PROTOTYPE OF GRID TENSION MONITORING SYSTEM

MUHDAMMAD SAIFUL AMIN BIN MOHD SUHAIMI

BACHELOR OF ELECTRICAL ENGINEERING TECHNOLOGY (POWER & MACHINE) with HONOURS

UNIVERSITI MALAYSIA PAHANG

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MUHAMMAD SAIFUL AMIN BIN MOHD SUHAIMI

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ABSTRAK

Projek ini bertujuan untuk membangunkan prototaip sistem pemantauan ketegangan grid pada talian penghantaran atas. Sebab di sebalik projek ini adalah untuk mencipta sistem pemantauan masa nyata untuk suhu talian penghantaran overhed ketegangan grid, paksi kendur dan nilai arus berkuasa elektrik. Kendur pada talian penghantaran boleh merosakkan menara penghantaran, projek ini bertujuan untuk memantau kendur dan menjadualkan penyelenggaraan sebelum kerosakan selanjutnya boleh dilakukan pada menara penghantaran dan talian penghantaran. Memandangkan kemalangan sentiasa dikurangkan dan diagnosis semakin pantas untuk grid automatik, penderiaan dan kawalan jauh masa nyata ialah konfigurasi untuk pelaksanaan grid pintar. Sekiranya berlaku kerosakan, voltan dan arus melebihi had operasi, yang memerlukan pemantauan dalam masa serta pelaporan diagnosis. Kertas kerja ini bertujuan untuk mewujudkan sistem pemantauan untuk tujuan analisis dan penyelenggaraan. Ini akan menghalang talian penghantaran yang terlalu kendur dan menjadikan penyelenggaraan selamat untuk dijalankan dan mungkin sebelum sebarang kerosakan selanjutnya. Projek ini juga menyediakan rangka kerja pemantauan penjejakan overhed untuk penganalisis industri atau profesional. Ini dicapai dengan menggunakan gabungan sensor dan microprocessor.

ABSTRACT

This project is aimed at developing a prototype of grid tension monitoring system on overhead transmission line. The reason behind this project is to create a real-time monitoring system for grid tension overhead transmission line temperature, sag axis and electrically powered current value. Sagging on the transmission line can damage the transmission tower, this project aims to monitor the sag and scheduled the maintenance before further damage can be done to the transmission tower and transmission line. As accidents are constantly being reduced and diagnoses are accelerating for automated grids, real-time remote sensing and control is the configurations for smart grid implementation. In case of malfunction, the voltage and current exceed the operating limit, which requires in-time monitoring as well as diagnosis reporting. This paper aims at creating a monitoring system for the purpose analyzing and maintenance. This will prevent over sagging of transmission line thus making maintenance safe to carry out and possible before any further damage. This project also provides overhead tracking monitoring framework for an industry analyst or professionals. This is accomplished by using the combination of sensors and microcontroller.

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LIST OF SYMBOLS

A	Ampere
V	Voltage
mAh	Milliampere-hour
g	Gram
kg	Kilograms
°	Degree
RM	Ringgit Malaysia
m	Meter
km	Kilometer
cm	Centimeter

LIST OF ABBREVIATIONS

SBPWM	Simple Boost Pulse Width Modulation
ZSI	Z source inverter

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Over the past two decades in Malaysia, the demand for energy has increased considerably from 1406kWh in 1993 to 4110kWh by the person of 2013. Fast economic growth led to rise in industrial energy and power demand. As the result of the next standard of living, more users presently claim and use technology-based energy consuming machines and devices. Modernization and business development have also increased power consumption through more facilities, production facilities, shopping malls and other entertainment facilities. Increment on energy consumption will also affect the efficiency of the grid. Since the demand of electricity is increasing therefore to maintain the quality of the grid is important. The overhead transmission line addition is a big component to step up grid capacity as top notch to use the available grid with maximum efficiency. However, maintaining the quality of grid to obtain maximum efficient of capacity needs a lot of observation on the grid. As a consideration of human safety and natural surroundings, the aim for this project is to develop IoT based grid tension monitoring system. The system consists of clamp mechanism, the clamped will be hanged at end to end of the transmission lines. The utilization of human being is minimized by utilizing clamped. The size of the clamp mechanism is compact and small which is suitable for gripping the grid lines. The clamp also can overcome from any impediments on power lines, for this it requires inflexible mechanical technology having power sources and power sensors.

1.2 Problem Statement

Every year, numerous of workers are killed as a result of electrocutions caused by overhead and underground power lines. [7]. Due to this risk, it is important that a method of maintenance with direct contact to the transmission line are eliminated and replace with the use of sensors.

Other than that, the system must also be able to observe the transmission line from a safe distance by allowing authorized personnel to access the readings obtained from the sensor. This is because transmission line today is longer and widely spread, some are in harsh terrain and weather condition. Due to this reason transmission line monitoring are using the combination of human, mobile robot and helicopter. Each of these methods are expensive and require a large labour force. Furthermore, transmission line conditions cannot be continuously monitored, and all transmission lines cannot be covered at the same time. [8].

1.3 Objectives of Project

The objectives of the prototyping of tension power grid monitoring system on overhead transmission line is to monitor the maximum capacity of power lines.

