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IOT based-system for telecom tower fire detection and aviation obstruction light monitoring

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IOT BASED-SYSTEM FOR TELECOM TOWER FIRE DETECTION AND AVIATION OBSTRUCTION LIGHT MONITORING

Thierry Ndayitezibiganza

A Project Report Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science in Embedded and Mobile Systems of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

Telecommunication towers are radio masts, typically tall structures designed to support antennas for telecommunications and broadcasting. Many telecommunication towers in Habari Node are installed in remote locations, on top of tall buildings, and sometimes on hilltop areas that are not easily accessible. These make them prone to natural hazards, equipment, fuel and battery theft, and electricity faults. In some cases, these issues can cause the malfunction of the aviation obstruction light and fire outbreaks. This challenge affects prompt mitigations during breakdown and the challenges of aviation obstruction light and fire outbreaks. However, technological inputs have been developed to tackle these challenges. However, many of these technologies are associated with low performance due to lack of real-time interventions and auto-report to the systems' concerns, awareness, and inadequate information. Hence, the study used qualitative methods of data collection which led to develop a cost-effective, versatile system that can detect, extinguish, and send early alerts about fire, aviation obstruction light, and electricity power issues. The proposed system was developed to monitor and control the telecommunication tower using ESP32 WROOM-32D as a microcontroller, fire sensor, buzzer, BH1750 ambient light, LDR darkness sensor, relays, Pzem-004t, ThingSpeak cloud, and the global service message module (GSM) to alert all tower's technicians and firefighters. The results revealed the prompt performance of the system in detecting and extinguishing fire. Also, the it can monitor aviation light for tower safety and turn on the automatic voltage and current regulator (AVCR) during overcurrent or overvoltage. Furthermore, the designed system has the capacity to initiate and send short message service (SMS) and call as an alert to check through mobile and web-based application.

DECLARATION

I, Thierry Ndayitezibiganza, do hereby declare to the Senate of the Nelson Mandela African Institution of Science and Technology that this project report is my original work and that it has neither been submitted nor being concurrently submitted for a degree award in any other institution.

Thierry Ndayitezibiganza		Le 25/07/2023
Name of Candidate	**Signature**	**Date**

The above declaration is confirmed by:

Prof. Anael Sam		27th July, 2023
Name of Supervisor 1	**Signature**	**Date**

Dr. Devotha Nyambo		26/07/2023
Name of Supervisor 2	**Signature**	**Date**

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by The Nelson Mandela African Institution of Science and Technology, a project report titled ***"IoT based-system for telecom tower fire detection and aviation obstruction light monitoring: A case of study Habari Node Public Compony"*** in partial fulfillment of the requirements for the degree of Master of Science in Embedded and Mobile Systems of the Nelson Mandela African Institution of Science and Technology.

Prof. Anael Sam		27th July, 2023
Name of Supervisor 1	**Signature**	**Date**

Dr. Devotha Nyambo		26/7/2023
Name of Supervisor 2	**Signature**	**Date**

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DEDICATION

I dedicate this work to my esteemed father and mother, Mr. Hilaire Nahimana and Ms. Madeleine Ntahomvukiye, for their dedicated time and encouragement that strengthened me during the entire academic journey.

TABLE OF CONTENTS

ABSTRACT ii
DECLARATION iii
COPYRIGHT iv
CERTIFICATION v
ACKNOWLEDGEMENTS vi
DEDICATION vii
LIST OF TABLES xi
LIST OF FIGURES xii
LIST OF APPENDICES xiv
LIST OF ABBREVIATIONS AND ACRONYMS xv
INTRODUCTION 1
1.1 Background of the Problem 1
1.2 Statement of the Problem 2
1.3 Rationale of the Study 3
1.4 Objectives of the Study 3
1.4.1 General Objective 3
1.4.2 Specific Objectives 3
1.5 Research Questions 4
1.6 Significance of the Study 4
1.7 Delineation of the Study 4
CHAPTER TWO 6
LITERATURE REVIEW 6
2.1 Overview of the Communication Sector in Tanzania 6
2.2 Telecommunication Tower Safety Infrastructure 6
2.3 Telecommunication Tower Disaster Monitoring 7

2.4 Classification of Emergency Disaster 7
2.4.1 Fire Outbreaks 7
2.4.2 Electricity Power Faults 8
2.5 Empirical Literature Review 8
2.6 Related Works 8
2.7 Technical Gap 9
CHAPTER THREE 11
MATERIALS AND METHODS 11
3.1 Study Area and Scope of the Study 11
3.2 Research Methodology 11
3.3 Target Population and Sample Size 11
3.4 Sampling Techniques 12
3.5 System Requirements 12
3.5.1 Data Collection 12
3.5.2 Data Analysis 13
3.6 System Development Approach 13
3.6.1 Agile Extreme Programming Approach 14
3.7 System Design 15
3.7.1 System Architecture 15
3.7.2 Block Diagram 15
3.7.3 Circuit Diagram 16
3.7.4 Flowchart Diagram 17
3.8 System Development 18
3.8.1 Hardware Tools 18
3.8.2 Hardware Integration 27
3.8.3 Programming Language and Software Tools Used 29

3.9 System Testing 31
3.9.1 Unit Testing 32
3.9.2 Integration Testing 32
3.9.3 Tower Testing of the Developed System 32
CHAPTER FOUR 33
RESULTS AND DISCUSSION 33
4.1 Results 33
4.1.1 The Major Causes of Fire Outbreaks and Aviation Obstruction Light Failure 33
4.1.2 Prototype Evaluation 34
4.1.3 Weaknesses of the Current Security System for Telecommunication Towers 34
4.1.4 System Results of the Developed System and Web-Based Application 36
4.1.5 Notification System 41
4.1.6 Webhost Database 42
4.1.7 Hardware Device 43
4.1.8 System Testing Results 44
4.1.9 System Validation 45
4.2 Discussion 46
CHAPTER FIVE 47
CONCLUSION AND RECOMMENDATIONS 47
5.1 Conclusion 47
5.2 Recommendations 47
REFERENCES 49
APPENDICES 56

LIST OF TABLES

Table 1: Proposed system hardware components 18

Table 2: Interfacing the LDR Sensor and ESP32-WROOM-32D 20

Table 3: Interfacing with GSM Module and ESP32-WROOM-32D........ 21

Table 4: Interfacing the Relay and ESP32-WROOM-32D........ 22

Table 5: Interfacing the Buzzer and ESP32-WROOM-32D........ 23

Table 6: Interfacing the Fire Sensor and ESP32-WROOM-32D........ 23

Table 7: Fire extinguisher types chart with cause to extinguish 25

Table 8: Interfacing the BH1750 Sensor and ESP32-WROOM-32D 26

Table 9: Interfacing the Pzem-004t and ESP32-WROOM-32D........ 27

Table 10: Functional Requirements 35

Table 11: Non-Functional Requirements........ 36

Table 12: User acceptance testing........ 44

Table 13: Existing System comparison with the developed system 45

LIST OF FIGURES

Figure 1: A visitation to the KIA telecommunication tower 13

Figure 2: Agile extreme programming Methodology approach 14

Figure 3: System architecture of the proposed and developed system 15

Figure 4: Block diagram of the developed system...15

Figure 5: Circuit diagram of the developed system 16

Figure 6: Flowchart of the developed system 17

Figure 7: Expressif Systems ESP32 Microcontroller (Schiller *et al.*, 2022) 19

Figure 8: Aviation obstruction light (Hasan & Sarker, 2020) 19

Figure 9: Light dependent resistor (LDR) sensor module (Chuah *et al.*, 2019) 20

Figure 10: Global system for mobile communication module (Kanani & Padole, 2020).....21

Figure 11: Relay channel two module (Kulkarni *et al.*, 2020) 22

Figure 12: Alarm buzzer (Bansal *et al.*, 2020)..22

Figure 13: Flame sensor (Ahmad *et al.*, 2019) 23

Figure 14: Plastic solenoid valve (Zaman, 2022) 24

Figure 15: Digital Light BH1750 sensor (Desnanjaya *et al.*, 2022b) 26

Figure 16: Pzem-004t module (Hasan & Kadhim, 2020) 27

Figure 17: Prototype system overview 28

Figure 18: Hardware components integration..28

Figure 19: Screenshot of the Arduino IDE 29

Figure 20: Screenshot of ThingSpeak IoT cloud 30

Figure 21: Screenshot of the EasyEDA simulation software interface.................................30

Figure 22: Field testing of the developed system 32

Figure 23: Main disaster source in telecommunication tower 34

Figure 24: Developed project system evaluation..34

Figure 25: Detection of fire with real-time extinguishing 37

Figure 26: Illuminance of the aviation obstruction light monitoring....................................37
Figure 27: Record of fire in telecommunication tower...38
Figure 28: Electricity power valuation monitoring...38
Figure 29: Web-based accessed through URL...39
Figure 30: A user interface for aviation obstruction light control and monitoring...............39
Figure 31: A user interface for fire record and monitoring 40
Figure 32: A user interface for electricity power monitoring..41
Figure 33: Short Message Service (SMS) for fire detection notification 42
Figure 34: Database implementation 43
Figure 35: The prototype 43

LIST OF APPENDICES

Appendix 1: Acceptance Letter 56

Appendix 2: Interview Guide 57

Appendix 3: Arduino Sketch Libraries and Declaration of the Developed System 59

Appendix 4: Code for the Aviation Obstruction Light Monitoring 60

Appendix 5: Code for Electricity Power Control 61

Appendix 6: Code for Fire Management 62

Appendix 7: PHP Script for Web-based Application 63

Appendix 8: Poster Presentation 65

LIST OF ABBREVIATIONS AND ACRONYMS

AC	Alternative Current
API	Application Programming Interface
ASDM	Agile Software Development Methodology
BMS	Building Management System
CSS	Cascading Style Sheet
DN	Diameter Nominal
ESP	Expressive Systems Module
FDA	Fire Detection Alarm
FDA	Fire detection and Alarm
GPRS	General Packet Radio Service
GSM	Global System for Mobile
HTML	Hyper Text Markup Language
ICT	Information and communications technology
IR	Infrared
IoT	The Internet of things
KIA	Kilimanjaro Airport
LDR	Light Dependent Resistor
LED	Light Emitting Diode
NTP	The National Telecommunications Policy
PHP	Hypertext preprocessor
PLC	Public Limited Company
PZEM	Part zone expansion module
SIM	Subscriber Identification Module
SMS	Short Message Service
SoC	System on Chip
SQL	Structured Query Language
TCP/IP	Transmission Control Protocol/Internet Protocol
URL	Uniform Resource Locator
UV	ultraviolet
WI-FI	Wireless Fidelity

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Telecommunication towers are tall structures generally designed for supporting parabolic antennas (transmitter and receiver) normally used for sending radio signs, microwave transmission for wireless communication and television signals to remote places (Hashim *et al*., 2020). The rapid growth of telecommunication technology and internet usage is resulting in the construction of millions of telecommunication towers in different parts of the world (Farooq & Raju, 2019). Therefore, the statistics showed that the number of internet users of the Tanzanian population increase day per day by using telecommunication companies (Airtel, Halotel, Smile, Tigo, TTCL, Vodacom, Zantel, Habari node) and other services like calls, and Short Message Service (SMS) (Asongu & Odhiambo, 2019). This implies that an interruption of anything in those telecommunication services or any issue is a big loss, even economically, depending on what happens.

Those companies provide a wide range of ICT-based in different computer-related services, like internet and data connection, organizing networks, hosting website, software creating, setting up computer systems and managing cloud and data centers, and cloud center. Unfortunately, most of those companies are still using security gardeners to ensure that their telecommunications equipment is safe. The most hazardous challenges faced by telecom towers are regular and unexpected due to the place of their location. Previous incidents demonstrate that fire, electricity faults, and aviation obstruction lights in telecom towers can result in devastating economic and life-loss consequences (Casey *et al*., 2020). Therefore, policies must be applied to avoid disastrous events by reducing the probability and effects of a fire and other complaints caused by unexpected situations or insecurity.

In general, fires can burn everything in a short time because people prefer saving money over investing in appropriate automatic fire extinguishment (Georgiev *et al*., 2020). As a result, issues like affordability, effectiveness, and response remained unsolved. Previous research in this area, such as real-time network-based systems and integrated fire detection and alarm (FDA) systems with building computerization, has been conducted to overcome these issues.

In this project, an IoT-based system for telecom towers will detect the presence of fire, overcurrent and overvoltage control, and monitoring the aviation obstruction light. In case of a fire is detected using flame detectors (it can detect infrared, ultraviolet and combined IR+UV), the system will automate the fire extinguisher which are manually, triggered ON the buzzer, and the concerned will receive an SMS notification and call automatically. Therefore, the system is combining all those parameters which previous research did not consider. In the case of over-current and the electrical contractor fails to take action, the system will turn on the automatic voltage and current regulator. A flame sensor is provided for the detection of any presence of fire, a poem-004t module for current and voltage, an LDR sensor and luminosity sensor for aviation obstruction light luminosity tracking, a GSM module for real-time alerting (Misbahuddin *et al*., 2020a) and monitor all tower equipment described parameters using the internet of things (IoT).

1.2 Statement of the Problem

Nowadays, fire has become the main issue in everything because it can destroy without avoiding possibility of some material loss. Furthermore, Habari Node PLC is one of the companies with many telecommunication towers in different areas of Tanzania. Telecommunication tower is equipped with electronics and electrical equipment susceptible to high fire risk, even in a short time. Those telecommunication towers face numerous challenges in warning against fires, overcurrent or overvoltage and aviation obstruction light down the time it was supposed to be ON due to their locations.

Therefore, the application of manual fire extinguishers is commonly used as mitigation by these telecommunications firms when a fire arises. Another challenge is that the overcurrent in electrical cables can burn the whole tower (Carretero-Ayuso *et al*., 2021). Furthermore, when aviation obstruction lights are not working, it can cause airplanes to bump into some masts leading to a fatal crash. Generally, two types of technology are used by the company to mitigate those challenges. The first one is to use gardeners to alert the nearest environment and can make some calls using mobile phones, which is cost-intensive (Rehman *et al*., 2019). The second is based on alarms, and those technologies are traditional. However, the promptness and proactiveness of the current mitigation approach remain a pivotal challenge to salvage conditions in fire warning and combating, electricity power control and aviation obstruction light monitoring. But the proposed new one is for sensors and actuators using internet of things which can increase the safety of telecommunication towers and real-time intervention and accurate information on the upcoming unexpected incident.

