College of Science and Technology

AFRICAN CENTER OF EXCELLENCE IN INTERNET OF THINGS

Research Thesis Title:

IOT MONITORING AND CONTROL SYSTEM OF DISTRIBUTION TRANSFORMERS IN RWANDA

A dissertation submitted in partial fulfilment of the requirements for the award of masters of science degree in internet of things: Embedded computing system

Submitted By:

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December, 2022

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Supervised by:

- Dr Philibert Nsengiyumva
- Dr Said R. Ngoga

December, 2022

DECLARATION

I Emmanuel BIMENYIMANA, Master 'student from African Center of Excellence in internet of things, at University of Rwanda. I declare that this research thesis is my own original work and it has never been presented before anywhere in the world.

Emmanuel BIMENYIMANA

Ref: 219014809

Signed: 

Date: 27/11/2022

BONAFIDE CERTIFICATE

This is to certify that this submitted Research Thesis work report is a record of the original work done by Emmanuel BIMENYIMANA (**Ref. Nu: 219014809**), MSc. IoT-ECS Student at the University of Rwanda / College of Science and Technology / African Center of Excellence in Internet of Things, the Academic year 2020/2022.

This work has been submitted under the supervision of Dr Philibert Nsengiyumva and Dr Said R. Ngoga.

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In a nutshell, my special thanks are addressed to my family, friends and classmates who have always been there for me offering encouragement and other necessary support. I will always be grateful to God for his favor. You have been a constant source of inspiration

ABSTRACT

In developing countries many customers do not get good quality of electricity power supply; frequent and prolonged power fluctuations/cuts usually disturb them. Distribution transformer (DT) is a service transformer that provides the final voltage transformation in the electric power distribution system, stepping down the voltage to the level used by the customers. Monitoring and control of DT (as a crucial and expensive asset in the network) is a key enabler of power stability to consumers. A power utility is said to be a business oriented with good image representation if it delivers a reliable and available electricity. Modern technologies such as the Internet of Things (IoT) offer a wide range of applications in the energy sector to smoothly monitor, control and optimize processes. Currently, Electricity Company in Rwanda is not yet implementing the remote system to control and monitor the secondary side of DTs and timely get the notifications of fluctuations/abnormalities occurred on those DTs. That's why it is still challenging and time consuming to intervene urgently and do the necessary actions to prevent severe power cuts/fluctuations and safeguard the damage of DT itself with customer's appliances connected on that DT. The secondary side of DT is the one connected directly and supply power to customers. For this reason, we developed an IoT system that automatically detects the abnormalities/fluctuations of three technical parameters of DT (voltage, current and temperature) and vandalism of DT equipment. Once one or all of those technical parameters become abnormal, the system cut off automatically the secondary side of DT and isolate the customers load in 2 seconds, and sends the corresponding short message service (sms) to the authorized person in 5 seconds. In case of movements around the DT (related to vandalism); PIR sensor detects the human motion then camera takes a picture to be sent to the utility with a corresponding sms. In addition, a Buzzer gives an alert warning on the site. If there is no abnormality detected, the system keeps sensing without sending the data to the cloud. This system is also built using current sensors, voltage sensors, and temperature sensor with ATmega 328P Microcontroller to collect and process data from sensors connected to DT system. GSM/GPRS module uploads all the data sensed to the cloud storage and displays them on web application and also sends sms to authorized person. Once there is abnormality, the power relay cut off automatically the secondary side of DT and it can be reclosed remotely to test if the fault has been cleared. This system is powered using a rechargeable battery. A web-based application was developed using PHP, HTML, CSS, and Java Script as the user interface for information visualization. The database for storing sensed data was developed using Mysql and this application was hosted to Afriregister Rwanda. This IoT system is designed to maximize efficiency in operations and maintenance, safeguard the DT itself and customers appliances connected on that DT. It prevents as well the vandalism of DT equipment.