1. To analyse the relationship of power losses with grid tension.

2. To develop grid tension detector to reduce power losses.

3. To develop real-time monitoring system for maintenance purpose.

1.4 Research Scope

The scope of work of this project focuses on designing a dynamic line rating monitoring system that detect the thermal and transmission line sag. This project also focuses on the development of system to monitor transmission line condition in real-time. Finally, the scope of work also includes the development of web monitoring by using IoT that will be designed based on Arduino Uno module and Blynk and ThingSpeak application which is a graphical programming.

1.5 Thesis Roadmap

The proposal highlights the discussion and progress of development and design of Prototype of Grid Tension Monitoring System.

Chapter 2: This chapter will be discussing on literature review. The literature review will be emphasized on the project previous research presented by other people in same are with relevant issue to Prototype of Grid Tension Monitoring System. There are about design and technology in grid monitoring and control design and technology in grid monitoring. Lastly, there is a summary of the literature review regarding to this project.

Chapter 3: This chapter will be highlighted on concept design of structure and framework of Prototype of Grid Tension Monitoring System. The sketching design, block diagram of hardware design, flowchart coding of the project and flowchart of the controller design will also be explained in this chapter.

Chapter 4: This chapter will be focusing on the result for the development of Surface Unmanned Vehicle. The discussion on the testing hardware of the surface unmanned vehicle will also be explained in this chapter.

Chapter 5: This chapter will conclude the study by summarising the key findings in relation to the issue statement and objectives, as well as reviewing the study's scope. It will also discuss the study's limitations and make suggestions for further research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Throughout this Chapter, I will talk through the proposed strategy for developing Hardware of the Prototype of Grid Tension Monitoring System. This chapter will go through the idea of the designed and the reason behind the project.

2.2 Grid Tension

Overhead power lines (transmission and distribution lines) are suspended on pole/tower supports. Mechanical tension is applied to suspended conductors, which must be kept below a safe level. The sag of the line is required because any change in weather condition and temperature will affect the tension of the lines. Excessive mechanical tension can cause the conductor to break. As a result, a conductor between two supports should not be entirely stretched and should be permitted to sag or dip. It is critical to maintain the acceptable sag in overhead power wires. If the sag is very low, the conductor is subjected to significant mechanical tension, which may cause the conductor to break. If the sag is very high, the conductor may swing at higher amplitudes due to the wind and may come into touch with surrounding conductors or trees. Lower sag indicates a tighter conductor and increased tension. The higher the sag, the looser the conductor and the lower the tension. As a result, a proper sag level must be determined to provide safe operation for both power provider, civilian and nature

2.2.1 Real-Time Overhead Transmission-Line

Transmission lines are exposed to the natural environment all year and are frequently impacted by severe weather, including intense storms, rain, ice, and snow. When extreme weather, such as strong winds, storms, and icing, causes overhead line failures, the failures are wide-spread, long-lasting, and result in significant losses, putting the grid safety in jeopardy [1]. As a result, a countermeasure that successfully prevents harsh weather from damaging the transmission line, as well as the safety and stability of the electrical system, is required [2]. The aim of sags in a transmission line is to reduce the tension on the wire between the line supports, which could otherwise damage transmission towers. However, the transmission line sag can differ due to heat dissipation caused by power distribution, as well as temperature variations and harsh weather occurrences [3]. Moreover, transmission line sags will also have an impact on the current(I) carrying capacity [4].

2.2.2 Hardware and Sensor

A specific ground clearance for transmission lines will be needed for the safety operation of the power system network [5]. This project will use the combination of sensor, microcontroller and IoT to monitor the grid tension (sag). Existing sag monitoring strategies have primarily focused on exploiting the relationship between sag and a number of physical factors that may be directly monitored using various sensors. The sag of a homogeneous overhead conductor, for example, can be directly associated with temperature, as heating might cause the transmission line to lengthen [6]. However, this project will propose using a different method which is by utilizing the axis of the transmission line. This can be accomplished by using the accelerometer sensor, ADXL-335 to be exact. The sensor measures 3-point axis of x, y, and z angle.

Figure 2.1: Conductor temperature monitors with radio links

Figure 2.1 above show the idea of the design for this project. The design of the hardware is closely similar to the figure above, which can be separate between two parts. Firstly, casing of the project and secondly, clamp structure. However, the approach is very different since this project will be using ADXL-335 Accelerometer.

2.3 Related Works

There are several projects regarding the monitoring of transmission line. The monitoring can be varied in various aspect. The first paper is Wireless Sensor Network for Single Phase Electricity Monitoring System via Zigbee Protocol (Anbya et al. 2012), the aim for this project is to monitor voltage and current in the transmission line by using Zigbee module. This project utilized the application of star topology wireless sensor network for single phase electricity monitoring system [9]. The advantages of this project are that it is low cost, low power consumption, low data rate, and support mesh networking. The limitation for this project is the limited transmission range of Zigbee which is 1.5 km.

The second paper is, IoT Based Power Monitoring System for Smart Grid Applications (Khan et al. 2020). The aim of this project is also the same as above which is to monitor the voltage and current on the transmission line. However, this project will use ThingSpeak as platform to store and monitor the recorded data [10].