1.3 Rationale of the Study

Telecommunication tower has become the main key for information transmission in many things, such as companies, businesses and institutions. Due to the widespread usage of communication through it around the world, its security and monitoring require highly advanced technology. For example, detecting fire, aviation obstruction light status and other parameters concerning general telecommunication tower security. Different works of researchers show that manual systems have a lot of limitations and challenges compared to automated systems (Costa *et al.*, 2018). Some of these limitations are time-consuming, human errors, budget increases, the difficulty of auto-report generation, and real-time information. As one of the main ways of getting information to the concerned people about fire, electricity power and aviation obstruction light monitoring has been taken as a key feature of many telecommunication companies, including Habari Node, which needs to be implemented. Despite the work done, telecommunication towers worldwide are still experiencing several challenges of fire and warning lights down, electricity power, climate change for those using solar energy and time waste when the issue is raised (Kalair *et al.*, 2021). In addition to these difficulties, an improvised budget for item replacement may be added at any time. Therefore, this study aimed to develop an IoT based-system for telecom tower fire detection and aviation obstruction light monitoring for Habari Node PLC to provide features of maximization of time, prevention of fire, overcurrent regulation, increase security, send alerts like calls and messages and monitor the status of the aviation obstruction lights in the Tower when there is a problem.

1.4 Objectives of the Study

1.4.1 General Objective

The general objective of this project was to develop an IoT based-system for telecom tower fire detection and aviation obstruction light monitoring using Habari Node PLC as a case study.

1.4.2 Specific Objectives

The study aimed to achieve the following specific objectives:

(i) To identify the requirements for developing an IoT based-system for telecom tower fire detection and aviation obstruction light monitoring.

(ii) To develop an IoT based-system for detecting fire and aviation obstruction light monitoring in the telecommunication tower.

(iii) To validate the developed system based on the specified requirements.

1.5 Research Questions

The study intended to answer the following questions:

(i) What are the requirements for developing an IoT based-system for telecom tower fire detection and aviation obstruction light monitoring?

(ii) How can an IoT based-system for telecom tower fire detection and aviation obstruction light monitoring be developed?

(iii) How can the developed system be validated based on the specified requirements?

1.6 Significance of the Study

The developed system will improve the existing system and help the manager, firefighters and technicians identify, alert and monitor the issue with real-time intervention, especially fire extinguishment, automatic power control and aviation obstruction light status tracking. Therefore, the system will send alerts to firefighters and all Habari node towers technicians by giving them remote accessibility using a mobile phone and web-based. This will enhance the tower security and increase remote services' reliability even in rural areas of countries where Habari Public Limited Company has the towers. Moreover, the system will help to reduce waste time by going to the tower without knowing the issue raised and increase productivity and confidence and avoid the risk that can happen in the tower in general.

1.7 Delineation of the Study

This study aimed to develop IoT based-system for telecom tower fire detection and aviation obstruction light monitoring by using Habari Node PLC as a case study to provide features and system requirements. In view of this, the goal was to improve issue tracking and following up of tower status remotely and resolve challenges in time, over current control and keep track of aviation obstruction light in normal conditions or down with real-time status notification. In addition, the system automates the chemical fire extinguisher when a fire is detected in the tower area.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of the Communication Sector in Tanzania

The National Telecommunications Policy (NTP) strategies in Tanzania, for the period 1997 up to 2020, had the aim of accelerating the development of an efficient telecommunications network that can provide an info-communication infrastructure and universal access to telecommunications services by all sectors of the national economy and segments of the population (Shi & Zhu, 2019). In addition, the NTP underscores the development of the telecommunications sector as a guideline to all stakeholders in line with national macroeconomic, legal, and regulatory regimes. To achieve those objectives, policies and strategies were geared towards encouraging investments in the sector and enhancing the quality and reliability of telecommunication services and networking in general (Dong *et al*., 2017).

Moreover, telecommunications towers are structures that hold communications in wireless applications such as mobile telephony, television, radio, and public safety communications networks and also, and they are buildings blocks on which telecommunication thrives (Faisal *et al*., 2018). Therefore, their cost forms a high part of the property, plant and equipment cost of telecommunication companies in their base station. Based on their locations, the product of telecommunication carriers works with their internal technical staff to satisfy specific needs that a company has in certain regions throughout the country. The engineering aspect is defined as Radio Frequency Engineering, or RF Engineering for short, which means that RF engineers must work in tandem with their firm ‘s site development and infrastructure staff to maximize any telecommunication tower site development and related infrastructure improvement, they may have planned in the whole of Tanzania.

2.2 Telecommunication Tower Safety Infrastructure

In the current political regime, important policies and processes must be implemented by the organization or company owner to protect or intervene in its property infrastructure against disasters with high-security technology. The manual and remote systems allow acting when any unexpected situation disturbs the security layer in wired or wireless, which can cause dysfunctionality of the tower in general (Sánchez *et al*., 2019).

2.3 Telecommunication Tower Disaster Monitoring

Every professional industry involves disaster and safety regulations (Ribeiro *et al*., 2021). Specific industries, such as telecommunications, are more hazardous than others because their equipments are located far away (Maswe, 2019). The hazardous jobs performed in those industries feed into our daily lives, which means that precautions must be taken for safety because of some factors (political, economic, technological, and environmental). Internet of Things based security using microcontrollers, sensors, actuators and software is trying to be implemented to monitor and control in nowadays technology. Therefore, some analog mechanisms and gardeners are manually still deployed to shut down operations in extreme circumstances. Although, even if there are, remote and automatic systems are required to take action with real-time information using internet of things (Vlachos, 2021). For those methods of monitoring and controlling, the concerns can have access everywhere.

2.4 Classification of Emergency Disaster

According to Rak *et al*. (2021), emergency disasters can be classified as natural, human-caused, or technology related. Natural disasters come from natural phenomena, such as earthquakes, hurricanes, typhoons, cyclones, volcanic eruptions, drought, lightning, or floods. Human-caused disasters include water leakage, explosions, terrorist actions, war and technology malfunctioning hardware and software, viruses from damaged or corrupted computer files, electromagnetic interference, power failures or fluctuations, and computer hardware/software theft. Therefore, it is necessary to identify the possible emergency disaster that might occur, then assess their likelihood and the potential damage they could bring. The following are the most that arise in telecommunication towers.

2.4.1 Fire Outbreaks

Fire is one of the disasters that can hurt and destroy most things without avoidance, and it is so fast-moving with serious effects (Albery *et al*., 2021). Fires can be caused by earthquakes or by people who set them on purpose, electricity power faults, or getting struck by lightning. In addition, fires can be caused by smoke, heat, and environmental destruction.

2.4.2 Electricity Power Faults

Many institutions and companies experience occasional disruptions in power, such as power outages, overcurrent and overvoltage (Etherden & Bollen, 2019). However, due to their politics, they do not consider these as emergency disasters, even if it is for a short time and can have disastrous consequences. For example, electronic data and computer programs can be affected; information may be lost or corrupted, damage of aviation obstruction light, and fire can occur. In addition, environmental controls may be disabled, leading to fluctuations in temperature and humidity.

2.5 Empirical Literature Review

Real-time fire intervention, electricity power control, and aviation obstruction light monitoring are efficient solutions for telecommunication towers in many places for adequate and satisfactory security. However, many telecommunication companies still have problems knowing the towers' situations due to their location (Pierucci, 2019).

2.6 Related Works

Various methods have been used to resolve the same issue, focusing separately on fire detection, electricity power and aviation obstruction light monitoring. Therefore, these are the most relevant research findings in this area.

Altowaijri *et al*. (2021b) developed a privacy-preserving internet of things fire detector due to significant fire destruction for lives and important properties of people in a short time, including telecommunication towers. Using Raspberry pi and camera for video recording by using convolutional neural network to make the system reliable to detect if there is a fire or not. Therefore, the system could send alerts to the concerns and upload the data to the cloud. However, the system was not able to extinguish the fire detected for quick intervention.

Badhon *et al*. (2019) developed a remote real-time monitoring and safety system for earthquake and fire detection based on the Internet of things to maintain safety and fire detection against electrical short-circuits in Bangladesh, which can cause damage to many things. The system was using ThingSpeak to record as a means of monitoring. Using the Arduino Uno flame sensor, NodeMcu Esp8266 relay, and buzzer, the system was able to detect Fire and shut down the power when there were electrical faults. However, the system was not able to extinguish the fire detected even with no notification when a fire is detected, except to check on the ThingSpeak cloud.

Alqourabah *et al*. (2021) implemented an Intelligent fire protection system and automatic watering system with IoT technology to protect against fire accidents. Therefore, some sensors were used to detect the cause of the fire. The system was using the IoT platform to make the data exchangeable from that cloud, faster and active every moment to the same platform because the system was sending the data to the cloud. By Minimizing false alarms and turning on automatically the water sprinkler, which made this system more reliable. However, they didn’t consider the overcurrent and overvoltage as a cause of the fire.

Pérez-Ocón *et al*. (2017) developed a new lightning system for aviation safety to reduce the accident rate of aircraft that was causing the danger of death and telecommunication tower destruction by using LED, Sphere, and fiber technology. The LED was emitting light beams that enter the integrating sphere and then the light enters the end face of the optical fiber and helps the pilots know the tower’s location. However, there was no remote system as well as notifications which means that when there was a need for maintenance, the operators were climbing the mast for intervention.

Misbahuddin *et al*. (2020) implemented an IoT-based Automatic Email and Audio Message Notification System for electric light Failure detection against electricity power failures that were common in unknown circumstances. The system developed a BMS solution that could be applied for light failure detections under circuit breakers and notifications related to the issue. However, compared to the existing systems of light failure detection, the developed system was straightforward and non-invasive.

Uwamahoro *et al*. (2021) developed system to monitor the battery voltage level of communication towers of Habari Node PLC based on embedded systems to monitor the voltage level, the current level of the batteries and fire. Users were able to access the system remotely through the mobile application with real-time notifications. However, that system was not able to extinguish the fire detected in the telecommunications tower cabinet.

2.7 Technical Gap

Based on the reviewed studies, various research and project works have been done to monitor telecommunication towers using IoT. However, the reviewed works did not consider the extinguishment of the fire detected, overcurrent or overvoltage control and aviation obstruction light in the telecommunication tower.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area and Scope of the Study

Habari Node PLC is one of the companies with many telecommunication towers in different regions of Tanzania: Dodoma, Dar-es-salaam, Mwanza, and Kilimanjaro. The developed system has been conducted at Habari Node Public limited Company in Arusha District, Tanzania country (Appendix 1), focusing on the tower near Kilimanjaro Airport located in Hai District, Kilimanjaro Region. Therefore, fire detection, aviation obstruction light status and other parameters that can disturb its safety was the main purpose of the developed system. In addition, the telecommunication tower was an aid in monitoring and controlling some causes of unexpected tower destruction.

3.2 Research Methodology

This study employed qualitative research methods. The qualitative research method is characterized as a showcase research strategy that can keep on getting information through open-ended and conversational communication. This strategy was helping in determining the success and overall quality of the research study and its documentation in general (Borish *et al.*, 2021). On top of that, interviews, discussions, and reliable responses were used to help achieve the research objectives.

3.3 Target Population and Sample Size

Habari Node Public Limited company technicians were targeted. In these technicians, the sample size was selected based on convenience strategy. Therefore, six technicians from wireless, wired, fiber, electrical and software departments, including the technician's manager, were sampled their experience. Furthermore, a simple random sampling technique was used. This method gave each technician the same chance of being chosen as a research participant to get information related to fire, electricity power, aviation obstruction light, and telecommunication towers in general.

3.4 Sampling Techniques

Non-probability sampling techniques were used because they are more convenient and more accessible during the data collection for qualitative methods than probability sampling techniques. Therefore, it could also be carried out by using a discussion and interview data collection, which allow the use of the discussion method and randomly picking participants (Tutz, 2022).

3.5 System Requirements

3.5.1 Data Collection

The research project has involved qualitative approaches to collect data. So, interviews and discussions with Habari Node PLC's technician manager and tower technicians were used to get the necessary information. Therefore, this method has led to the improvement of the manually existing system and development of a new one, which is automatic. The developed system is real-time, affordable, usable, and will fulfill the tower safety requirements.

Information about the security of telecom towers, like fire detection systems with automatic extinguishers and aviation obstruction light monitoring, helps to ensure that some problems are fixed automatically by tracking and controlling the towers.

(i) Primary Data

The primary data during this research project were obtained from Habari Node PLC Company, with the address 23101 Nyerere 15 Road, Mahakama Street, Arusha, Tanzania and from the visit of one of the towers located near Kilimanjaro Aeroport, as well as from technicians. Discussion, observation, interviews and face-to-face conversation were used to obtain all the needed information. A discussion method was conducted with the technician manager to get a good understanding of the existing system, which is manual and to determine its weaknesses and strengths. The observation was conducted on both fire issues and aviation obstruction light in order to analyze how they solve the problem when it is raised in the tower, which is very far away, while the interview was conducted with both technician's manager and technicians in different careers such as in wireless, wired, electrical, nock fiber and software to investigate scenarios that the telecommunication tower is constantly faced with and to hear what challenges they face and how they intervene using the existing system. Finally, the face-to-face conversation method was used when interviewing the technician's manager and technicians to identify and agree on the requirements of the developed system.

Figure 1: A visitation to the KIA telecommunication tower

(ii) Secondary Data

The documentation method was used to gain an understanding of the system's functionality. By combining other varieties of sources, including academic journals, books and the Internet, to find out what other academic researchers have done and what insights, suggestions and answers they have proposed.

3.5.2 Data Analysis

The collected qualitative data and checklists were classified, coded and analyzed. Therefore, a simple tabular analysis was done on the data using Microsoft Excel 2019 and the data was recorded using the current version of the software. Finally, the results were compared, contrasted, and interpreted according to the proposed system.

3.6 System Development Approach

There are a variety of approaches to system development, including waterfall, the V-Model, and Agile. Depending on the nature of the project, any of these systems could be a good fit. Agile was used in this method because it is adaptable and allows real-time communication between developers and end-users (François, 2019). The prototypes had both hardware and software requirements to be developed and implemented successfully. It showed that the system needs a certain set of hardware and software tools to work properly.

3.6.1 Agile Extreme Programming Approach

Agile software methodology was used for the problem identification, solution planning, development and evaluation phase. As a result, ASDM was chosen for the IoT-based security system for telecommunications fire detection and aircraft carrier lighting monitoring because it adapts easily and quickly to changes, has greater visibility into project management and efficiency, and enables continuous improvement at every stage of the system.

However, Extreme Programming (XP) was used because it is a branch of the Agile system development life cycle (Rai *et al*., 2018). Therefore, this methodology is better for small projects than Scrum. The scrum method is the most popular, but it is more usable when working on large projects. It focuses on teamwork and organizing work. So, it needs a large team to use the scrum method. For the developed system, XP was more applicable because it helped in the prototype development. It focuses on efficiency, concerns feedback and the quality of the product. The Extreme Programming methodology includes the following steps (activities): planning the activities, designing, coding, and testing, as shown in Fig. 2.