Keywords: Internet of Things (IoT), distribution transformer, current, voltage, temperature

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LIST OF ACRONYMS

IoT: Internet of things

DT: Distribution Transformer

GSM: Global System for Mobiles

GPRS: General Packet Radio Services

REG: Rwanda Energy Group

EUCL: Energy Utility Corporation Limited

EDCL: Energy Development Corporation Limited

LTD: Limited

LV: Low voltage

MV: Medium voltage

AC: alternating current

DC: Direct current

TDMA: Time Division Multiple Access

LCD: Liquid Crystal Display

GDP: Gross Domestic Product.

MCU: Microcontroller unit

PHP: Hypertext Preprocessor

HTML: HyperText Markup Language

CSS: Cascading Style Sheets

SQL: Structured Query Language

SMS: Short Message Service

KPIs: Key Performance Indicators

SAIDI: System Average Interruption Duration Index

SAIFI: System Average Interruption Frequency Index

EEPROM: Electrically Erasable Programmable Read-Only Memory

RTU: Remote Terminal Unit

CHAPTER 1: GENERAL INTRODUCTION

1.1 INTRODUCTION

Nowadays, electricity plays an important role in serving power to users in different domains like industry, education, hospital, commerce, residence, telecommunication, etc. and this improves the welfare of citizens and socio-economic development such as GDP, life expectancy, literacy and levels of employment**.** Distribution transformer (DT) [1] is a key asset in the electricity network responsible for supplying the final voltage transformation by stepping down the voltage to the level used by customers connected on it.

Fluctuations/abnormalities of current, voltage and temperature on secondary side (low voltage output side) of DT cause short circuit/over current, overload, over voltage, under voltage and overheat hence the impact of frequent power cuts, on and off, dim electricity supply, voltage fluctuations that damage customer's appliances/equipment and defective of DT. Using IoT Monitoring and Control System of DT [2] is important since it may improves the reliability and efficiency of electricity service delivery by timely interventions and safeguarding the DT itself with appliances/equipment of customers connected on that DT due to abnormalities originated on the secondary side of DT. This system may prevents as well the vandalism of DT equipment.

1.2 BACKGROUND AND MOTIVATION

REG (Rwanda Energy Group) [3] is a holding company in charge of energy in Rwanda.
It has a role to supervise and monitor its two subsidiary companies, EDCL (Energy Development Corporation Ltd) and EUCL (Energy Utility Corporation Limited). These two subsidiaries are the ones that deal with operations and services. EDCL deals mainly with development projects while EUCL is the one that does the commercial activities and maintenance. When customers have electricity issues, EUCL is the one that intervenes.
Electrical distribution system [4] is the final stage in the delivery of electricity to end users. The distribution system's network carries electricity from the transmission system and delivers it to consumers. Step-down distribution transformers are used to bring the voltage levels down to consumers. REG serves electricity to both residential, non-residential, business consumers and productive users through distribution transformers [5].

A need to maintain, upgrade and keep sustainability of distribution transformers (as key assets in the distribution network system) [6] is much recommended in order to have a stable network and keep supplying reliable power to consumers. That is why real time monitoring and control of distribution transformers is required to have timely key needed information or data of technical parameters (voltage, current, temperature) of distribution transformers for improving efficiency, reliability, availability, safety and security of power supply to consumers with further decision-making.

Normally the allowed operating limits of technical parameters (current, voltage and temperature) of distribution transformers are written on their nameplates depending on their type and capacity. Going beyond those operating limits means that there is abnormality or faults exerted on distribution transformer. Figure 1.1 shows a sample nameplate of a transformer.