Smart Grid (Wazeer 2018), this paper discusses about suggestion and proposals for the regional approach to mini/micro grid development that explains the demand for smart grid capability [11]. This paper aim to manage the electricity distribution to rural area and reduce electrical bills. This proposal however has its own downside which is, unsecure generator safety from outside threat. Consumer Privacy ais also the concern as the user's information can be stolen thus the it needs high and reliable network security.

Another related works is, Real-Time Overhead Transmission-Line Monitoring for Dynamic Rating (Douglass et al. 2016). Real-time line monitoring devices used to determine the dynamic thermal rating of an overhead transmission line by measuring the line clearance, conductor temperature, and weather data in the line right of way [4]. This is done by using ultrasonic anemometers, air sensor, and solar sensor. The main advantage of this project is it can predict schedule maintenance outages.

Finally, Overview of Robotic Applications for Energized Transmission Line Work (Elizondo et al. 2010). This paper review various type of transmission line monitoring including by using helicopter, robot, and monitoring system. The paper also explains that by using robot or monitoring system, it can reduce the risk of human life [12].

2.4 Summary

From the research and the study, the development of hardware for the prototype of grid tension monitoring system is designed closely similar to the design of conductor monitor. The reason behind this is because conductor monitor has major advantage in stability and ease of installation. Moreover, the design also has advantage in a simple and effective design with low cost and less moving mechanical parts.

This project will utilize the ADX-335 Accelerometer to measure the pitch angle of the transmission line to monitor the grid tension (sag). While, the pitch angle of the sensor is measured to monitor the external factor that affect the transmission line such as wind or rain. There are many similar works to this project however the approach and method are very different because the aim of the work is to monitor other output such as faulty monitoring, and temperature monitoring.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will be focusing on the methods on hardware development of prototype of grid tension monitoring system. The hardware design is very important in this project as it will help the project get the desired result.

3.2 Flowchart

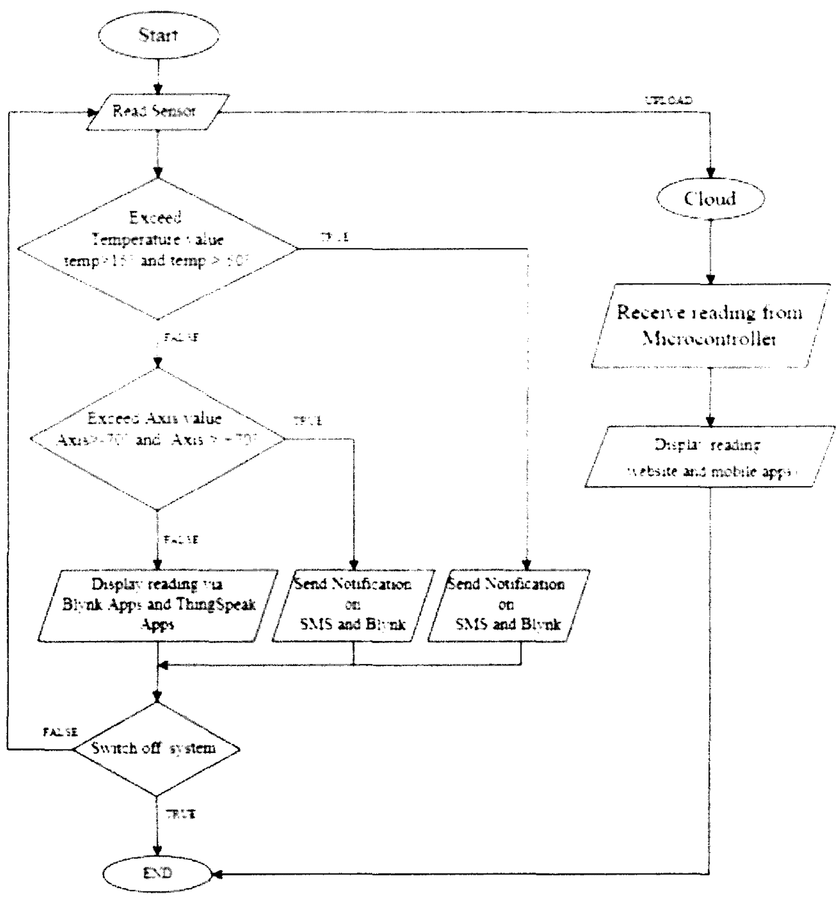

Figure 3.1: Flowchart

3.3 Proposed Hardware Design

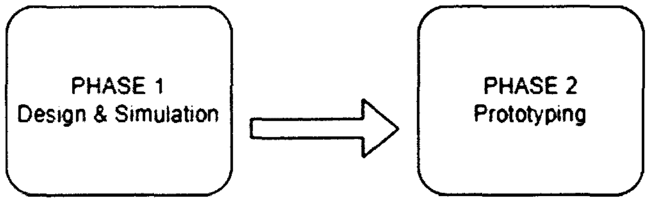

Figure 3.2: Hardware Phase

The project is divided into two phases. Based on the Figure 3.2 above, the first phase is design and simulation, and the second phase is prototyping. For the first phase, the hardware design is done over by using fritzing software. Fritzing software is needed to build a circuit, this is necessary to give a picture as a reference before proceeding into the prototype production. Fritzing also gives a freedom to simulate the project effectively by avoiding mistake such as shorting, wrong connection and even component being burnt down.