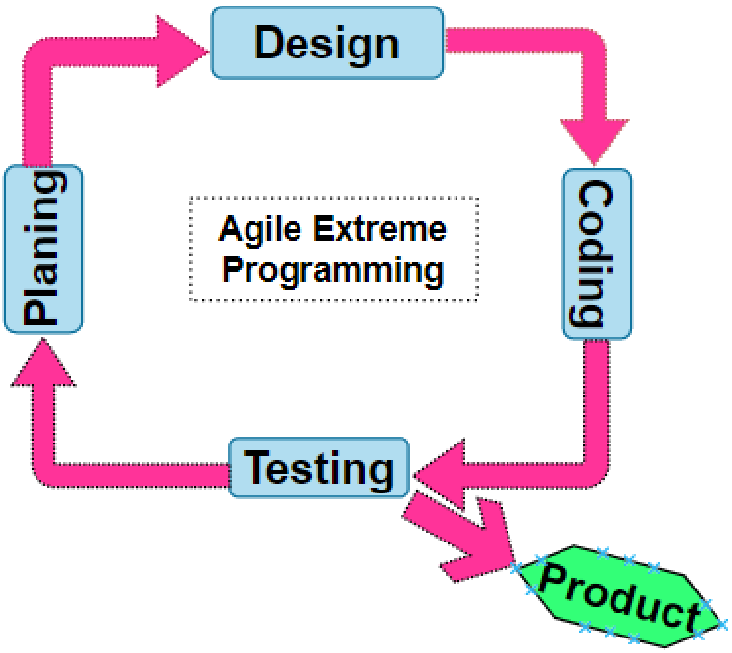

Figure 2: Agile extreme programming Methodology approach

3.7 System Design

3.7.1 System Architecture

The proposed IoT-based system provides real-time remote control, monitoring, and alerts. Figure 3 shows the functionality of the proposed and developed system.

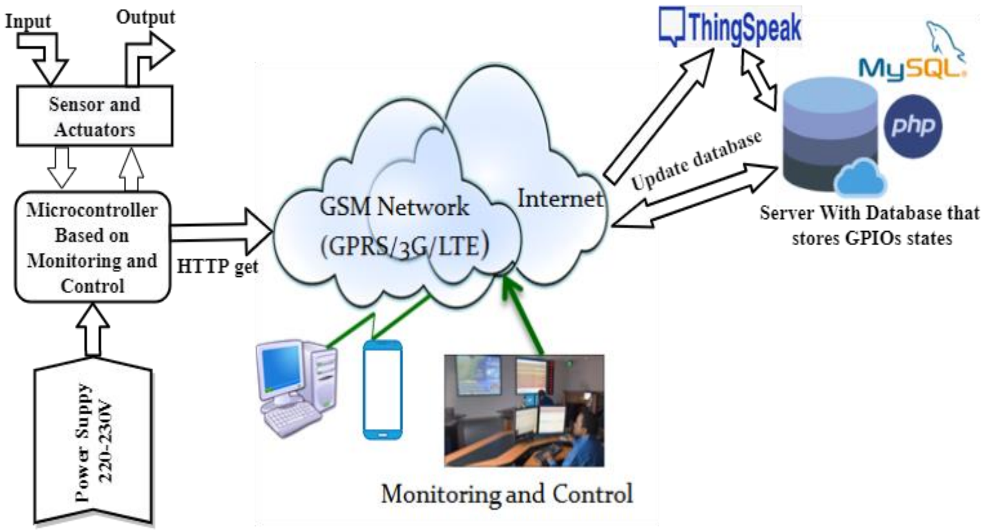

Figure 3: System architecture of the proposed and developed system

3.7.2 Block Diagram

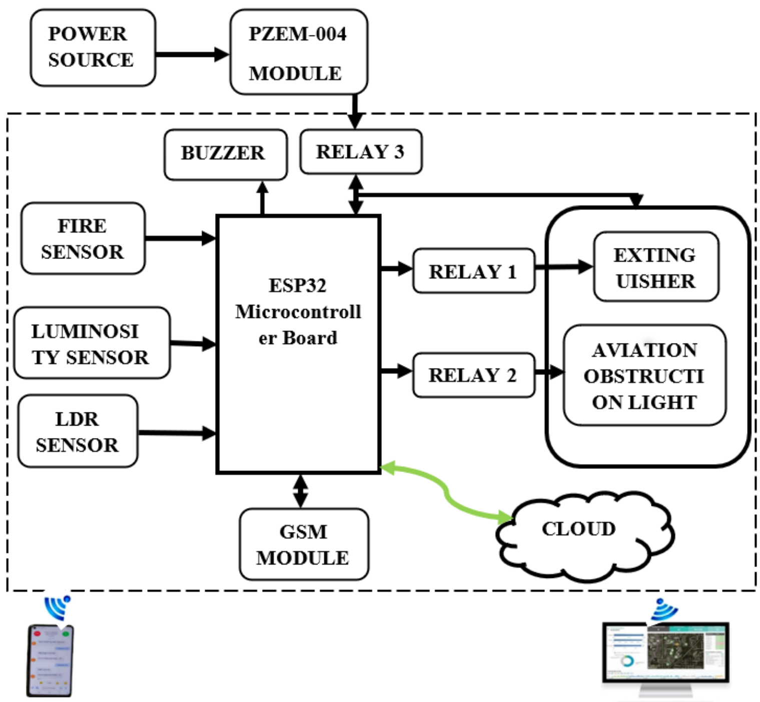

Figure 4: Block diagram of the developed system

3.7.3 Circuit Diagram

The system architecture of the proposed system is composed of an ESP32-WROOM-32D microcontroller board, two relays channel two, buzzer, fire Sensor, GSM SIM800L, LDR sensor, BH1750 light sensor, Pzem-004t, and aviation obstruction light connected between them. The digital fire sensor is connected to pin 34 of the microcontroller and a buzzer connected to pin 13 is used to alert the nearest environment if any hazard happens. Furthermore, two relays channel two are connected. The first is to control the over-current and overvoltage using PZEM-004T and turn ON/OFF the chemical fire extinguisher when a fire is detected in the tower to pin 28; the second is to control the aviation obstruction light connected to pin 15. Regarding aviation light monitoring, the LDR sensor is connected to pin 23 to turn OFF/ON the aviation light during the night or daily, and the BH1750 sensor is for luminosity monitoring to pins 21 and 22.

The transmitter (Tx) and receiver (Rx) pins of GSM SIM800L module are connected to pins 17 and 16 of the ESP32-WROOM-32D microcontroller. Therefore, all sensors and actuators are integrated and powered by 5V and 3.3V from the same microcontroller as shown in Fig. 5.

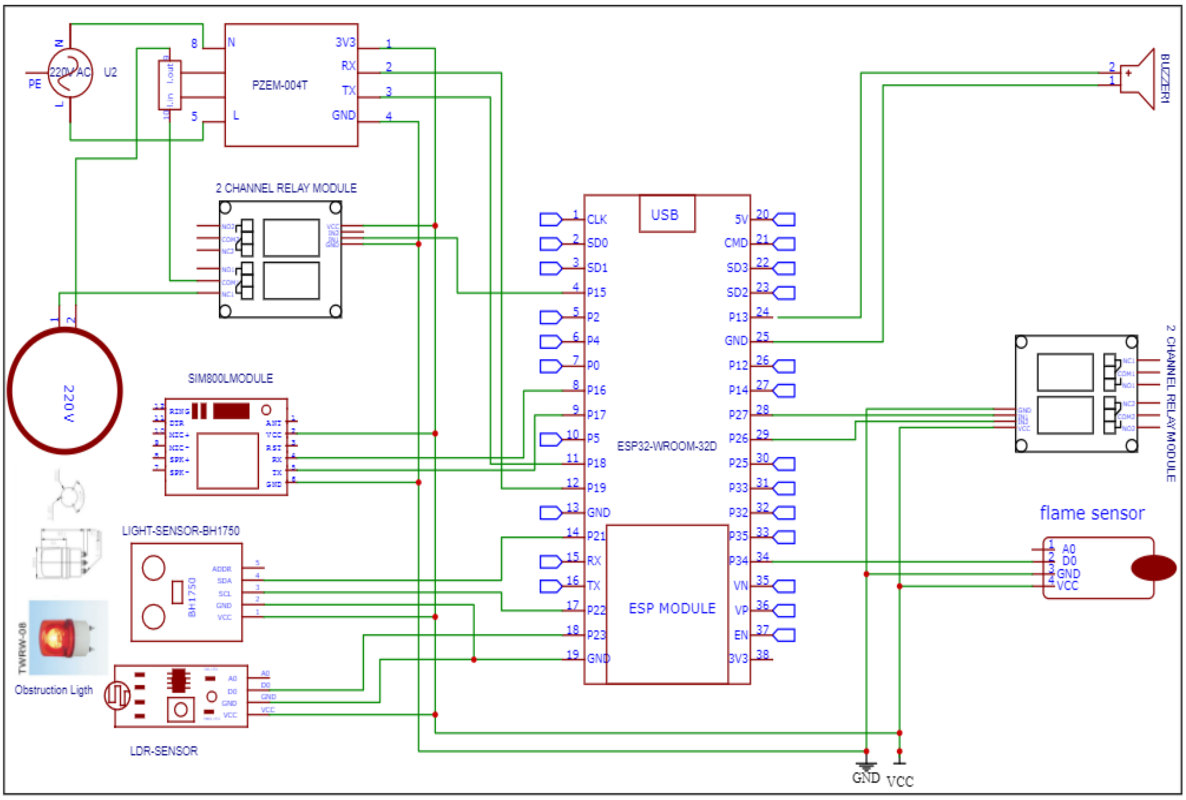

Figure 5: Circuit diagram of the developed system

3.7.4 Flowchart Diagram

This flowchart diagram, as shown on Fig. 6, describes the algorithm of the developed system and shows how a system works from the beginning to the end, step by step. Different kinds of boxes and rows show the activities and the order in which they are linked. Therefore, the system was turned on and started to operate iteratively.

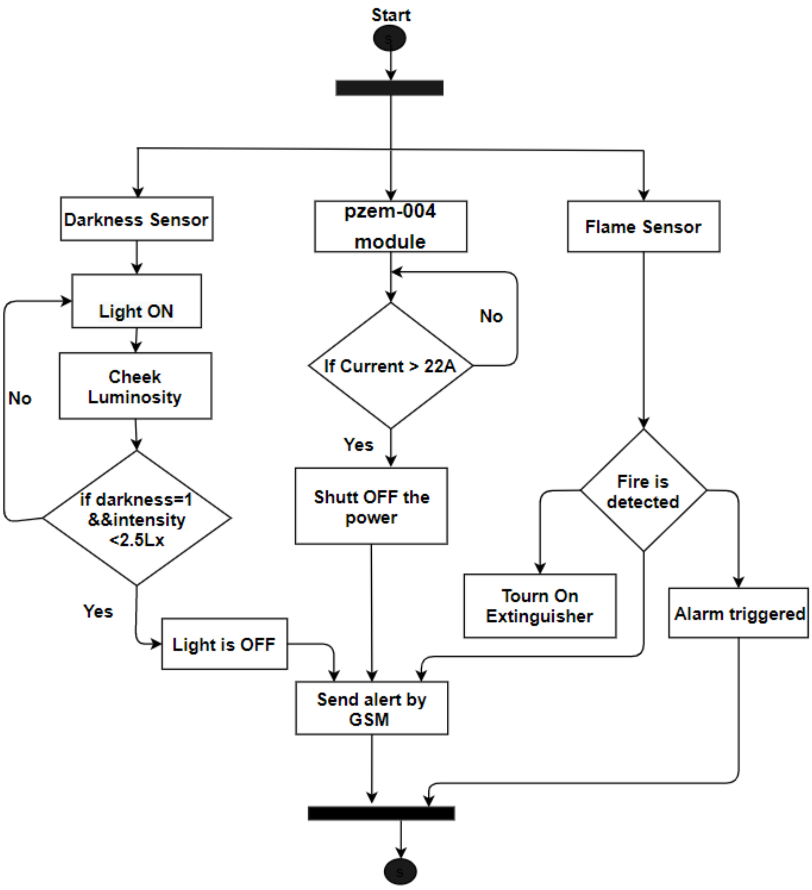

Figure 6: Flowchart of the developed system

In this project, the LDR darkness sensor was used to shut on /off the aviation obstruction light if it is night or daily and the ambient light to check the status of the aviation obstruction light. The PZEM-004T module continuously monitored the electricity power by turning ON the automatic voltage and current regulator if it was beyond 22 Amps because the Habari node tower uses 5000 Wats, and all types of equipment are powered by 220 volts. The fire sensor detects any fire in the tower environment; if detected, the fire extinguisher can be activated. The data collected by the sensors was sent to the microcontroller for processing and analysis. Furthermore, an alarm emitted by the buzzer informed the nearby surroundings, and an SMS or phone message was sent to all towers involved.

3.8 System Development

3.8.1 Hardware Tools

In terms of hardware tools, different physical devices were used during the development. It was about a computer device and a mobile device, Sensors and actuators, and other devices to make the prototype work appropriately according to the company's need for security and good functionality of the telecommunication tower, as shown in Table 1.

Table 1: Proposed hardware components of the system

S/N	Hardware Component	Specification
1.	Microcontroller	ESP32-WROOM-32D
2.	GSM module	GSM SIM800L
3.	Flame Sensor	UV/IR detector
4.	Resistor	1K
5.	Jumper wires	A few
6.	Aviation obstruction light	L 810
7.	Light Dependent Resistor	Module
8.	Relays	Relay Channel 2
9.	Buzzer	Passive buzzer
10.	Light Sensor	BH1750
11.	Pzem Module	Pzem-004T 3.0
12.	Solenoid Valve	AC DN15 solenoid valve

(i) Expressif Systems ESP32 Module

The Expressive Systems ESP32-WROOM-32D Module is a low-cost SoC microcontroller developed by the same company that created the ESP8266 SoC (Babiuch *et al*., 2019). As shown on Fig. 7, the 32-bit Xtensa LX6 Microprocessor from Tensilica is like ESP8266; the ESP32-WROOM-32D includes RF components such as a power amplifier, a low-noise receiver, an amplifier, an antenna switch, filters and an RF balun integrated with Wi-Fi, Bluetooth and Bluetooth LE MCU (Maier *et al*., 2017). Moreover, only a few extra parts are needed to make hardware for the ESP32-WROOM-32D; it's straightforward to make it. Therefore, the board was used to build the prototype, which can control all the sensors and actuators of the whole system and store all the code concerned with the project.