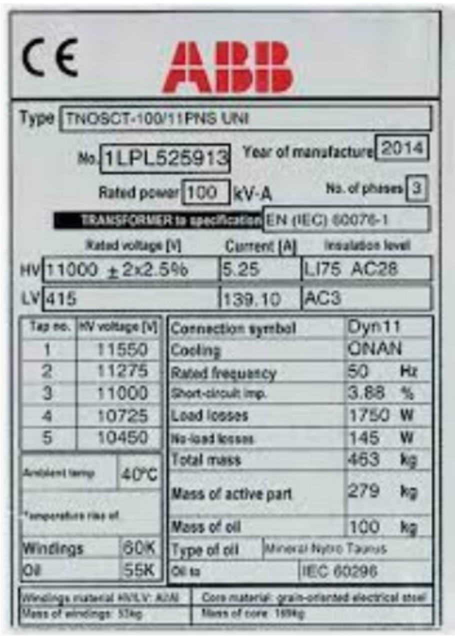


Figure 1. 1 Sample of nameplate for a transformer.

1.2.1 FREQUENT FLUCTUATIONS/ABNORMALITIES OCCURRED ON SECONDARY SIDE OF DT

Frequent faults or anomalies happening on secondary side of DT are [7][8][9]: short circuit/over current, overload, over voltage, under voltage and over heat.

The voltage fluctuation: Over voltage or under voltage can damage the customer's appliance (loads) and the distribution transformer itself.

Sometimes voltage fluctuation can be a technical issue coming from the power generation and/or transmission sides where they can send to distribution side (it means distribution transformers) a voltage which is out of admissible range/limits due to inappropriate voltage regulation. In that time, the distribution transformer output (secondary side/low voltage) will also send to consumers the abnormal voltage (out of admissible range/limits) and damage consumer's appliances (loads) as the secondary side of the distribution transformer is connected to consumer's side (loads). The voltage fluctuation can also be originated from internal misbehavior of components making a distribution transformer like transformer ratio failure. Lightning strikes applied to distribution transformer (with inefficient protection against lightning) can also be a root cause of overvoltage on distribution transformer since lightning strikes produce excessive electric charges which will be added to the existing electric charges (voltage) of a distribution transformer.

The over current: It is another fault which damages a lot the consumer's appliances and transformer itself. The root cause can be a short circuit (contact between two lines/phases or between line/phase and ground/neutral) from secondary side systems of a distribution transformer. Internal misbehavior of the distribution transformer are for example poor/degradation properties of insulating oil, low/excessive reduction of oil level, short circuit between turns or windings, etc. This over current issue can also be observed when a distribution transformer is overloaded, meaning that the customers/consumer's appliances (loads) connected on the transformer have been increased in numbers or changed with bigger ones in terms of capacity where they exceed the maximum limit of the current of the distribution transformer which is normally written on its nameplate.

The excessive abnormal temperature: It is also a sign of over voltage or over current/overload of a transformer. Normally, there is operating range of temperature a distribution transformer can withstand too in normal condition.

Currently, distribution transformers especially their low voltage sides (outputs), are operated locally. It is not currently implemented on the Rwanda grid to control and monitor remotely the secondary side of DT and timely get the corresponding notification of the fluctuation/abnormality occurred. If this was done, it could increase efficiency in operations hence reduction of power restoration time and safeguarding the DT itself and appliances/equipment of customers connected on that DT.

Even though there are some monitoring smart meters connected on low voltage side (output side) of distribution transformers [10]; they usually only allow manual viewing of loading profile for further decision making which is also time consuming and error prone, thus there is no remote control and monitoring about faults, their notifications and detection of vandalism. Based on loading profile of distribution transformers [11], if there is an overload you can analyze and take a decision of making interchange, prior the transformer is burnt. Voltage can as well be adjusted manually using a tape changer of the transformer[12]. The phase imbalance can be corrected [13]by shifting some clients from one phase to another on the three phase distribution transformers.

The low voltage circuit breakers [14]are used like switches to manually isolate or connect the low voltage side of the distribution transformer to consumer's appliances/equipment (loads) . Circuit breakers protect also distribution transformers against overcurrent (short circuit) and overload from the distribution network systems (load/consumers). On medium voltage (MV) side (primary/input side) [15], there are manual MV fuses with isolator switch or switchgears with MV circuit breakers, which can be operated locally or remotely if supervisory control and data acquisition (SCADA) system is incorporated.