Firstly, all of the component will be listed down because fritzing does not contain all of the library needed for the project, such as ADXL335 and GSM900. The library is downloaded through www.github.com. All of the component needed for this project is Arduino Uno, GSM900 Shield, ADXL 335, DHT22. The circuit are designed based on the datasheet of each of the components to prevent any shorting or error. Figure 3.3 and Figure 3.4 below shows the finished circuit design and the interface of fritzing software.

All of the connections are referred through datasheet each of the components used. ADXL-335 and DHT-22 library are downloaded through www.github.com website.

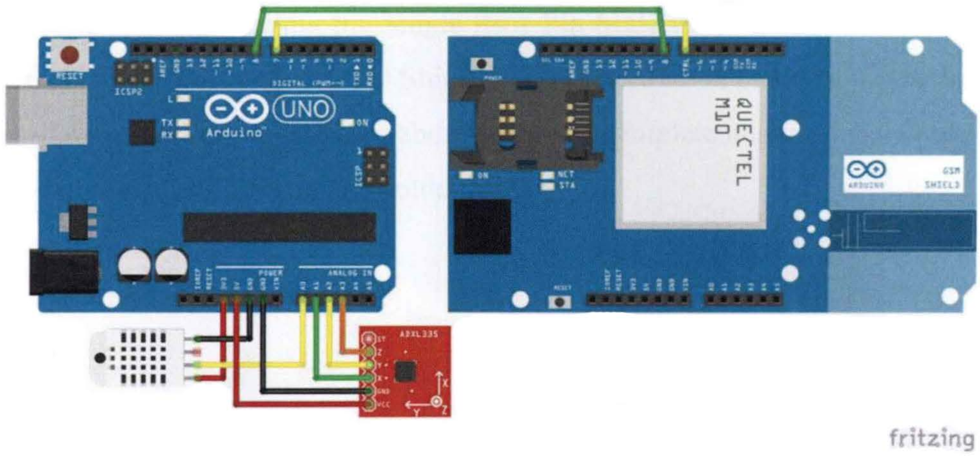

Figure 3.3: Hardware Design and Connection

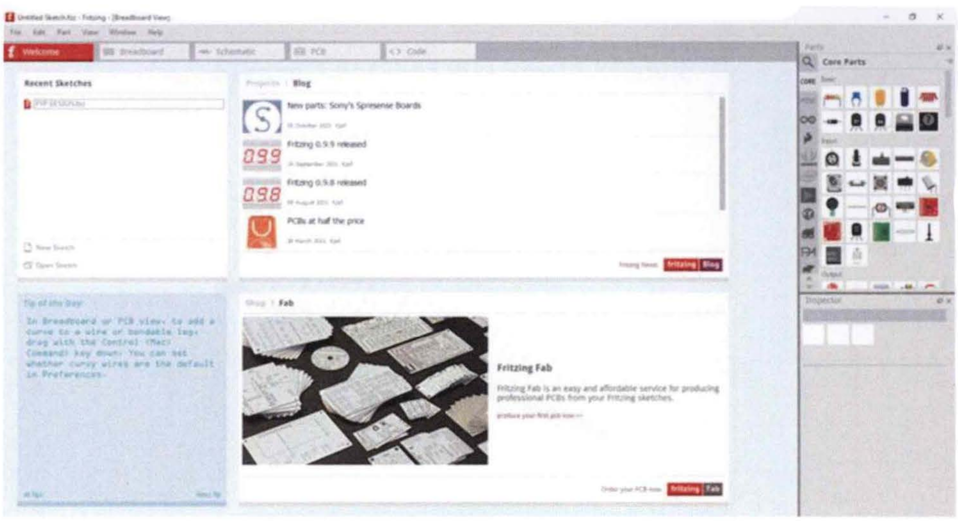

Figure 3.4: Fritzing GUI

3.3.1 System Design

The casing for the project is designed by using Perspex, the first step of this process is by taking the measurement of the component to make sure perfect fitment for the case. Arduino dimension is 6.9cm x 5.3cm, so the base of the design needs to be more than the dimension of the Arduino.

Second step is soldering the Single Row Pin Male Header into GSM900 Shield Module, this is because the GSM 900 Shield Module need to be place on top of Arduino UNO pin. The soldering process take about 1 hour to complete and the whole process is done manually using solder gun and solder lead.

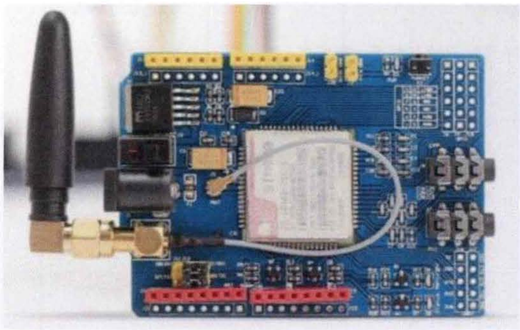

Figure 3.5: GSM 900 Shield Module

Figure 3.6: Single Row Pin Male Header

After the soldering process, the GSM module can be insert on top of Arduino UNO and the measurement of the heigh of the hardware can be taken which taken at the heigh of 3.81 cm. The casing dimension after measurement is 6cm x 6cm x 11cm, the extra space was taken to make sure both sensors can be fit inside the case. Figure 3.7 show the cross section of the casing that were designed by using draw.io, after that the Perspex were cut by using angle grinder to ensure smoot and straight cut.