Figure 7: Expressif Systems ESP32 Microcontroller (Schiller *et al*., 2022)

(ii) Aviation Obstruction Light

It is used to improve the tower's visibility, tall buildings, and structures to make safe aircraft flight. Aviation obstruction lighting is widely installed on telecommunication towers, buildings and even fences in regions where low-flying aircraft may operate (Basov & Sysun, 2019).In addition, some aviation regulators require the installation, operation, red color, or status notification of obstruction lighting in specified regions. These illumination systems generally employ one or more high-intensity strobe or LED devices that may be seen by pilots from many miles away from the barrier for optimal visibility and collision avoidance.

Figure 8: Aviation obstruction light (Hasan & Sarker, 2020)

(iii) Light Dependent Resistor (LDR) Sensor Module

The light intensity is determined by the LDR sensor. This can be connected to the board's digital and analog output ports (Kapoor *et al.*, 2018). When light is present, the resistance of LDR decreases in proportion to the intensity of light (Mohanty, 2019). Therefore the LDR sensor was used to automate the aviation obstruction lights and compare the ambient luminosity, then notify the concerned whether the Light is working or not.

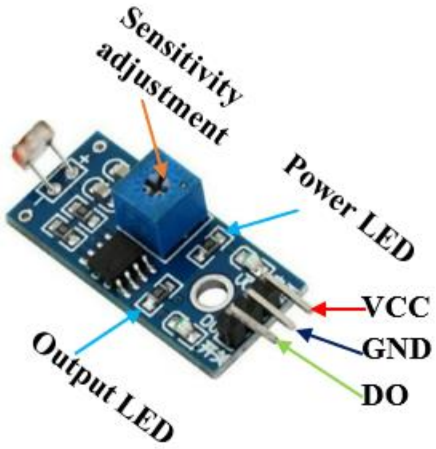

Figure 9: Light dependent resistor (LDR) sensor module (Chuah *et al.*, 2019)

Table 2: Interfacing the LDR Sensor and ESP32-WROOM-32D

Light Dependent Resistor	ESP32-WROOM-32D
Power (V cc)	3.3V
Ground (GND)	GND
Digital pin (Do)	GPIO 23

(iv) Global system for mobile communication (GSM) Module SIM800L

Therefore, the GSM SIM800L is a small GSM module with a modem that may be included in a wide variety of internet of things projects due to its adaptability (E-gizmo, 2017) (Fig. 10). It can send and receive text messages, make and receive calls from outside the system and connect to the internet via GPRS and TCP/IP by using the same module. Moreover, it can facilitate the real-time transmission and receiving of various forms of data (voice, text) over long distances.

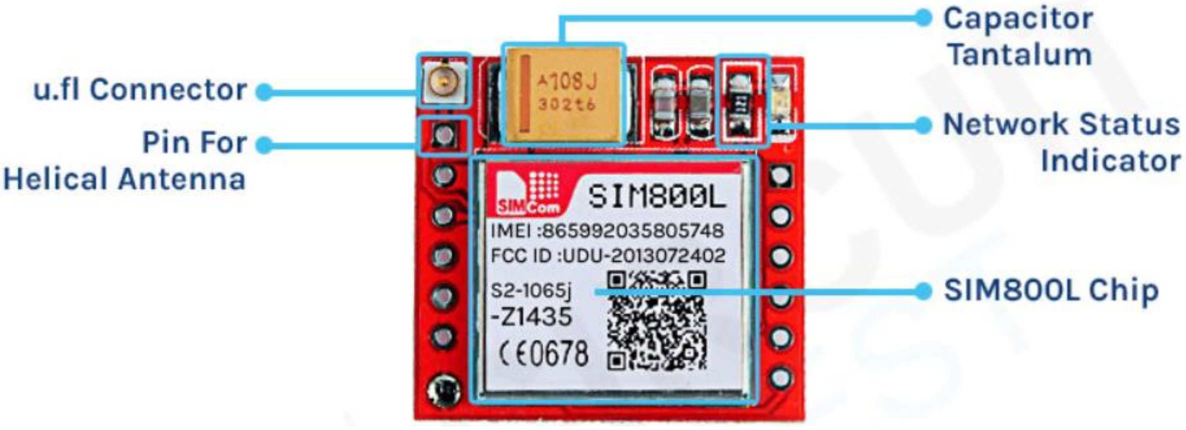

Figure 10: Global system for mobile communication module (Kanani & Padole, 2020)

Table 3: Interfacing with GSM Module and ESP32-WROOM-32D

GSM Module	ESP32-WROOM-32D
Transmitter (TX)	GPIO 17
Receiver (RX)	GPO 16
Ground (GND)	GND
Power (VCC)	5V

(v) Relays

A relay is an electrically operated switch (Fig.11). Relays perform the function of opening and closing circuits electromechanically and automatically (Suresh *et al*., 2017). It regulates the conductivity of one electrical circuit by opening and closing the contacts of another circuit and vice versa. Relays are normally open (NO) when there is an open contact in the circuit, but they are not energized when the relay is closed (NC). When a relay contact is marked as "Normally Closed" (NC), the contact remains closed even if the relay is turned on and power is supplied. Then the relay will make the aviation obstruction Light automatic control using remote access through remote access using mobile phone or computer through a web-based application.

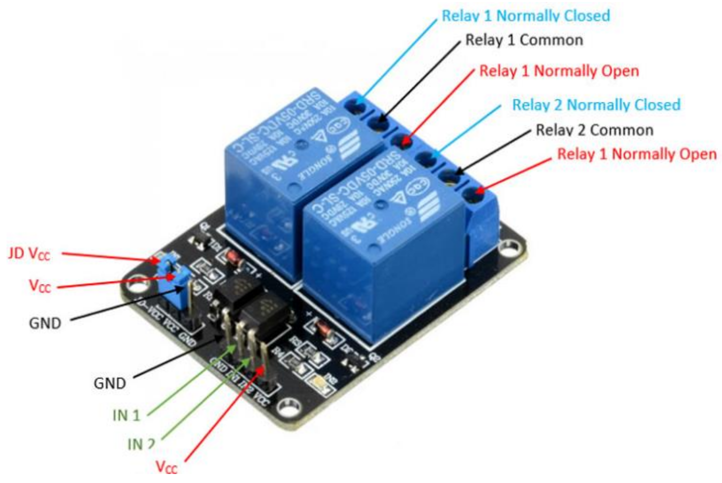

Figure 11: Relay channel two module (Kulkarni *et al*., 2020)

Table 4: Interfacing the Relay and ESP32-WROOM-32D

Relays channel two	**ESP32-WROOM-32D**
Power (VCC)	3.3V
Ground (GND)	GND
Input to activator one (IN1)	GPIO 27
Input to activator one (IN2)	GPIO 26
Input to activator two (IN1)	GPIO 15

(vi) Buzzer

A buzzer, also known as a beeper, is an audio signaling device (Fig. 12). It generates some sound according to the frequency as an audio indication. The hearing threshold is at its maximum in the frequency range of 1 to 7 kHz. As a result, the buzzer sound is so piercing that it can be heard even in a boisterous environment. A buzzer can make the sound of a click, beep, or ring (Hussien *et al*., 2020). So, in the developed project, the buzzer sends a warning signal to the nearest environment to act quickly.

Figure 12: Alarm buzzer (Bansal *et al*., 2020)

Table 5: Interfacing the Buzzer and ESP32-WROOM-32D

Buzzer	ESP32-WROOM-32D
Negative	GND
Positive	GPIO 13

(vii) Fire detector Sensor

A fire detector sensor works by detecting a fire or heat (Fig. 13). The device responds to the presence of fire or extremely high temperatures that are present at the moment (Sarwar *et al*., 2019).

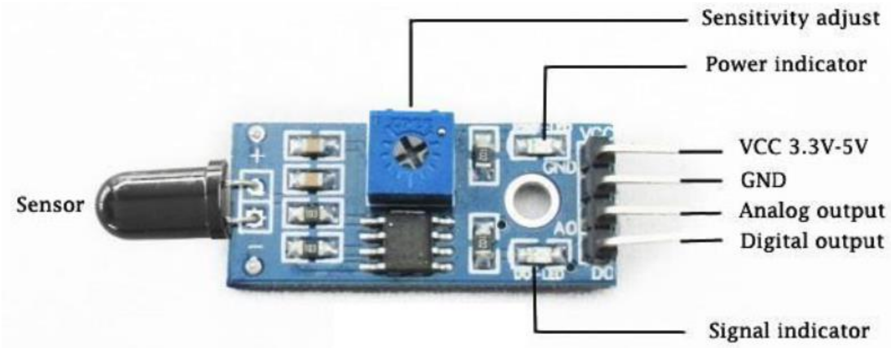

Figure 13: Flame sensor (Ahmad *et al*., 2019)

Table 6: Interfacing the Fire Sensor and ESP32-WROOM-32D

Light Dependent Resistor	ESP32-WROOM-32D
Power (VCC)	3.3V
Ground (GND)	GND
Digital pin (Do)	GPIO 34

(viii) Plastic Solenoid Valve

A plastic solenoid valve is a valve that can be operated by electricity (Fig. 14). With a solenoid, a rotating magnetic core (plunger) is located in the center of an electric coil. The plunger's resting position closes a small orifice. In producing a magnetic field, an electric current must be passed through the coil. Therefore, the plunger is propelled upwards through the magnetism, thus allowing the orifice to be opened.

Figure 14 illustrates the solenoid valve. Electromagnetically inductive coils are built around an iron core known as a "plunger”. When it's not in use, it can either be normally open (NO) or normally closed (NC); when the system is de-energized. A typically open valve and a typically closed valve are typically closed, and current flows across a magnetic field-generating coil in an electric solenoid, making it magnetically active. To open a valve, the plunger lifts the seal out of the orifice, allowing fluid passage through (Vanaja *et al*., 2020). Normally closed valves have their plungers pushed downward, preventing media from the valve's incoming flow and blocking the orifice with a seal. In addition, using the shade ring prevents AC coils from vibrating or humming. In the developed system, the solenoid valve opens the fire extinguisher automatically and is connected to the relay (Table 4).

Figure 14: Plastic solenoid valve (Zaman, 2022)

(ix) Chemical fire extinguisher

Fire extinguishers are portable equipment that are utilized to put out fires or intervene before firefighters arrive. These are kept at fire exits, buildings, factories, and public transportation (Yuan *et al*., 2021). The type and number of fire extinguishers required by law in a specific place depends on the safety laws or the kind of house or equipment that apply there (Table 7).

In some apartments, fire extinguishers are strategically placed around the workplace that can be easily accessed with fire, depending on the cause (Saghafian *et al*., 2020). They are usually found in corridors, laundry rooms, meeting rooms, kitchens, mechanical and electrical rooms, and areas close to the exit doors. The potential magnitude of a fire, as well as the kind of fire that can break out in a site, such as an office, a storage area, a research facility, etc., can influence the type of fire extinguisher, the number of fire extinguishers and where they should be placed (Benson, 2019). Therefore, workers have to learn how to use them and be aware of fire extinguishers in their workplaces. The following are fire extinguisher installation requirements.

(i) Every structure, except housing units, is required to have a portable chemical fire extinguisher installed.

(ii) Portable extinguishers with a gross weight not greater than 20 kg shall be installed so that the extinguisher shall be mounted 1m above the floor level.

(iii) Portable extinguishers having a gross weight of 20 kg or less shall be installed so that the top of the extinguisher is not more than 1.5m above the floor.

(iv) The operating instructions for portable extinguishers shall face outward when the extinguishers are located in cabinets, in-wall recesses, or on shelves.

Table 7: Fire extinguisher types chart with cause to extinguish

The symbol you can find on the fire extinguisher and what they mean	Water	Foam spray	ABC powder	Carbon dioxide	Wet chemical
Wood, paper & textiles (A)	✓	✓	✗	✓	✓
Flammable liquids (B)	✗	✓	✓	✓	✗
Flammable gases (C)	✗	✗	✓	✗	✗
Electrical contact	✗	✗	✓	✓	✗
Cooking oils & fats (F)	✗	✗	✗	✗	✓

(x) Digital Light BH1750 Sensor

The BH1750 is a digital sensor for detecting ambient light (Fig. 15). Due to the fact that employs the I2C communication standard, it is compatible with microcontrollers. It uses an extremely tiny quantity of electrical current. This sensor detects light with the assistance of a photodiode. A PN junction can be found inside this photodiode. The depletion area experiences the creation of electron-hole pairs whenever light shines on it (Desnanjaya *et al*., 2022a). In the photodiode, electricity is generated as an output of the photoelectric action that occurs within. The amount of electricity generated is directly equal to the amount of light that can be absorbed.

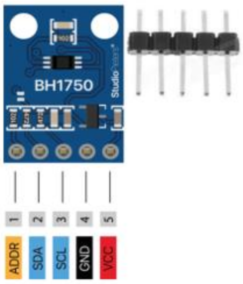

Figure 15: Digital Light BH1750 sensor (Desnanjaya *et al*., 2022b)

Table 8: Interfacing the BH1750 Sensor and ESP32-WROOM-32D

BH1750 Digital Light Sensor	ESP32-WROOM-32D
Power (Vcc)	3.3V
Serial Data (SDA)	GPIO 21
Serial Clock (Do)	GPIO 22
Ground (GND)	GND

(xi) The PZEM-004T Module

The PZEM-004T is an electronic module that measures voltage, current, frequency, energy, and power factors (Fig. 16). With all of these capabilities and characteristics, the PZEM-004T module is perfect for control or experiments involving power measurement on an electrical network, such as a home or building. Peace fair manufactures the PZEM-004T module, which can measure the range of 10 Ampere and 100 Ampere variants (Chooruang & Meekul, 2019). Therefore, it controls the power by turning ON the automatic voltage and current regulator when there is an overcurrent or overvoltage in the proposed system.

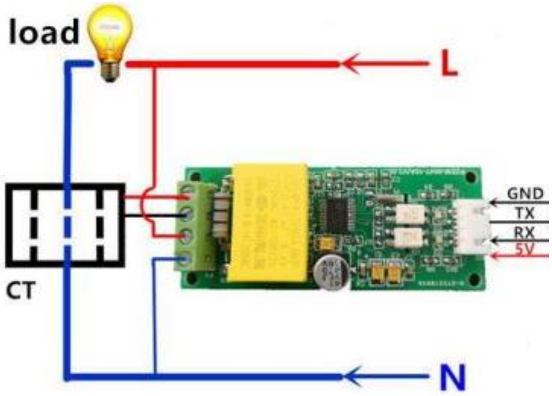

Figure 16: Pzem-004t module (Hasan & Kadhim, 2020)

Table 9: Interfacing the Pzem-004t and ESP32-WROOM-32D

Light Pzem-004t	**ESP32-WROOM-32D**
Power (Vcc)	3.3V
Receiver (RX)	GPIO 19
Transmitter (TX)	GPIO 18
Ground (GND)	GND

3.8.2 Hardware Integration

(i) System Overview of the Proposed System

The proposed system shows the system installed in the coverage area of a communication tower. Its design he consists of four parts. The first part consists of the sensor unit. The sensor system enables this through fire sensors, BH1750 sensors, LDR sensors, Pzem004t and ESP-WROOM-32D microcontrollers. Sensory data is sent and stored in the cloud. The second part of the proposed system is data processing, using an ESP-WROOM-32D microcontroller to process detection data, control relays when fires are detected for automatic fire extinguishers, flight obstacle lights control, and change direction. Automatic voltage and current regulators provide warnings in the event of overcurrent or overvoltage, alerting concerns to immediate intervention. The third part of data visualization by web-based application via mobile phone or computer. The final part is the remote control of the relay, sending signals to the ESP WROOM-32D microcontroller through the same web-based application.