1.3 PROBLEM STATEMENT

The problems below occur due to the use of the present system:

- When there is abnormality of technical parameters (current, voltage, temperature) of distribution transformers, you can't get remotely the corresponding notifications via sms and root cause to speed up the intervention
- You can't control remotely (ON and OFF) the LV side (output side) of the distribution transformers to increase efficiency in operations and maintenance.
- There is no online security monitoring against vandalism on distribution transformers

1.4 STUDY OBJECTIVES

This study is needed to prevent vandalism of DT equipment, get timely corresponding notifications of fluctuation/abnormality happened on secondary side of DT for optimizing efficiency in operations and maintenance hence reduction of power cuts and restoration time with safeguarding the damage of DT itself and customer's appliances/equipment connected on that DT.

1.4.1 GENERAL OBJECTIVE

Design an IoT monitoring and control system of distribution transformers in Rwanda

1.4.2. SPECIFIC OBJECTIVES

The specific objectives of an IoT monitoring and control system of distribution transformers are:

- Remote monitoring of technical parameters (current, voltage, temperature) of distribution transformers
- Automatic notifications via sms of faults happened (abnormalities of technical parameters and movements related to vandalism) on distribution transformers to authorized/responsible persons
- Remote control/switching of distribution transformers on their secondary side (output side) connected to consumer's loads.

1.5 HYPOTHESES

- How do the design of IoT monitoring and control system of distribution transformers in Rwanda?
- How components and devices required on IoT monitoring and control system of distribution transformers will be integrated?
- Which programming used to program the IoT monitoring and control system of distribution transformers to monitor, collect and generate essential technical parameters of distribution transformers, perform analytics to have a real time decision making of what to do in terms of control, protection, quick interventions and avoiding the hazard incidents related to vandalism?

1.6 STUDY SCOPE

This project of IoT monitoring and control system of distribution transformers in Rwanda is implemented in order to help Rwanda Energy Group to monitor, collect and generate essential technical parameters (current, voltage, temperature) on secondary side of distribution transformers. It performs analytics to have a real time decision making of what to do in terms of control, protection, quick interventions and avoiding the hazard incidents related to vandalism especially in City of Kigali for one transformer chosen in the distribution network for the case study. The distribution transformer is located in Kicukiro District, Masaka Sector, Gako Cell and Butangampundu Village in REG Kanombe Branch.

1.7 SIGNIFICANCE OF THE STUDY

The importance of this project is to protect the customer's appliances/equipment and distribution transformers of the utility from the failures and defects caused by the abnormalities of voltage, current, temperature and vandalism acts. The utility will save the cost of replacing/repairing the damaged distribution transformers. The utility sales and customer service delivery will be optimized since the interventions will be done in short period of time after getting the remote notification about any power failure/cut.

1.8 ORGANIZATION OF THE STUDY

The rest of the document is organized as follows; Chapter 2 present the literature review, Chapter 3 outlines the research methodology applied in the study, Chapter 4 presents the system analysis and design, the results and analysis is presented in chapter 5, Chapter 6 gives the conclusion and recommendation.

1.9 CONCLUSION

Currently, distribution transformers are monitored locally and you can't be informed remoted about any faults or incidents/vandalism happened on them and get timely the corresponding notifications to fast intervene and increase efficiency in operations. As we know, Rwanda has put big effort in promoting technology in every corner of the country. In order to support our country in that policy; we thought about implementing an IoT system that will help to monitor human motions on DT, collect and generate essential technical parameters (current, voltage, temperature) of DT and perform analytics to check that those technical parameters are in the accepted range/limits or not as per the DT type and capacity.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, we will have the summary of other related works of IoT monitoring and control system of distribution transformers. We start with a brief description of distribution transformers [16] and then present the other pieces of work related to ours.