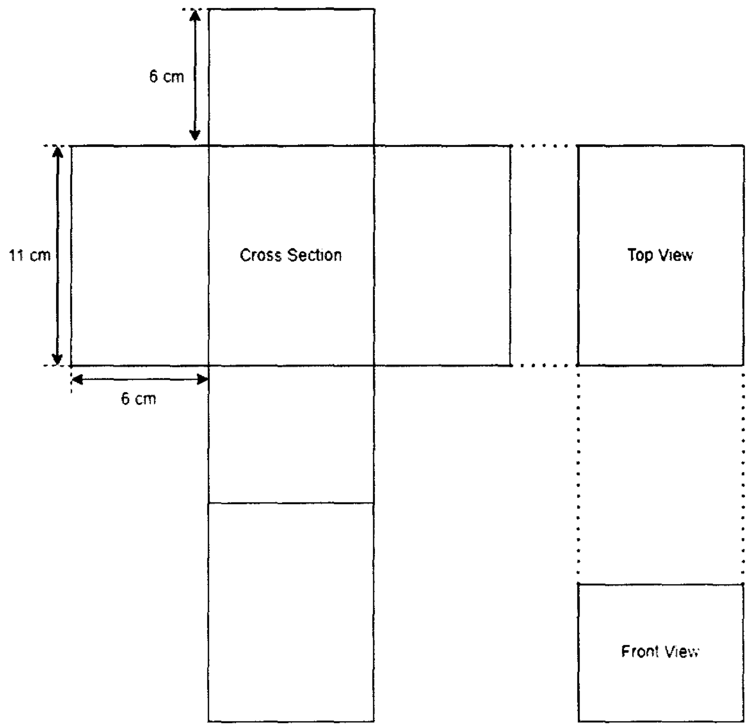

Figure 3.7: Cross section of Casing

Every cut of the Perspex is joined by using instant glue for Perspex to ensure the sturdiness of the casing. The hole for the hinges and power jack adaptor are drilled by using mini drill with the diameter of 10mm for the Arduino power jack, and 5mm for the hinge and clamp.

For the ADXL 335, the sensor needed to be placed with perfectly levelled with the bottom part of the case. Any slight tilt of angle for the sensor can lead to an error of the project reading. To install the ADXL 335, 20mm PCB stands (Figure 3.9) are used since it can be tightened directly to the bottom part of the casing thus making it perfectly flat.

DHT 22 and Arduino also installed by using PCB stand, 10mm PCB stands are used to mount the DHT 22. The first step to do this is marking the correct drill hole on the Perspex and drill the hole with the diameter of 5mm. Drilling process is done by using mini drill with the drill bit of 5mm, picture can be referred to Figure 3.10

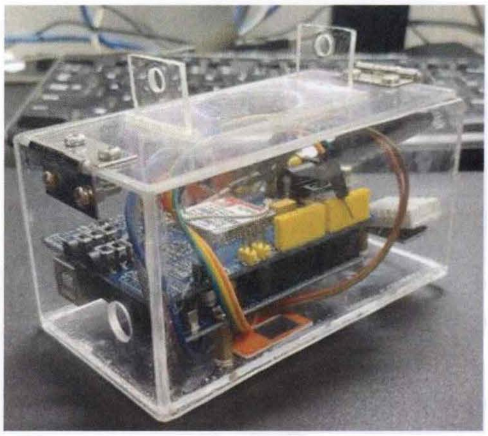

Figure 3.8: Casing Design

Figure 3.9: PCB stand

Figure 3.10: Mini drill but (10mm & 5mm drill)

3.3.2 Electronic Design

Firstly, all four main components are tested to see if it's in working condition or not, after all four components are tested and working as intended. Simple code is run to the Arduino to see all of the pin function correctly. as for ADXL 335 and DHT 22, the sensor is connected to the Arduino and default code from the Arduino library were compiled to see the output of the sensor. Output was monitored from serial monitor of the Arduino IDE software. GSM 900 Shield Module also tested by using a mobile sim-card, since the module cannot work with all of the sim-card provider in Malaysia, the GSM 900 Shield Module can only work with Celcom, Maxis, and DIGI sim-card. After that the project is connected based on the schematic that is designed using fritzing, figure below show the connection of the project. In this phase the project just connected without any body/case to see if any error occurred or component error, it can be fixed easily. All of the component are working perfectly fine and ready for the next step which is casing design hardware installation.

DHT 22 data pin is connected into the Analog pin 0, for the ADXL 335, the data pin of X, Y, and Z are connected into Analog pin 1, 2, and 3. This is because ADXL 335 sensor takin data in form of analog data that later be converted into digital from by the ADXL library. Same goes to DHT 22, the sensor reading is based on digital reading and the library will convert the reading into digital unit.