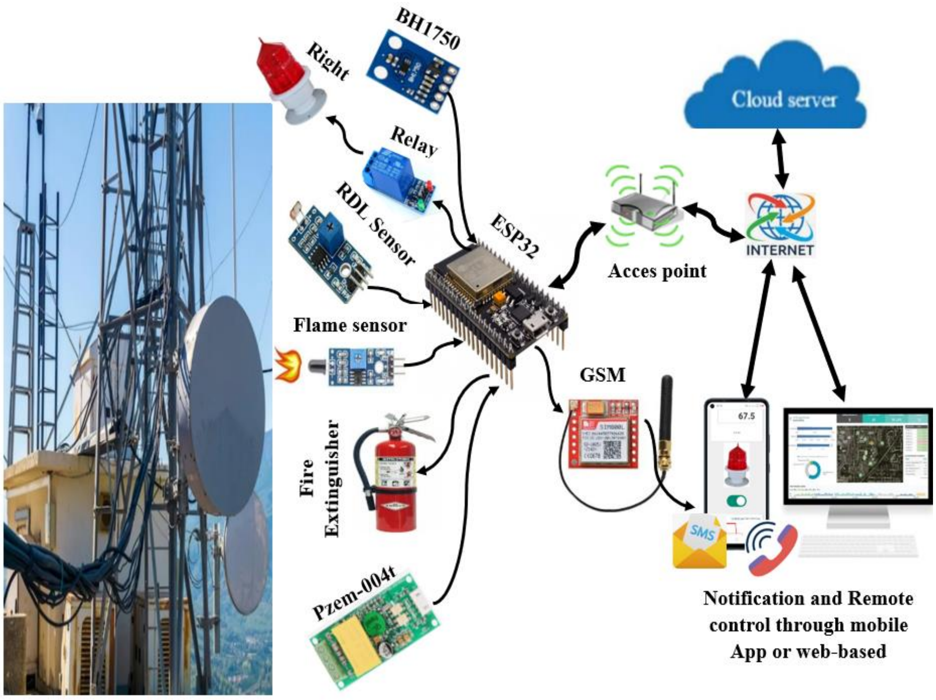

Figure 17: Prototype system overview

(ii) Steps of System Hardware Integration of the Developed System

The hardware components were integrated with real applications and interactions that proved the functionality and compliance of the system. Figure 18 shows the step-by-step integration of all hardware components, from the sensor and actuator system to the waterproofing of the coating.

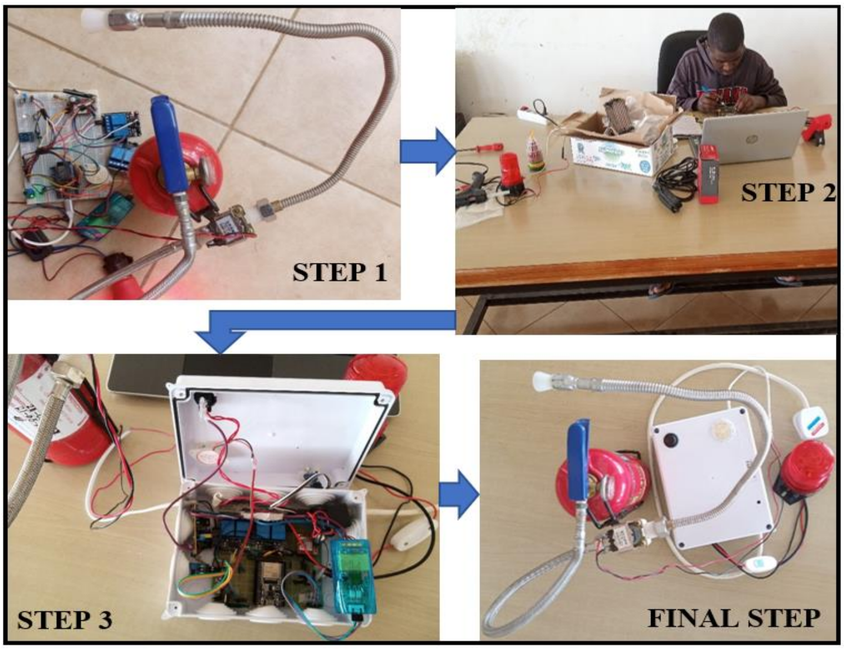

Figure 18: Hardware components integration

3.8.3 Programming Language and Software Tools Used

(i) Arduino Integrated Development Environment (IDE)

As shown in Fig. 19, the integrated development environment is a free and open-source software package that serves as a platform for creating sketches for various Arduino boards. The integrated development environment consists of several components: a text editor for writing code, a message box, a text console, and a toolbar with buttons to perform fundamental activities. To upload the code and enable communication, a connection is established within the hardware. This software comes with a tool kit that may be used to compile the hexadecimal file. The. ino file extension is used to save the sketch codes developed in the IDE's text editor. After writing a sketch on the Arduino board in the manner demonstrated in Appendices 3,4,5 and 6, the sketches are checked for defects before being uploaded to the board. The Arduino editor (IDE) came with all required libraries for Microcontroller ESP32-WROOM-32D programming and the cloud platforms (software and APIs) to facilitate all services in data storage, visualization, and remote control with relays automation (Baig *et al*., 2021).

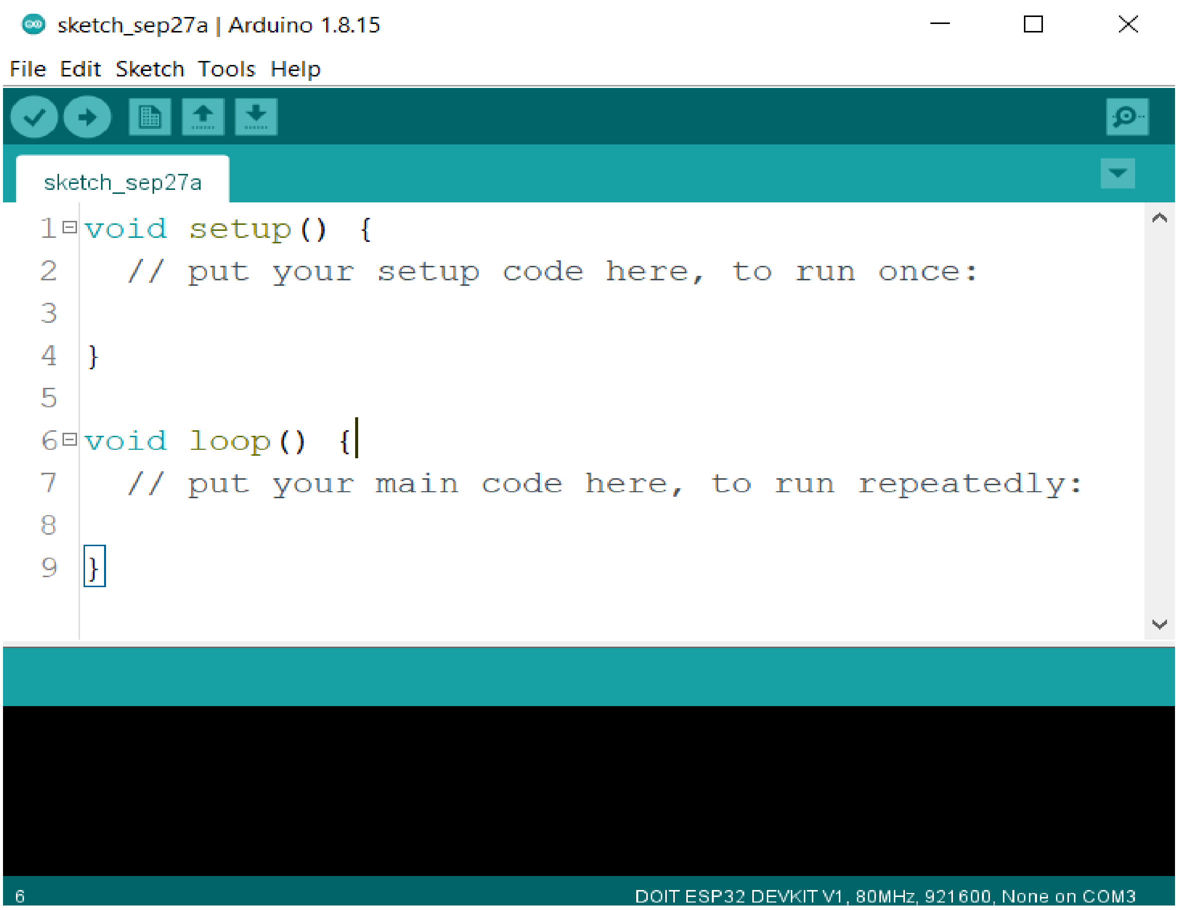

Figure 19: Screenshot of the Arduino IDE

(ii) ThingSpeak

ThingSpeak is an open-source IoT and analytics platform for connecting, analyzing and visualizing data in the cloud. The platform is essential for the storage and retrieval of sensor unit data over the Internet using a hypertext transfer protocol. The ThingSpeak platform continuously monitored the data collected by all the sensors used in this project. Surveys enable IoT developers to capture, visualize and analyze real-time data streams in the cloud.

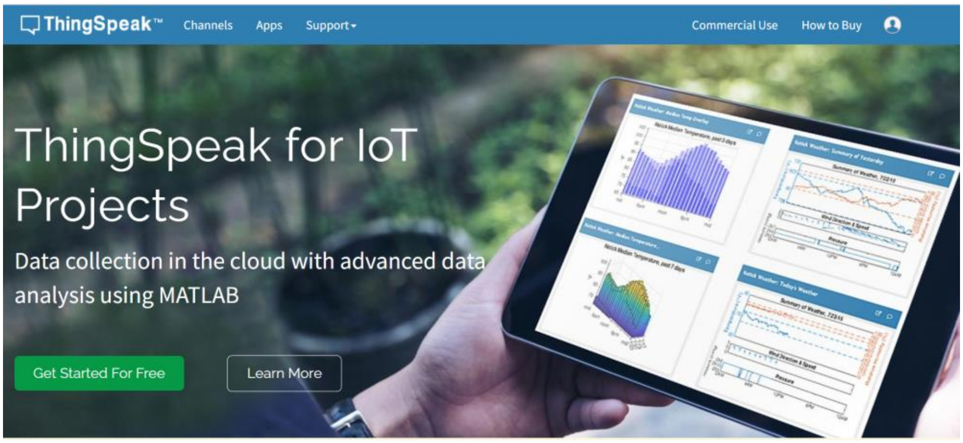

Figure 20: Screenshot of ThingSpeak IoT cloud

(iii) EasyEDA (Standard) 6.4.31

EasyEDA (standard) 6.4.31 is a web-based EDA tool that helps hardware engineers to design, simulate, share publicly and privately and discuss schematics, simulations and print circuits or PCB boards (Abdrakhmanov *et al*., 2021) as shown in Fig. 21.

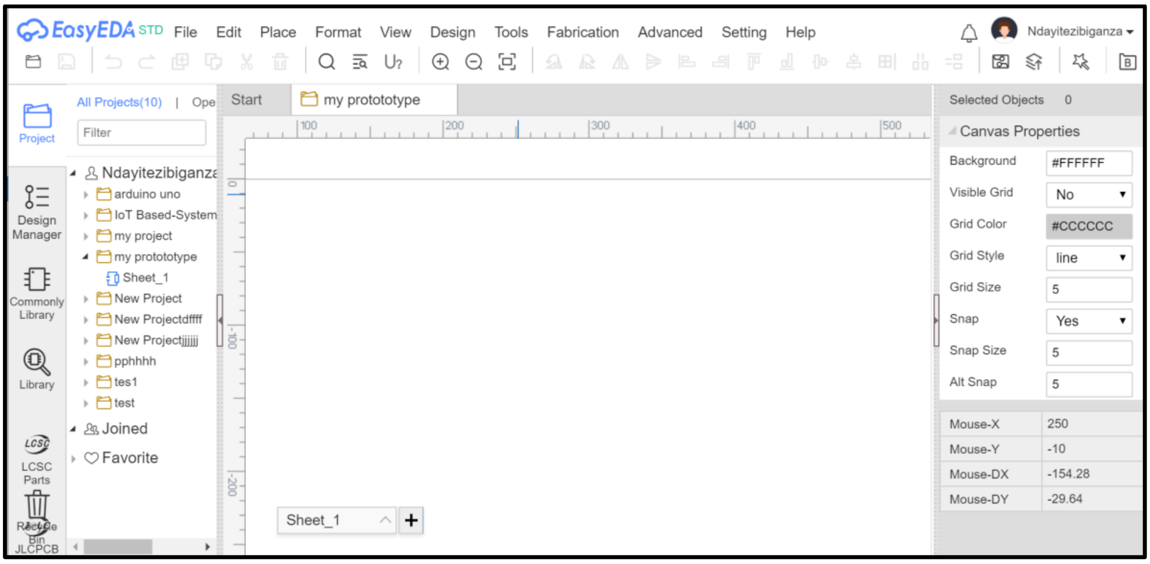

Figure 21: Screenshot of the EasyEDA simulation software interface

(iv) Hypertext Markup Language

Hypertext Markup Language (HTM) is a standard for creating web pages. The HTML Version 6 was used due to its standardized features, such as the web socket protocol, which is accountable for full-duplex communication in web technology and is supported by cascading style sheets and JavaScript technologies (Germano & Eliseo, 2021).

(v) Cascading Style Sheets

Cascading Style Sheets (CSS for short) is a style sheet language that gives HTML-based web pages a more presentable appearance. In addition, it is a way to make a web page its unique look and feel by modifying things like font, size, and color (Uzun, 2020). In this particular research project, this programming language was utilized to design the overall appearance of the front-end interfaces.

(vi) JavaScript

Java script is a high-level client-side scripting language used in the creation of web pages. It is a valuable tool for creating dynamic web forms and has first-rate features. The JavaScript programming language supports functional, imperative, and object-oriented programming paradigms (Robinson *et al*., 2020).

