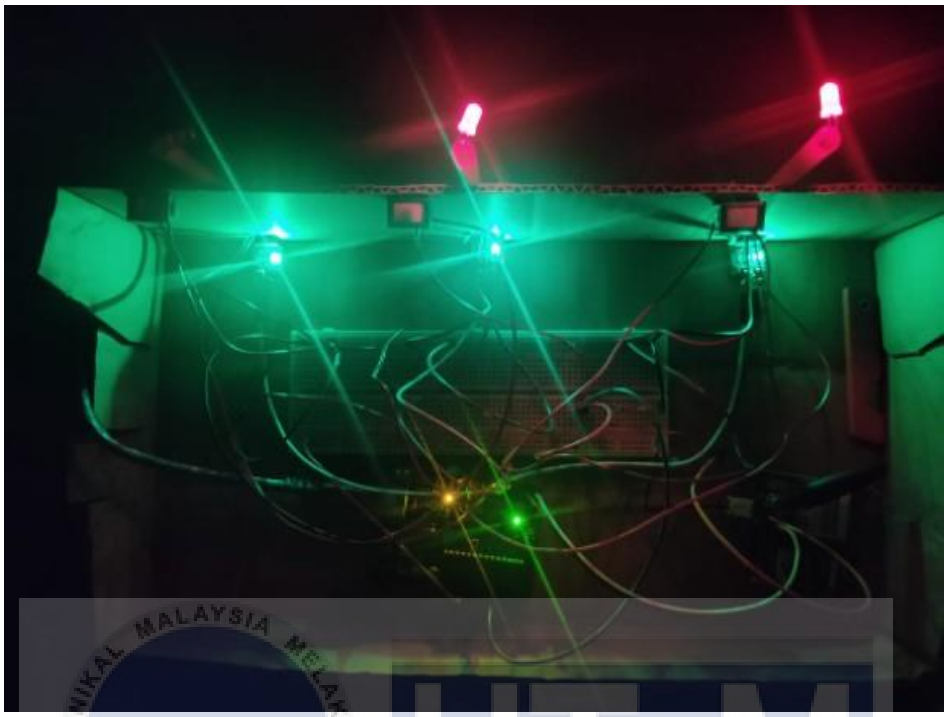


Figure 4.5 shows when the fault happened at Light 1

Figure 4.5 showed the Light 1 were turned OFF when there were any fault happened. Each LED have their own switches as an indicator to show that the Lights have faults. When the faults happened to the LEDs, then the processor which is Arduino UNO will detect which of the three lights were at fault. A warning or notification SMS will be send to the specific number phone that were set in the coding.

During testing, the interface is also important as to see if the connection is in the right place and the continuity of the wirings were connected to each other. The project can detect the exact location of the faulty street light can then from using the GSM Module, an alert warning message will be sent to the mobile phone. The content of the message can be edited at the coding. By developing this project, many benefits can we got, such as the power consumption of the street light can be reduced significantly, the energy current will not be

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

wasted and also the cost of the maintenance can be reduced. Figure 4.6 showed the interface that happened when there were any faulty street light so that we can monitor the reading.