GSM 900 Shield Module is designed to be perfectly mount on top of Arduino UNO, but the TX and RX pin for the GSM need to be switch manually by changing the jumper pin into D8(RX) and D7(TX), as shown in Figure 3.11. Other than digital pin 7 & 8, all of it can be used to for other purposes.

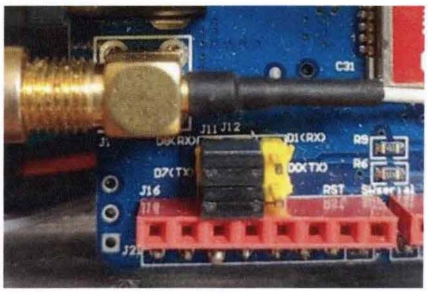

Figure 3.11: RX and TX jumper pin

3.4 Cost Analysis

Table 3.1: Cost Analysis

No	Item	Cost (RM)
1	Arduino UNO	22.00
2	GSM 900 Shield Module	51.95
3	ADXL 335	23.36
4	DHT 22	18.40
5	2mm Perspex, 3ft x 3ft	30.00
6	1-inch Hinges	1.95
7	PCB stand	11.49
	TOTAL	159.15

3.5 Summary

In this chapter, the author has explained about flow, method and also material that used to design the hardware and casing of the prototype of grid tension monitoring system.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, will be explaining on the control board module design and fabrication. This chapter also will explain how the electronic control system of prototype of grid tension monitoring system work and the detail about the component used to design the control system board for the project.

4.2 Interface of grid tension monitoring system

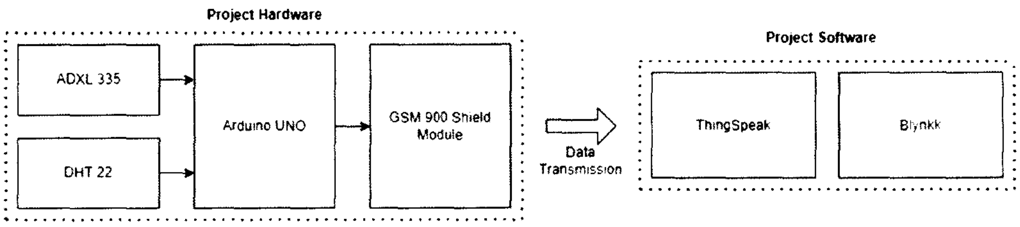

Figure 4.1: Hardware and Software interface

Based on the figure, the first block shows the hardware side of the project. On the hardware side, ADXL 335 and DHT 22 will take a reading and transfer it into Arduino UNO. ADXL 335 Accelerometer can measure 3-axis of force in the form of axis X, Y and Z. The ADXL 335 sensor take the reading in g unit which is the gravity form - $9.81m/s^2$. the reading is converted into the unit of degree in series of equation from the project code. While the DHT 22 is a very direct sensor since the library of DHT22 can be include directly into the code, so there is no unit of conversion for DHT 22.

The data from the sensor are transmitted to the ThingSpeak and Blynk through GSM 900 Shield Module by using GPRS connection. GPRS connection is short for General Packet Radio Service, which are standard unit for 2G and 3G connection, so this form of connection has less likely to face connection issue since Malaysia has a wide coverage of at least 2G connection. The rate of transfer for ThingSpeak is 180 seconds, so for every 180 seconds the data will be transmitted to the ThingSpeak.

Table 4.1: Design specification

Specification	
Dimension of Project	6 cm x 11 cm x 6 cm
Weight	253g
Supply	12W
Transmission Rate	180 seconds
Connection	GPRS
Server	ThingSpeak & Blynk

Based on the table 4.1 the final dimension of the prototype is 6cm X 11cm X 6cm with the weight of only 253gram. This is accomplished with the use of Perspex which eliminate extra weight but added durability of the while structure.

The supply needed to run the whole system is 12V 1A which is equivalent to 12W. Before this the prototype was running on 6W power supply but the GSM module will loss connection and cannot transmit the data due to power shortage of the supply. The GPRS connection of transmission worked flawlessly which the system can run most of the place, with as low connection as 2G connection needed.

4.3 Field Test

Figure 4.2: Simulation test 1

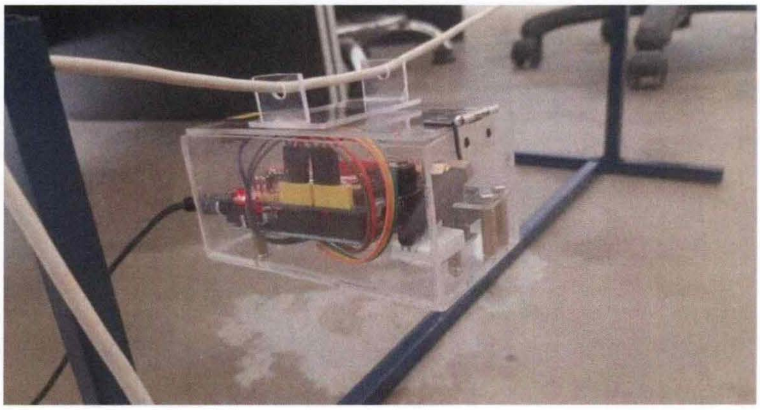

Figure 4.3: Simulation test 2

Based on the Figure 4.2 and Figure 4.3, the pictures show the finish prototype of the project. The system is hanged to the wire which act as a transmission grid, testing for the project was run overnight from 8:00 PM to 8:00AM. From the testing, it can be concluded that the system work flawlessly. Any change in pitch angle of the system will be transmitted and recorded through the ThingSpeak server, same goes to the roll angle too. The second sensor which is DHT 22 also work as well which gives out correct output reading of surrounding temperature and humidity.