(vii) My Structured Query Language

MySQL is open-source, reliable, compatible with all major hosts, and affordable (Győrödi *et al*., 2020). It was chosen for this project because it is easy to use, is the best tool for relational database management systems, and is based on a structured query language. It allows users to query data by typing MySQL SQL.

3.9 System Testing

System testing is a process that is performed on an entire integrated system. Before testing the overall system, all components and their functioning were subjected to unit and integration testing. Field testing was used to test and assess how well the produced system complied with the requirement.

3.9.1 Unit Testing

Unit testing is a type of test performed on a code section to ensure that it is functional. This is accomplished on a practical level. This refers to testing the accuracy of individual modules and integrating numerous system modules as part of the unit test. Then, the unit testing will start with fire detection and light control. First, the tower will be monitored and controlled against fire, which can destroy the telecommunication tower devices. Therefore, it was helpful to know that, through the light, the system is working from the area installed up to the concerning information using the cloud.

3.9.2 Integration Testing

Any kind of software testing aimed at validating the interfaces between components against the program design is called integration testing. Its primary purpose is to expose interface module issues. During this phase, several approaches were used to test the entire system, such as mixing and testing several software components simultaneously. In addition, the data flow between modules was monitored and tested during the integration testing process. This form of testing is carried out under the supervision of a tester.

3.9.3 Tower Testing of the Developed System

Tower testing for the developed system was carried out using an assembled circuit based on a designed printed circuit board (PCB) and the entire prototype. Therefore, the system was able to sense fire, monitor the aviation obstruction light, and control the power, and then it was able to store all parameters in the cloud and make alerts.

Figure 22: Field testing of the developed system

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

In this session, the results of the developed system will be discussed in detail in relation to the project goals. The aim was to develop an automatic fire extinguisher that can intervene when a fire is detected, monitor the aviation obstruction light and control the electricity power when there is an overcurrent, or high voltage in the telecommunication tower, which is far away and send alerts to the concerns.

As a result, having an automatic fire extinguisher to extinguish the fire when it is detected in the tower with alerts to the owner of the tower, firefighters and the nearest environment using the buzzer to take quick action. Moreover, the system is reporting to the technician manager and all towers' technicians the status of all towers concerning fire detection, electricity power and aviation obstruction light status; especially when it is not working at the time, it was supposed to be ON.

Moreover, the system could detect fire and extinguish it automatically, display the status of the aviation obstruction light, control the electric power, send notifications (SMS and call) and send all values to the ThingSpeak cloud using a microcontroller board. Figures 30, 31 and 32 show how the microcontroller manages the whole system remotely using a mobile device or computer.

4.1.1 The Major Causes of Fire Outbreaks and Aviation Obstruction Light Failure

The purpose of the study was to understand the main causes of fires and aviation obstruction light failure in telecommunication towers. The Habari node technicians responded that electrical faults caused fire due to overcurrent and overvoltage, which can cause cable damage and short circuits, grass burns during the summer period system, heating of some equipment, smoking and lightning.

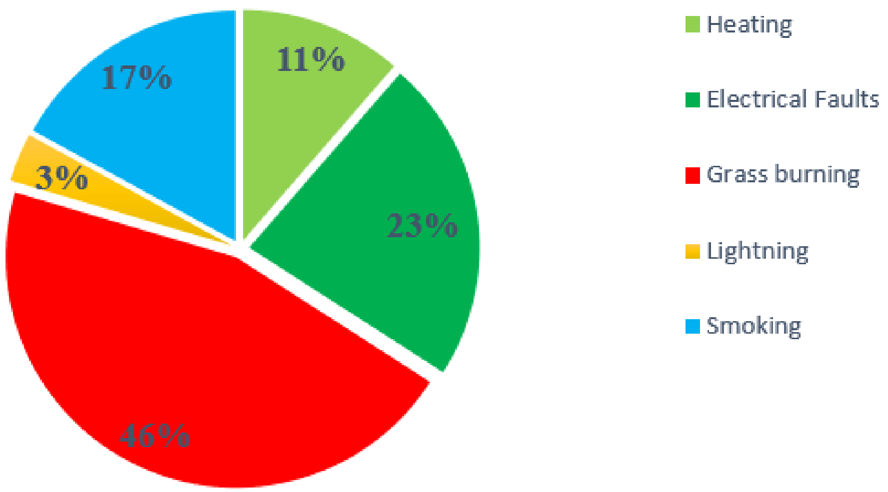

Figure 23: Main disaster source in telecommunication tower

4.1.2 Prototype Evaluation

The results obtained from six technicians in all departments as well as wireless, wired, electricity software, and fiber showed that 93% of the respondent agreed with the produced prototype's simplicity and its web-based application, confidentiality 70%, integrity 95%, availability 80%, Clarity of the result 95%, authentication 75%, authorization 83%, accounting 85% and visualization 75% as shown in Fig. 24.

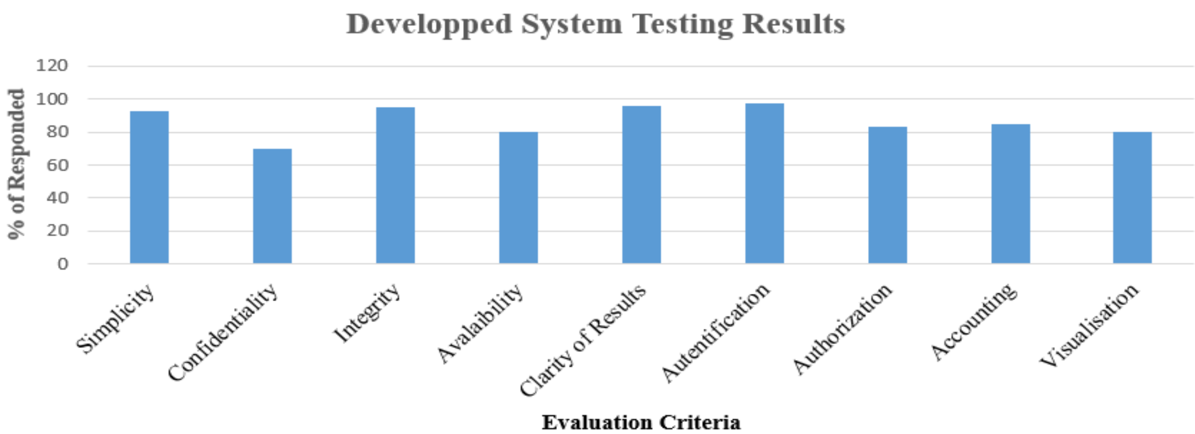

Figure 24: Developed project system evaluation

4.1.3 Weaknesses of the Current Security System for Telecommunication Towers

The study found different main categories of security systems used in Habari node PLC. These categories are security gardeners, fire extinguishers installed near the cabinet, cameras for video recording, software for internet pinging and their system management, and electricity contactors for switching OFF the main power source when any unexpected power happens.

The database system is stored daily in a safe place for all towers and GPS location tracking. System administrators always stay on the system monitoring and wait for some client complaints or a call from security gardeners if one of the towers is not working correctly. This wasn't good that made to come up with a system that could accomplish the system requirement and non-functional requirements.

Table 10: Functional Requirements

Requirements	Results description
Fire detection	The system should detect any fire in its environment
Fire extinguisher activation	The system extinguisher should activate the fire extinguisher at any time there is a presence of fire sensed in the tower
Electricity power control	The main switch of electricity power was turned ON the automatic voltage and current regulator when there was an overcurrent or overvoltage in the tower or when there was a fire sensed
Aviation obstruction light control	The system should switch OFF the aviation obstruction light during the day and ON at night or when there is darkness detected
Notification and alert	The system should trigger the buzzer for the nearest environment with real-time mobile phone alerts (SMS and call) to all concerns
General data uploading and processing	The system should upload and display to ThingSpeak and web-based application

Table 11: Non-Functional Requirements

Requirements	Results description
Performance	The system should handle multiple tasks and work all the time
Reliability	The system should be reliable by providing real-time data
Scalability	Modification and improvement should be performed without any effect

4.1.4 System Results of the Developed System and Web-Based Application

This section presents data from the study results and the methodology used to develop the system. The web application allows remote control of aviation obstruction, helping monitor the status of the fire and the electricity power. In addition, the virtual push-button may switch ON/OFF based on the signal sent to the database after receiving the notification that the light is not working. Any browser on a PC or smartphone can be used to access this application. as shown in Fig. 30.

(i) The Real-Time Fire Extinguishment

When a fire occurs in any telecommunication tower, a significant amount of loss, including the loss of people, data, and equipment, may occur. Therefore, the developed system detected the presence of fire in the telecommunication tower and performed all the necessary steps to extinguish it for quick intervention. The flame sensor, fire extinguisher, buzzer, and GSM module were implemented in the system to make this system effective, as shown in Fig. 25.

When a fire is detected, an alert is sent to all concerned as well as the technician's manager, all tower technicians, gardeners, and firefighters that the fire is detected, as shown in Fig. 27; when the fire is detected, fire extinguisher activity is automatically recorded in real-time, and the information is stored in a database at the same time.

Figure 25: Detection of fire with real-time extinguishing

(ii) Tower Monitoring Using ThingSpeak

The tower security monitoring system comprises the fire sensor, LDR sensor, BH1750 sensor, PZEM-004T, GSM SIM 800L module and ESP32-WROOM-32D (Fig. 5), and the ThingSpeak cloud storage. In addition, the illuminance of the aviation obstruction light was able to accurately detect the luminous flux of light incident per unit area in lux and save it to the thingSpeak cloud as shown in Fig. 26.

Figure 26: Illuminance of the aviation obstruction light monitoring

Figure 27 shows how fire visualization was recorded and analyzed in terms of the tower's security using ThingSpeak cloud by referring to the fire sensor datasheet. The used fire sensor was connected to the microcontroller using a digital pin (Table 5), which means when the Fire is detected, it displays 0 and not detected 1.

Figure 27: Record of fire in telecommunication tower

Therefore, electricity power is on the cloud to help the technicians to analyze the current and voltage power variation in real-time. However, the monitored current and voltage values are displayed on thingSpeak cloud for system accuracy, as shown in Fig. 28.

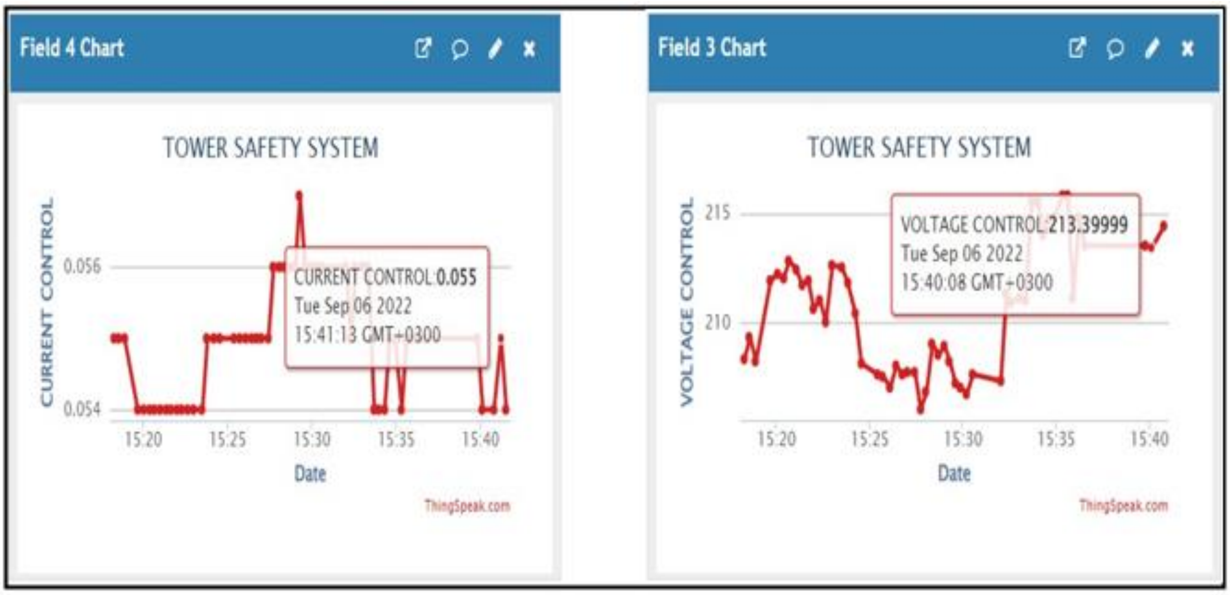

Figure 28: Electricity power valuation monitoring

(iii) Remote Control Using Web-Based Application

The link “https://towersafety.000webhostapp.com/esp-outputs.php” is used to access the web-based application connected to the database where the system is hosted (from any device connected to the same database within the system) by using it in the device's browser through URL as shown in Fig. 29. Therefore, the remote monitoring and control of the system was using PHP scripts to interact with hardware (Appendix 7).

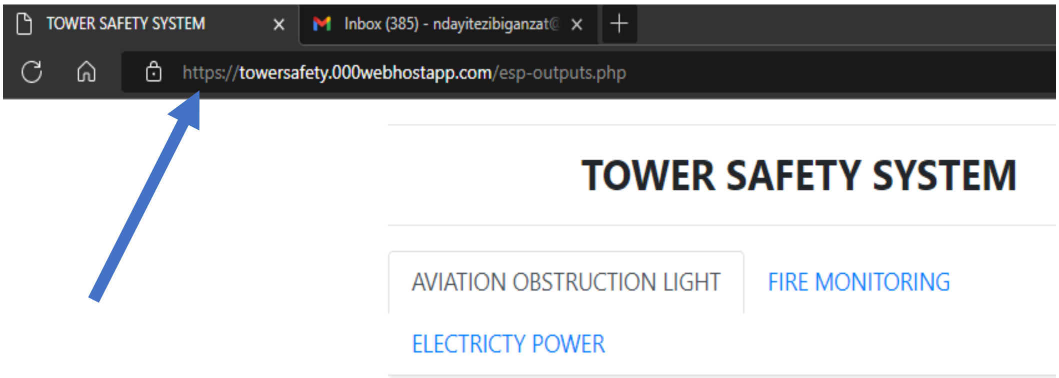

Figure 29: Web-based accessed through URL

(iv) Web-Based Application Monitoring and Control of the Aviation Obstruction Light

The virtual on/off buttons (Fig. 30) can send high or low signals to the board pins attached to the aviation obstruction lights. They then send an input signal to the ESP board to control the relevant device connected directly to the ESP board's pins through the database.