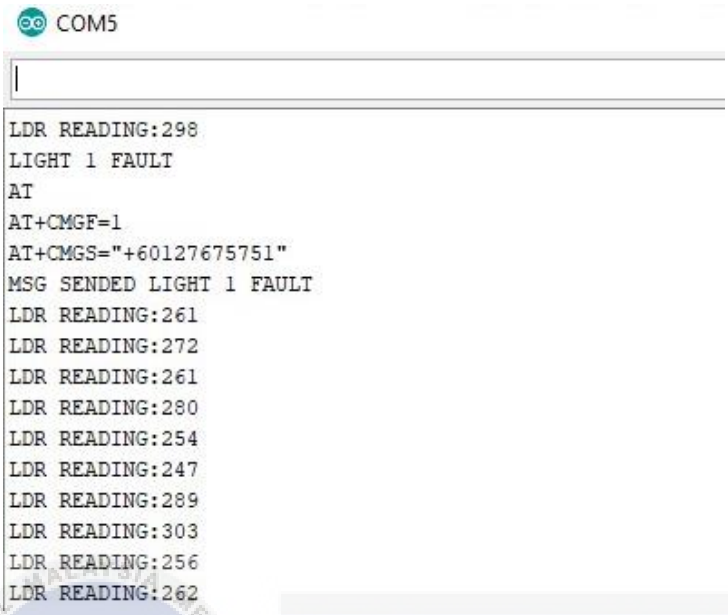


Figure 4.6 shows the serial monitor when the fault happened

The time taken to be received the SMS is measured by using a mobile phone stopwatch. The time taken or duration for the SMS to be received from the corresponding mobile phone is around below than 30 seconds which is a good warning alert to tell the lighting technicians or the farmers about the faulty street light early on.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Figure 4.7 shows the SMS received when the fault happened

The placement of the LED	Condition of the Street Light	Time Take to received the message
1st	Faulty	15 seconds
2nd	Good	-
3rd	Good	-

Table 4.3 shows 1st street light is at fault

The placement of the LED	Condition of the Street Light	Time Take to received the message
1st	Good	-
2nd	Faulty	14 seconds
3rd	Good	-

Table 4.4 shows 2nd street light is at fault

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

The placement of the LED	Condition of the Street Light	Time Take to received the message
1st	Good	-
2nd	Good	-
3rd	Faulty	15 seconds

Table 4.5 shows 3rd street light is at fault

4.2.3 IR sensor Detectect the Presence

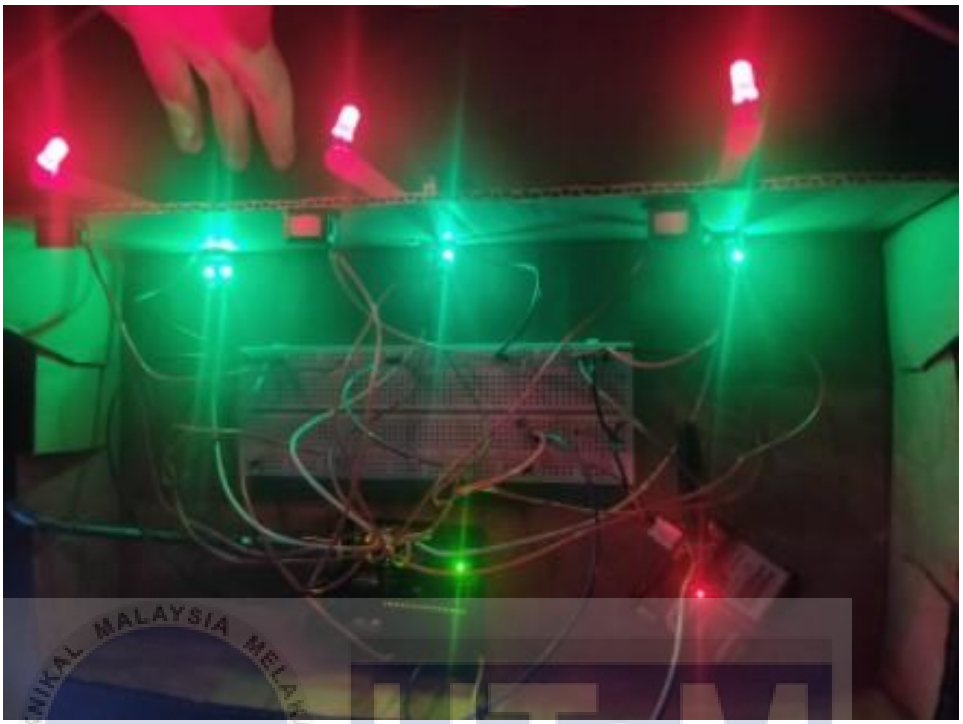


Figure 4.8 shows the IR sensor detected the movement.

Figure 4.8 showed that the IR sensor that connected to the Arduino UNO detected the presence of any movement nearby. IR sensor have 2 indicator which is the first one is the Power LED and the other is Obstacle LED. Power LED will show that the IR is truly connected to the hardware and the current and voltage can flow through the IR sensor while the Obstacle LED will be turned on when the lights falls to IR receiver.