Figure 4.4: Output results

Figure 4.4 show the output reading recorded in thingspeak server; the transmission rate is 180 second for every data transfer. Field 1 shows the reading of temperature value which is 25°C throughout the time scale, this is because the project was running in a room with air conditioned turned on. Field 2 show the humidity reading, the humidity rises throughout the day which also related due to the air conditioned turned on.

Field 3 shows the pitch angle of the ADXL-335 sensor, from the figure around 11.00 AM there are sudden spike in pitch angle which because the simulation of sagging is applied to the prototype of the grid. Finally, field 4 shows the roll angle of the system, this throughout the time period there are positive and negative value in roll angle. This is due to the movement of the system in which simulating wind or rain that affect the grid.

CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter will conclude the study by summarising the key findings in relation to the issue statement and objectives, as well as reviewing the study's scope. It will also discuss the study's limitations and make suggestions for further research.

5.2 Conclusion

View of the foregoing information, it can conclude that by establishing a real-time monitoring system for maintenance reasons, this can reduce the time that will influence the other systems during repair. By developing a grid tension detector, it is possible to cut power losses while also solving the safety problems connected with existing monitoring systems. It will be useful in the future to carry out transmission line maintenance. This system runs on an automated mechanism that accepts and monitors data using Blynk and ThingSpeak apps. Finally, this system features a small and simple design that is great for cost- saving.

5.3 Obstacle

The obstacle face during hardware fabrication is to provide flat and square casing design for the ADXL 335 since any positive and negative tilt on the placement of the sensor may lead to error on the real-time reading. The clamp design also needs to be as tight as possible to the prototype of the transmission line since any sudden movement on the sensor can lead to high change of axis of the sensor because the sensor is based on accelerometer.

Secondly, while Perspex can be hard and durable but the material is very hard to work on, cutting the Perspex with the thickness of 20mm can be challenging without special tools such as angle grinder. The second problem for this material is gluing the Perspex into a single piece, since the material is like hard plastic, the surface of both end of the material needs to be as flat as it can to ensure perfect the perfect joint.

5.4 Limitation

The limitation for this project is that the hardware is power supply issue, Arduino UNO has limited supply of power from power jack which is maximum of 20 volts. However, 20 volts are be considered unsafe since it can heat up the voltage regulator. The recommended power supply is 6V 1A, but since the GSM 900 Shield Module can consume a lot of power for data transmission adding more sensor are going to be a problem. So, if any further addition of sensor to this project need to run on separate power supply to prevent the Arduino or GSM module to prevent from sudden shut shutdown.

5.5 Recommendation for future works

To summarize, to strengthen this project in future, some suggestions have been noted there is still work that has to be done for Blynk and ThingSpeak to make it more powerful for creating IoT applications. The system also needs to have additional dashboard with multifunctional reading such as for check the quality of the sag. The addition of function offers additional demands of this system.

Other than that, built in standalone battery and solar make the gadgets more compatible. For this prototype the system run on power supply which required external power. To further improve this prototype, built in battery and solar panel can make the prototype run independently without any external power sources.