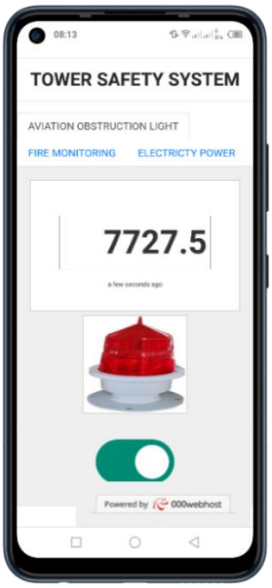

Figure 30: A user interface for aviation obstruction light control and monitoring

(v) The Fire Management Web-Based Application

Through thingSpeak, the fire was managed and recorded by being displayed on a web application using mobile phone or computer, as shown in Fig. 31.

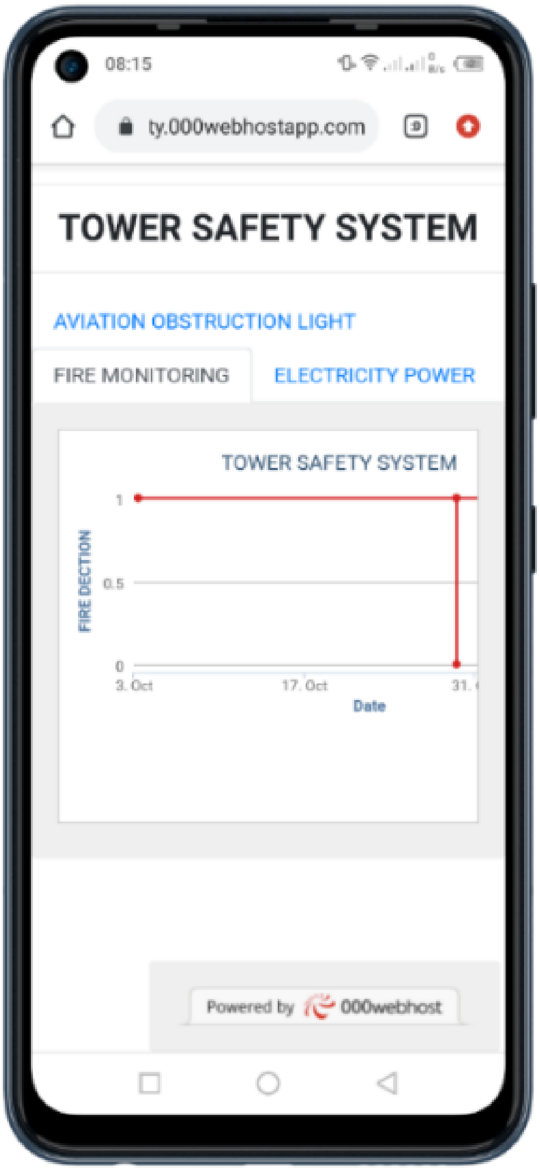

Figure 31: A user interface for fire record and monitoring

(vi) Electricity Power Management Using Web-Based Application

The real-time electricity power was monitored through a web-based mobile application to facilitate the real-time tower's current electricity power monitoring and prevention of overcurrent and overvoltage parameters (Fig. 32).

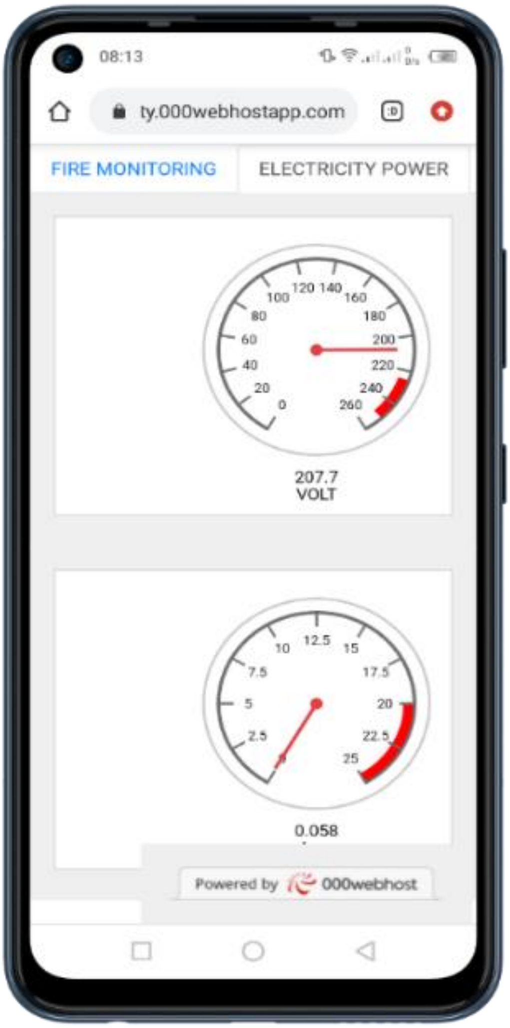

Figure 32: A user interface for electricity power monitoring

4.1.5 Notification System

On the side of notification, there is a sent alert to the technician Manager and all towers' technicians. In addition, SMS notifications and call alerts are raised when the tower has an issue concerning fire and aviation lights. An SMS is sent for the early warning, but because some people can ignore the message open after a moment, the system makes an automatic mobile call to notify the concerns immediately as shown in Fig. 33.

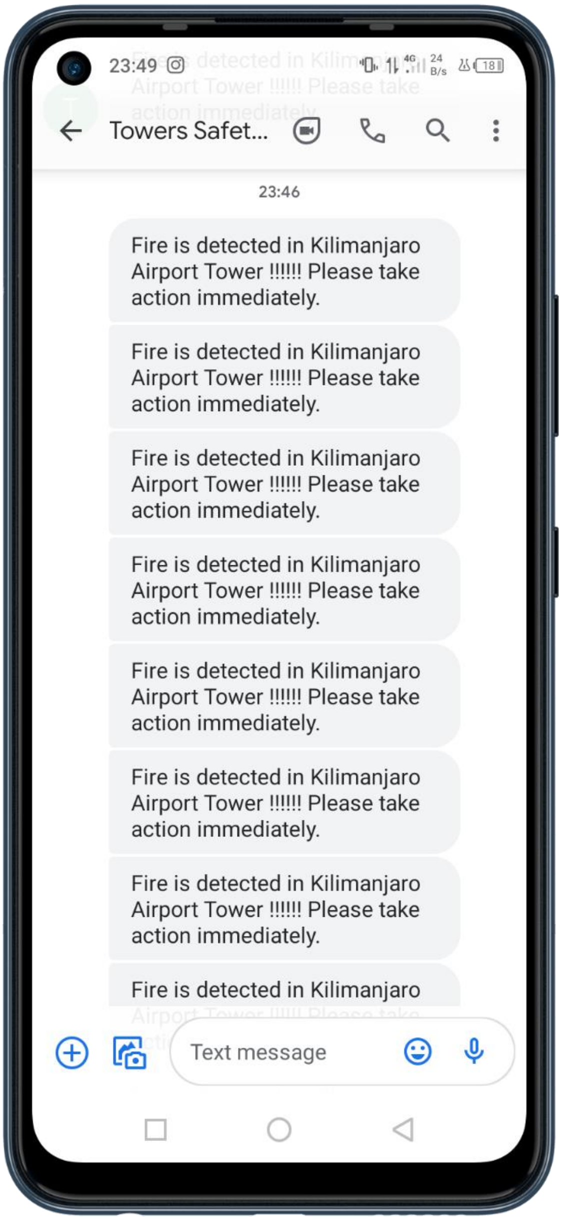

Figure 33: Short Message Service (SMS) for fire detection notification

4.1.6 Webhost Database

The MySQL database and PHP scripts were used to implement this system's web-based applications, as shown in Fig. 35. The roles table is used to specify the roles of the users, outputs, and boards, with each part having a unique set of permissions.

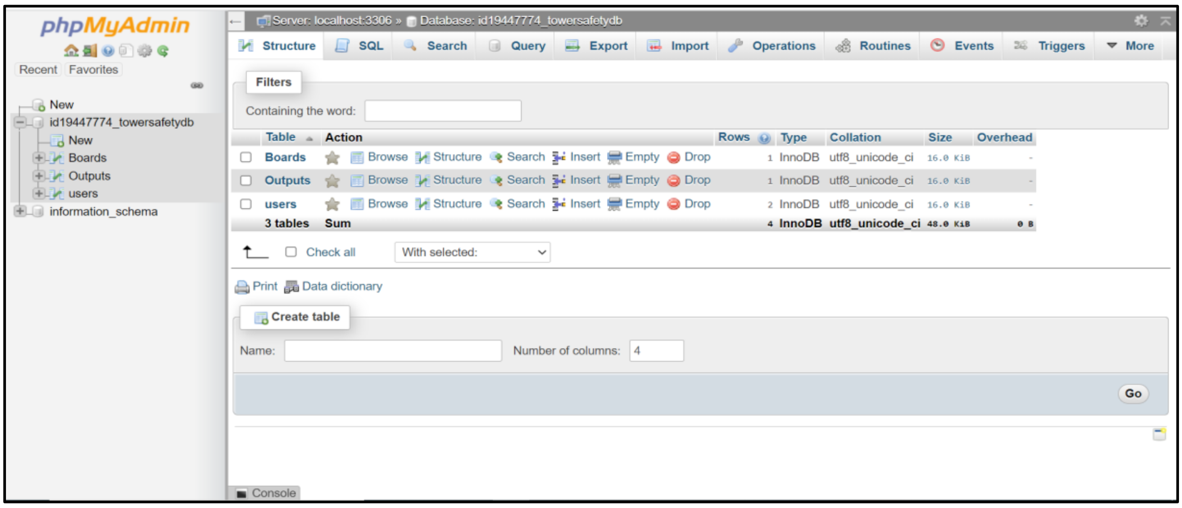

Figure 34: Database implementation

4.1.7 Hardware Device

The developed system is based on telecommunication tower safety include remote monitoring, alerts and a real-time intervention system. The entire prototype size is shown in Fig. 35.

Figure 35: The prototype

4.1.8 System Testing Results

System testing was performed to confirm that the produced system was fit for its intended purpose and functioned properly in real-world applications. It entailed testing the component specifications prior to evaluating the developed system. Following each component's interfacing design and testing, the system was tested in the field and performed as expected.

(i) User Acceptance Testing

User acceptance testing involves testing the developed system using dummy data to ensure that the system meets the requirements specified in the tower security report. This required varying levels of control to try whether the developed system was acceptable for use and could be deployed to end users. Respondents found the system impressive and believed it would produce positive results. In addition, the system has made notable contributions, such as better management information systems and better decision support.

Table 12: User acceptance testing

Validation aspects	Responded			
	Strongly agreed	Agree	Disagree	Not sure
The web-based application is very easy to use	x			
The appearance of the developed web-based application is user friendly.		x		
The purpose of the system is well implemented		x		
Is the developed system different from the existing system	x			
I am satisfied with the developed system	x			

4.1.9 System Validation

The fire detection system, aviation obstruction light monitoring and alerting system were tested and validated according to the system requirements. Furthermore, the same parameters were transferred to the cloud and displayed on a mobile device and web-based app. Finally, the system prototype was presented to and tested by Habari Node Company's Technical Manager and tower technicians to ensure that all the system's functions performed as planned.

Comparison of the Systems Existing System to the Developed Systems

From the results of field tower testing, the proposed system overcomes some of the limitations of existing systems, as shown in Table 5.

Table 13: Existing System comparison with the developed system

S/N	Existing system	Developed system	Results
1.	Real-time notification for alerting the concerns	Make a call and SMS as an alert to the technician Manager and tower technician manager and tower technician when there was a fire detected or unworking of the aviation Light at the time it was supposed to be ON.	PASS
2.	High technological methods	Low cost and low power consumption	PASS
3.	Methods used for towers security are manually	The system provides an automatic system that can extinguish fire, shut down the power when there is an overcurrent and High voltage, and control the aviation light.	PASS
4.	No centralized system	Provide a centralized system for accessing the security towers' parameter live data whenever necessary.	PASS

4.2 Discussion

Different experiments were conducted during the testing and development of this system in the selected tower and confirmed that the developed system could manage to detect, extinguish the fire, electricity power control and monitor the aviation obstruction light. The fire, the ambient light, electricity power and darkness in the tower were monitored with the help of a flame sensor, Pzem-004t module, LDR module, buzzer and BH1750. Therefore, the system is suitable for monitoring and controlling the Habari node KIA telecommunication towers. Its suitability is the required goal for high performance, where Habari node technician manager and towers technicians will get information regarding those parameters and automatic alert when there is an issue raised in telecommunication tower. Data processed by the sensor were sent to the cloud in real-time, as shown in Figs. 28, 29, 30, 31, 32 and 33, to visualize the ambient light, current, voltage, through the online web-based application and early warning on fire if detected.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The developed system establishes the basis for developing an IoT based-system for telecom fire detection and aviation obstruction light monitoring to ensure the proper functionality of the tower. Therefore, the developed system aimed to improve the safety of the Habari Node PLC telecommunication towers by remotely controlling the aviation obstruction light, automating the manual fire extinguishers, and controlling the electrical power because when a fire occurs in a telecommunication tower located far away, it could cause a big loss of all equipment and in case of overcurrent or overvoltage, it can also cause a fire that can burn everything or destroy the aviation obstruction.

The developed system will monitor through web-based applications and ThingSpeak with a real-time alert of calls or SMS. The developed IoT based-system for telecom tower fire prevention and aviation obstruction light Monitoring is connected to the database, which stores all sensor data and gives remote monitoring and control access through a mobile phone or web base. Therefore, the developed system will help the technician manage higher to visualize all towers and all technicians to identify the issue and reduce waste on going to the towers without knowing the problem. As part of future work, researchers have to find a technology that could be applied to the fire extinguisher to extinguish with a focus on the fire point and protect and monitor the aviation obstruction light against lightning.

5.2 Recommendations

This study recommends the following:

(i) All technicians must be familiarized with the system to have a transparent service orientation. Also, they are recommended to be active with any tower alert unless it can cause a significant loss.

(ii) The technician Manager is required to check the tower safety status daily and verify all systems not delivering the tower's information for maintenance.

(iii) Ethernet can improve internet connectivity through the GSM module and avoids delays in transmitting and receiving towers from the cloud.

(iv) Machine learning can be applied to enable the system to extinguish the fire with a focus.

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APPENDICES

Appendix 1: Acceptance Letter

HABARINODE

Better Solutions • Lasting Connections

Date: 16th November ,2021

Email: sales@habari.co.tz

Phone: +255 411 200 900

Postal address:1215 Arusha

Mr. Thierry NDAYITEZIBIGANZA

P.o Box 447

NM-AIST

Arusha -Tanzania

Dear Mr. Thierry,

Re: Offer of Internship at Habari Node Company.

This is in response to your internship application dated November 12th, 2021 at Habari Node Company, Arusha.