When there were no presence around the IR sensor, the intensity of the light will become low and dim. The lights will be in full intensity when there were any movements detected by the IR sensor. Figure 4.9 showed that the IR sensor detect movements presences at Light 1 and Light 3. So when there were a slight movements, it showed that there is a movements at the located nearby street light.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

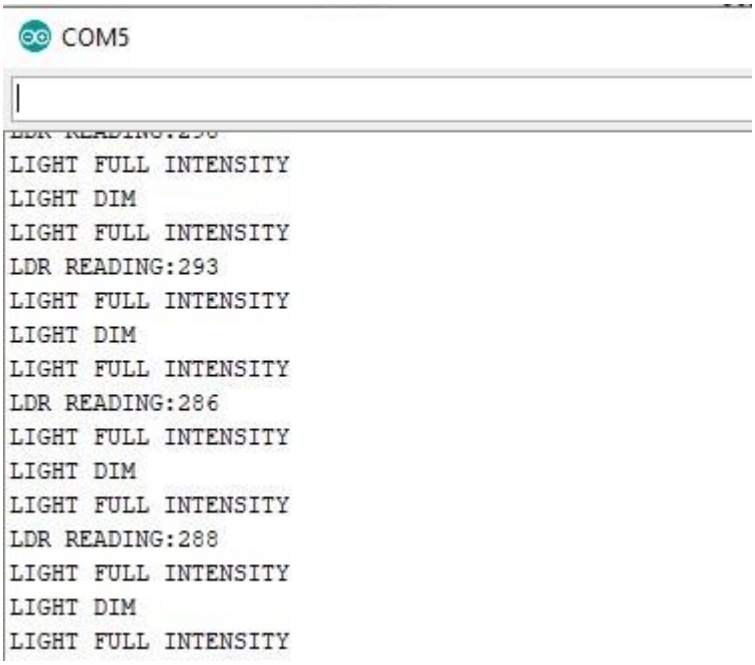


Figure 4.9 shows the serial monitoring when the IR sensors detect movements

The placement of the LED	Condition of the LED
1st	Full intenssity
2nd	Low intensity
3rd	Full intensity

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Table 4.4 shows the condition of the LED when IR sensor detects any movement

4.3 Summary

This chapter presented case studies in detecting the fault of the street light by utilizing the Internet of Things (IoT). As Malaysia is one of the country that has a high energy consumption and the maintenance cost a lot to the government, by having this type of project and implement it in real will be worth it as it brings a lot of benefits to many people, such as to street users and other areas including, the farmers, drivers, bikers, and also pedestrians, it also bring benefits to the lighting technicians and also the government. The intensity of the LED can also be controlled which will save the energy consumption of the project. While the fault detection can make the lighting technician to work more efficiently and will not be wasted the energy from the current flow through the street light when there is any damage or fault happen to the street light.

This project's analysis consistes of the time taken for the SMS to be received by the mobile phone. According to the results, the time taken for the message to be received is around 15 second which is quite fast fot the farmers or technicians to check for the faulty street light.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project demonstrates a way for creating a fault-detecting IoT-based smart street light. The suggested technique is successful and robust in obtaining good results using just completely reasonable methodologies, simulation, and the outcome. The proposed approach of using the LDR and infrared sensor (IR sensor) was to be able to low the energy consuming from the street light. A case study of the energy power saving can go up 48% in Malaysia, which are in reasonably accurate as they are in close agreement (range energy saving 40%-60%). TNB, a Malaysian electricity company, recently completed a feasibility study to assess and evaluate the implementation of LED and induction street lighting technology. The result shows that the average power saving energy by using LED light is between 40% - 60%.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Overall, the study given in this thesis has contributed to a better understanding of the relevance of a practical and successful system. The proposed technique makes use of a suitable quantity and kind of data input, resulting in rapid, believable, representative, and reasonably accurate outcomes. As a result, it provides a foundation for the proposed future research. Where traffic is minimal most of the day, remote urban and rural regions are ideal locations for implementing such street lighting systems. Because of the independent power network, this system may be used in remote places where traditional systems are more expensive. The system is easily expandable, versatile, and adaptable to the user's requirements. The system became wireless and less sophisticated thanks to the use of GSM technology.