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APPENDICES

Appendix A: Gantt Chart

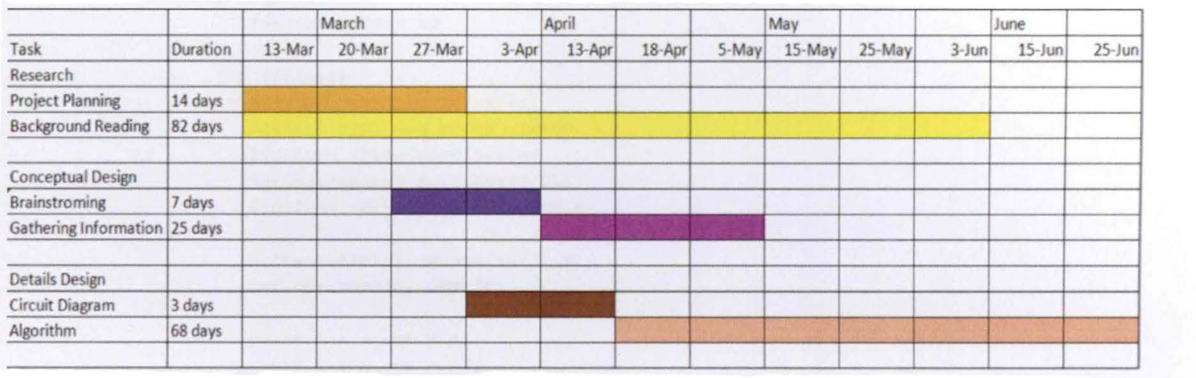

Figure 5.1: SDP 1 Gantt chart

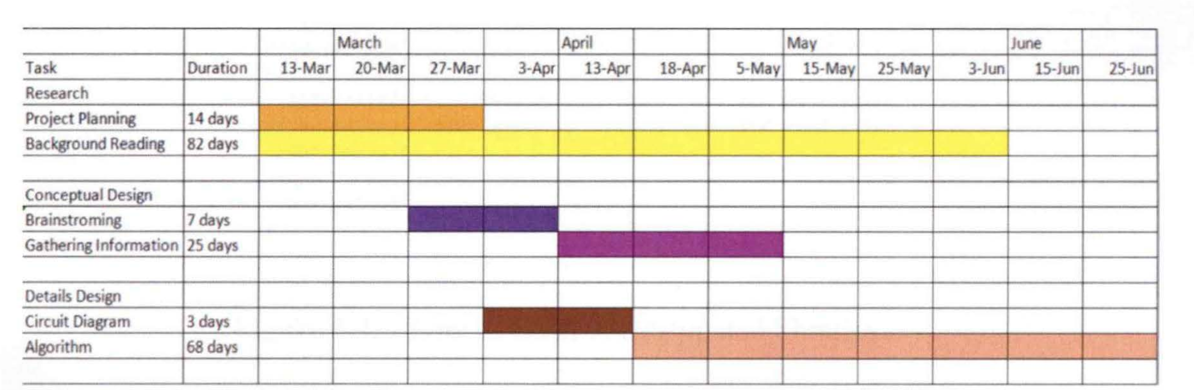

Figure 5.2: SDP 2 Gantt chart

Appendix B: Coding for Prototype of Grid Tension Monitoring System

```
#include <math.h>
#include <SoftwareSerial.h>
#include <String.h>
#include <DHT.h>
#define DHTPIN A0

 //blynkk
#define BLYNK_PRINT Serial
#define TINY_GSM_MODEM_SIM900
#include <TinyGsmClient.h>
SoftwareSerial SerialAT(7,8);
#include <BlynkSimpleTinyGSM.h>

SoftwareSerial gprsSerial(7,8);
DHT dht(DHTPIN, DHT22);

const int x_out = A1;
const int y_out = A2;
const int z_out = A3;

//blynkk setup
char auth[] = "nCjf_NwW7EdAqTdHaRFJLIhWQktRl-xA";
char apn[]  = "Celcom4g";
char user[] = "";
char pass[] = "";
TinyGsm modem(SerialAT);

void setup()
{
  gprsSerial.begin(9600);          // the GPRS baud rate
  Serial.begin(9600);              // the GPRS baud rate
  dht.begin();

  delay(1000);
}
```

Figure 5.3: Blynk & GSM 900 setup and libraries

```
void loop()
{
      float h = dht.readHumidity();
      float t = dht.readTemperature();

      int x_adc_value, y_adc_value, z_adc_value;
      double x_g_value, y_g_value, z_g_value;
      double roll, pitch, yaw;
      x_adc_value = analogRead(x_out);
      y_adc_value = analogRead(y_out);
      z_adc_value = analogRead(z_out);

      x_g_value = ( ( ( (double)(x_adc_value * 5)/1024) - 1.65 ) / 0.330 ); // Acceleration in x-direction in g units
      y_g_value = ( ( ( (double)(y_adc_value * 5)/1024) - 1.65 ) / 0.330 ); // Acceleration in y-direction in g units
      z_g_value = ( ( ( (double)(z_adc_value * 5)/1024) - 1.80 ) / 0.330 ); // Acceleration in z-direction in g units

      roll = ( ( (atan2(y_g_value,z_g_value) * 180) / 3.14 ) + 180 ); // Formula for roll
      pitch = ( ( (atan2(z_g_value,x_g_value) * 180) / 3.14 ) + 180 ); // Formula for pitch

      delay(100);

      Serial.print("Temperature = ");
      Serial.print(t);
      Serial.println(" °C");
      Serial.print("Humidity = ");
      Serial.print(h);
      Serial.println(" %");
      Serial.print("Roll = ");
      Serial.print(roll);
      Serial.print("\t");
      Serial.print("Pitch = ");
      Serial.print(pitch);
      Serial.print("\n\n");
```

Figure 5.4: ADXL-335 tilt angle & roll angle equation

```
if (gprsSerial.available())
  Serial.write(gprsSerial.read());

gprsSerial.println("AT");
delay(1000);

gprsSerial.println("AT+CPIN?");
delay(1000);

gprsSerial.println("AT+CREG?");
delay(1000);

gprsSerial.println("AT+CGATT?");
delay(1000);

gprsSerial.println("AT+CIPSHUT");
delay(1000);

gprsSerial.println("AT+CIPSTATUS");
delay(2000);

gprsSerial.println("AT+CIPMUX=0");
delay(2000);

ShowSerialData();

gprsSerial.println("AT+CSTT=\"celcom4g\",\"\",\"\"");//start task and setting the APN,
delay(1000);

ShowSerialData();

gprsSerial.println("AT+CIICR");//bring up wireless connection
delay(3000);
```

Figure 5.5: GSM 900 data transmission