Your internships have been accepted by the company for a period of six months, and you will be assigned to the IT department under the supervision of the Technical Manager.This internship will begin on February 28, 2022 and will end on August 28, 2022.

However, you should be aware that Habari Node Company may or may not provide financial assistance or allowances to interns. This is subject to discussion. In the meantime, interns will be responsible for their own maintenance throughout the duration of the internship.

Interns should conduct their relevant industrial Supervisor if they have any concerns or need clarification.

Your Sincerely,

HABARI NODE PLC
P. O. BOX 1215
ARUSHA - TANZANIA

Eng. Lomayani Solomon

Technical Manager, Habari Node Company Arusha.

Appendix 2: Interview Guide

IoT based-system for telecom tower fire detection and aviation obstruction light Monitoring

Section A: Opening Questions

1. Would you mind if we can conduct this interview in your office, or do you have an idea of another place which is more comfortable?

2. Can I know a little about you and what tasks are performing in this company?

3. How long have you been working in this company?
4. Do you have any questions for me before we continue with our interview?

Section B: Introductory Questions

5. How is your experience of working in this company?

6. What are the processes for intervention if a telecommunication tower got an issue?

7. What kind of security intervention do you use in telecommunication towers (for concentrated juice, dilute juice and juice ready for fermenting) and why?

Section C: Key Questions

8. How do you get the information related to the Fire detected in the telecom tower?

9. What are the cause of fire and aviation obstruction lights in telecommunication towers?

10. What are the consequences caused by fire, aviation obstruction, light down and high electricity power?

11. What kind of devices do you use to monitor the aviation obstruction light?

12. What is kind of systems and equipment installed to extinguish the fire when it rises?

13. How do you know the issue in telecommunications tower

14. Do you know internet of things in fire safety systems?

15. What are the consequences caused by fire, aviation obstruction, light down and high electricity power?

16. How do you try to overcome these challenges?

Section D: Concluding Questions

17. Do you think an IoT based-System or Telecom Tower Fire Detection and Aviation Obstruction Light Monitoring can solve those issues in your company?

18. What would be the benefits of using an IoT based-System or Telecom Tower Fire Detection and Aviation Obstruction Light Monitoring in your company?

19. Are there any important items that we missed in our discussion today?

Appendix 3: Arduino Sketch Libraries and Declaration of the Developed System

```
#include <WiFi.h>
#include <Wire.h>
#include <Arduino_JSON.h>
#include <BH1750.h>
#include <SoftwareSerial.h>
#include <PZEM004Tv30.h>
#include <WiFiClient.h>
#include <ThingSpeak.h>
#include <WiFiServer.h>
#include <ESPAsyncWebServer.h>
#include <HTTPClient.h>
const char* serverName = "http://towersafety.000webhostapp.com/esp-outputs-
action.php?action=outputs_state&board=1";
//Your IP address or domain name with URL path
// Update interval time set to 5 seconds
const long interval = 50;
unsigned long previousMillis = 0;
String outputsState;
const char * myWriteAPIKey = "QQOCAA6QQJZ8HTL4";
const char* thingspeak_server = "api.thingspeak.com"; // API for thingspeak
const char *ssid =  "ESP32";     // replace with your wifi ssid and wpa2 key
const char *pass =  "79143502";
WiFiClient client;
SoftwareSerial mySerial(16, 17);
BH1750 lightMeter;
int ldrPin1 = 23;
int relay2= 25;
int val = 0;
PZEM004Tv30 pzem(Serial2,18, 19); // Software Se589rial pin 18 (TX) & 19
(RX)
int relay3= 26;
int Buzzer = 13 ;        // used for ESP32
//int Fire_analog = 4;    // used for ESP32
int FirePin = 34;   // used for ESP32
int relay1= 27;
String data_send ="";
```

Appendix 4: Code for the Aviation Obstruction Light Monitoring

```
int val = digitalRead(ldrPin1);
float lux = lightMeter.readLightLevel();
Serial.print("Darkness:");
Serial.println(val);
Serial.print("Aviation Obstruction Light: ");
Serial.print(lux);
Serial.println(" lx");
delay(500);
if(val ==HIGH && lux >2.50 ){
digitalWrite(relay2, HIGH);
Serial.println("Its Dark, The aviation Obstruction Light is working");
Serial.println("the Aviation Obstruction light is working properly");
}
else if(val ==HIGH && lux <2.50 )
  {

Serial.println("the light has a problem");
 mySerial.begin(9600);
 sendSMS("+255764718618", " the Aviation Obstruction light is working properly
please do the quick intervention " ); // send msg one time#
  delay(3000);
    }
else{
digitalWrite(relay2, LOW);
Serial.println("Its daily, Turn off the aviation obstruction Light");
}
```

Appendix 5: Code for Electricity Power Control

```
 float voltage = pzem.voltage();
if(voltage != NAN){
   Serial.print("Voltage: ");
   Serial.print(voltage);
   Serial.println("V");
} else {
   Serial.println("Error reading voltage");
} float current = pzem.current();
if(current != NAN){
   Serial.print("Current: ");
   Serial.print(current);
   Serial.println("A");
} else {
   Serial.println("Error reading current");
} float power = pzem.power();
if(current != NAN){
   Serial.print("Power: ");
   Serial.print(power);
   Serial.println("W");
} else { Serial.println("Error reading power");
}  float energy = pzem.energy();
if(current != NAN){
   Serial.print("Energy: ");
   Serial.print(energy,3);
   Serial.println("kWh");
} else {
   Serial.println("Error reading energy");
}float frequency = pzem.frequency();
if(current != NAN){
   Serial.print("Frequency: ");
   Serial.print(frequency, 1);
   Serial.println("Hz");
} else {
   Serial.println("Error reading frequency");
} float pf = pzem.pf();
if(current != NAN){
   Serial.print("PF: ");
   Serial.println(pf);
} else {  Serial.println("Error reading power factor");
}Serial.println();
```

Appendix 6: Code for Fire Management

```
int fire = digitalRead(FirePin);
 // save data to cloud
    ThingSpeak.setField(2, fire);
    int Data = ThingSpeak.writeFields(1682342, myWriteAPIKey);
    if(Data == 200){
      Serial.println("Channel updated successfully!");
    }else{
      Serial.println("Problem updating channel. HTTP error code " + String(Data));
    }
delay(3000);
  if(fire == 0) {
     Serial.println("fire is detected now");
     digitalWrite(Buzzer, HIGH) ; //send tone
     digitalWrite(relay1,HIGH);
     sendSMS("+255764718618", " Fire detected...! take action immediately:  " ); //
send msg one time#
    delay(3000);
   Serial.println("making call1");
    mySerial.println("AT"); //Once the handshake test is successful, i t will back to
OK
  updateSerial();
  mySerial.println("ATD+ 255764718618;"); //  change ZZ with country code and
xxxxxxxxxxx with phone number to dial
  updateSerial();
  delay(20000); // wait for 20 seconds...
  mySerial.println("ATH"); //hang up
  }
  else {
    Serial.println("there is no fire");
    digitalWrite (Buzzer, LOW) ;  //no tone
    digitalWrite(relay1,LOW);
  }
  delay(500);
}
```

Appendix 7: PHP Script for Web-based Application

Script for voltage Monitoring

```
<body>

      <hr> <h3> <center><b>TOWER SAFETY SYSTEM</b></center> </h3><hr>

    <ul class="nav nav-tabs">
  <li class="nav-item">
    <a class="nav-link" href="esp-outputs.php">AVIATION OBSTRUCTION</a>
  </li>
  <li class="nav-item">
    <a class="nav-link" href="fire_detection.php">FIRE MONITORING</a>
  </li>
  <li class="nav-item">
    <a class="nav-link active" href="volume_monitoring.php">ELECTRICITY POWER</a>
  </li>

</ul>

    <div>

         <!--...thingspeak Plot voltage...-->

        <iframe width="100%" height="260" style="border: 1px solid #cccccc;" src="https://thingspeak.com/channels/1682342/widgets/513866"></
        iframe>
    </div>

          <div>

         <!--...thingspeak Plot current...-->
        <iframe width="100%" height="260" style="border: 1px solid #cccccc;" src="https://thingspeak.com/channels/1682342/widgets/515394"></
        iframe>
    </div>

</body>

</html>
```

Script for Current Monitoring

```
<body>

      <hr> <h3> <center><b>TOWER SAFETY SYSTEM</b></center> </h3><hr>

    <ul class="nav nav-tabs">
  <li class="nav-item">
    <a class="nav-link" href="esp-outputs.php">AVIATION OBSTRUCTION LIGHT</a>
  </li>
  <li class="nav-item">
    <a class="nav-link" href="fire_detection.php">FIRE MONITORING</a>
  </li>
  <li class="nav-item">
    <a class="nav-link" href="volume_monitoring.php">ELECTRICITY POWER</a>
  </li>
  <li class="nav-item">
    <a class="nav-link active" href="#">CURRENT</a>
  </li>
</ul>



      <div>

         <!--...thingspeak Plot current...-->
        <iframe width="80%" height="200" style="border: 1px solid #cccccc;" src="https://thingspeak.com/channels/1682342/
        widgets/515394"></iframe>
    </div>

    <a href="logout.php">Logout</a>
</body>
```

Script for Fire Monitoring

```html
        <title>TOWER SAFETY SYSTEM</title>
    </head>
<body>

     <hr> <h3> <center><b>TOWER SAFETY SYSTEM</b></center> </h3><hr>

    <ul class="nav nav-tabs">
  <li class="nav-item">
    <a class="nav-link" href="esp-outputs.php">AVIATION OBSTRUCTION LIGHT</a>
  </li>
  <li class="nav-item">
    <a class="nav-link active" href="#">FIRE MONITORING</a>
  </li>
  <li class="nav-item">
   <a class="nav-link" href="volume_monitoring.php">ELECTRICITY POWER</a>
  </li>

</ul>

    <div>

         <!--...thingspeak Plot Fire Detection...-->

        <iframe width="100%" height="300" style="border: 1px solid #cccccc;" src="https://thingspeak.com/channels/1682342/charts/2?bgcolor=%23ffffff&color=%23d62020&dynamic=true&results=60&type=line&update=15"></iframe>

    </div>
</body>

</html>

```

Script for Aviation Obstruction Light Monitoring

```html
   <!--...thingspeak Aviation Light Monitoring...-->
            <iframe width="100%" height="200" style="border: 1px solid #cccccc;" src="https://thingspeak.com/channels/1682342/widgets/510762"></iframe>
    <!--...Bulbe...-->
 <img width="50%" height="150" style="border: 1px solid #cccccc;" src="light.png">
 </div>
    <!-- <br> -->
    <div style="text-align: center;">

    <?php echo $html_buttons; ?>
</div>
    <!-- <br><br> -->
    <?php //echo $html_boards; ?>
    <!-- <br><br> -->
   <script>
        function updateOutput(element) {
            var xhr = new XMLHttpRequest();
            if(element.checked){
                xhr.open("GET", "esp-outputs-action.php?action=output_update&id="+element.id+"&state=1", true);
            }
            else {
                xhr.open("GET", "esp-outputs-action.php?action=output_update&id="+element.id+"&state=0", true);
            }
            xhr.send();
        }
        function deleteOutput(element) {
            var result = confirm("Want to delete this output?");
            if (result) {
                var xhr = new XMLHttpRequest();
                xhr.open("GET", "esp-outputs-action.php?action=output_delete&id="+element.id, true);
                xhr.send();
```

Appendix 8: Poster Presentation

IoT Based-System for Telecom Tower Fire Detection and Aviation Obstruction Light Monitoring

1. Thierry Ndayitezibiganza, 2. Dr. Devotha Nyambo, and 3. Prof. Anael Sam

Introduction

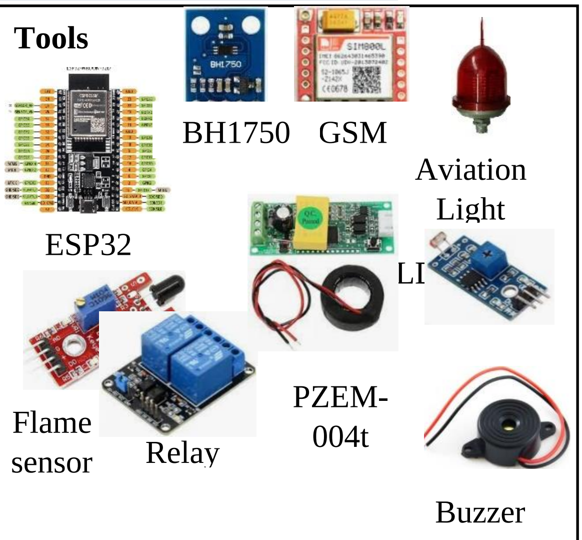
Telecommunications towers are structures that hold communication equipment used in wireless applications such as mobile telephony, television, radio, and public safety communications networks.

Problem Statement

Fire has become the main issue in many things because it can destroy without avoiding the possibility of some material loss. Many places where the t owers are installed, like parks, villages, and forests, are not easy to reach when the aviation obstruction light goes down, such as in a place where it is very far, there is no system of surveillance for notifying the manager.

Methods

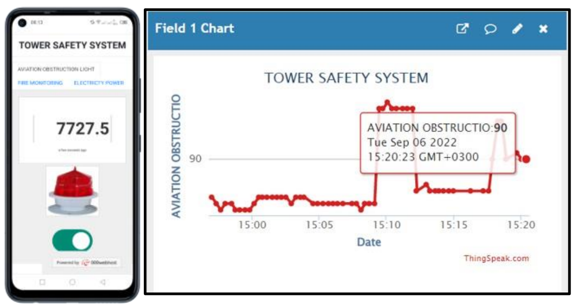
Tools

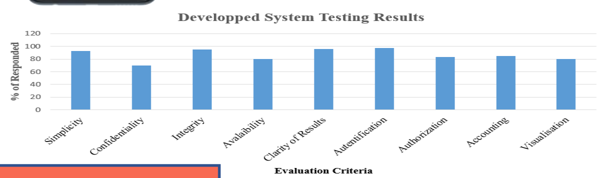


Results

As a result, having an automatic fire extinguisher to extinguish the fire when it is detected in the tower with some alerts using GSM to stakeholders of the tower, firefighters and the nearest environment using the buzzer to take quick action. Moreover, the system is reporting to the technician manager and all towers' technicians the status of all towers concerning fire detection, electricity power and aviation obstruction light status, especially when it is not working at the time it was supposed to be ON

Tower Monitoring and Control





Conclusion

The study aims to contribute to monitoring and controlling with real-time intervention and alert byESP32, fire, BH1750, LDR, PZEM-004t, and GSM, the system was able to control all assigned parameters. The developed system proved that the system can extinguish fire, control aviation obstruction, and regulate the power.