5.2 Future Works

The accuracy of GSM network estimate findings might be improved in the future as follows:

i) Wider range of possible for GSM network and can easily connected to the network.

ii) Include study to find a better and accurate value of the LDR reading and time taken.

iii) It's possible that the system will be improved to incorporate an alarm system. Whenever the red light is switched on, for example, an alert should sound and the maintenance team should be notified. The maintenance staff will also not ignore the faulty street lights.

UTeM
اونيۏرسيتي تيکنيکل مليسيا ملاک
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

REFERENCES

[1] Painter, K. (1996) The Influence of Street Lighting Improvements on Crime, Fear and Pedestrian Street Use, after Dark. Landscape and Urban Planning, 35, pp.193- 201

[2] Yeen Oh, I. (2020, April 27). Streetlights on automatic timer, say local councils. Retrieved June 16, 2021, from https://www.thestar.com.my/metro/metro-news/2020/04/28/streetlights-on-automatic-timer-say-local-councils

[3] M. (n.d.). Street Lighting. Retrieved June 16, 2021, from https://www.mytnb.com.my/business/street-lighting

[4] A. (2017, December 2). Common Electrical Problems and Solutions. Anchor Electricals - Blog. https://lsin.panasonic.com/blog/common-electrical-problems- and-solutions/

[5] Kee, K. K., Lau, S., & Affandi, M. H. (2020). An Energy-efficient Smart Street Lighting System with Adaptive Control based onEnvironment. Borneo Journal of Sciences and Technology. Published. https://doi.org/10.35370/bjost.2020.2.1-09

[6] Centre for Transport Studies, UCL (University College London). (n.d.). Night-time accidents: a scoping study. Report to The AA Motoring Trust and Rees Jeffreys Road Fund - UCL Discovery. Ward, H.; Shepherd, N.; Robertson, S.; Thomas, M.Retrieved June 2, 2021, from https://discovery.ucl.ac.uk/id/eprint/1428/

[7] Hindu, T. (2016, September 22). Without street lights, it is scary and dangerous towalk at night. The Hindu. https://www.thehindu.com/news/cities/bangalore/Without-street-lights-it-is-scary- and-dangerous-to-walk-at-night/article14625107.ece

[8] Kili, K. A. (2014, March 21). Faulty traffic and street lights are giving teething problems to motorist. Retrieved June 18, 2021, from

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

https://www.thestar.com.my/news/community/2014/03/22/inconvenient-travel- faulty-traffic-and-street-lights-are-giving-teething-problems-to-motorist

[9] Valuekeep. (2020, December 4). Preventive and corrective maintenance: what are they? Retrieved June 16, 2021, from https://valuekeep.com/resources/e-books-articles/preventive-and-corrective-maintenance-what-are-they/

[10] M. A. D. Costa, G. H. Costa, A. S. dos Santos, L. Schuch, and J. R.Pinheiro, "A high efficiency autonomous street lighting system based on solar energy and LEDs," in Proc. Power Electron. Conf., Brazil, Oct.1, 2009, pp. 265–273.

[11] Po-Yen. Chen, Yi-Hua. Liu, Y.-T. Yau, and H.-C. Lee, "Development of an energy efficient street light driving system," in Proc. IEEE Int. Conf. Sustain. Energy Technol., Nov. 24–27, 2008, pp. 761–764.

[12] Hengyu Wu, Minli Tang, Guo Huang, "Design of Multi-functionalStreet Light Control System Based on AT89S52 Single-chipMicrocomputer." in 2010 2nd International Conference on IndustrialMechatronics and Automation, pp. 134-137.

[13] Alzubaidi, S., & Soori, P. K. (2012). Study on energy efficient street lighting system design. 2012 IEEE International Power Engineering and Optimization Conference. doi:10.1109/peoco.2012.6230877

[14] Nunoo, S., Attachie, J. C., & Abraham, C. K. (2010). Using solar power as an alternative source of electrical energy for street lighting in Ghana. 2010 IEEE Conference on Innovative Technologies for an Efficient and Reliable Electricity Supply. doi:10.1109/citres.2010.5619814

[15] Malik, T. (2020, May 28). SIM900A GSM Module. Retrieved June 15, 2021, from https://microcontrollerslab.com/sim900a-gsm-module-pinout-examples- applications-datasheet/

UNIVERSITI TEKNIKAL MALAYSIA MELAKA