2.2 DISTRIBUTION TRANSFORMER

The distribution transformer provides the final voltage transformation in the power grid, stepping down the voltage used in the distribution lines to the customer's level. Figure 2.1 shows an image of a distribution transformer while Figure 2.2 shows the schematic of distribution transformer.

Figure 2. 1 Distribution transformer.

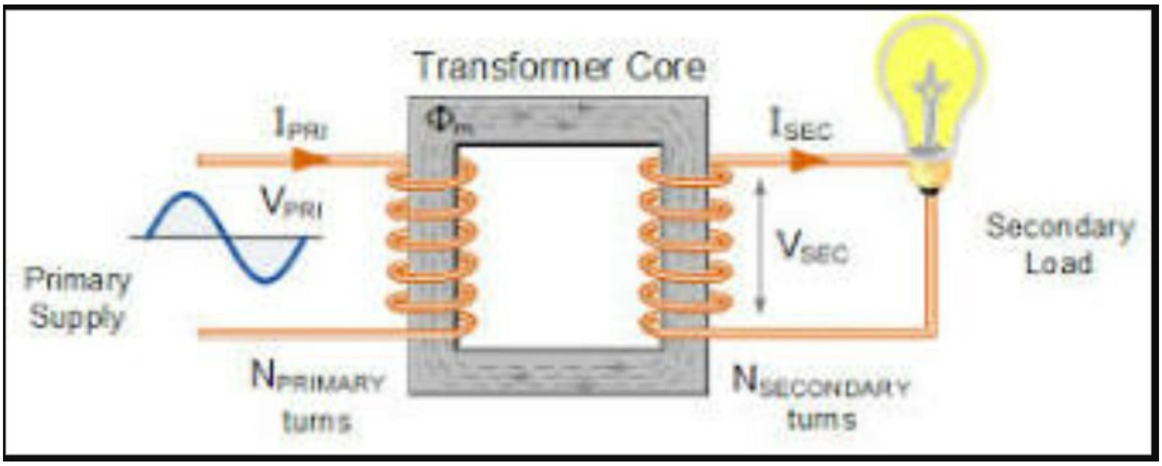


Figure 2. 2 Schematic of a Transformer.

The distribution transformer has four parts: the input connection, the output connection, the windings or coils, and the core.

a. Input Connections

Figure 2.3 shows input connections of DT. Input connections are also called the primary side because electricity goes into the transformer; it has to be connected to this side.

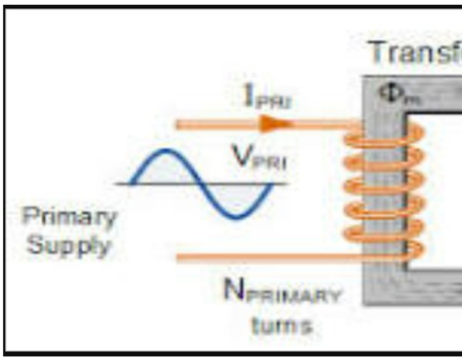


Figure 2. 3 Input connections of DT.

b. Output Connections

Figure 2.4 shows output connections of DT

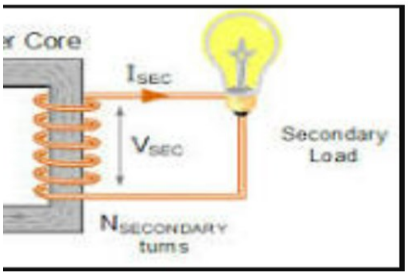



Figure 2. 4 Output connections of DT.

The output side has another name, which is the secondary side of the transformer. On that side, electrical power is sent to the electric device in your house or factories. Usually, the voltage in the transformer's output side (or secondary side) is lower than in the primary side.

c. Winding

Figure 2.5 shows windings of DT

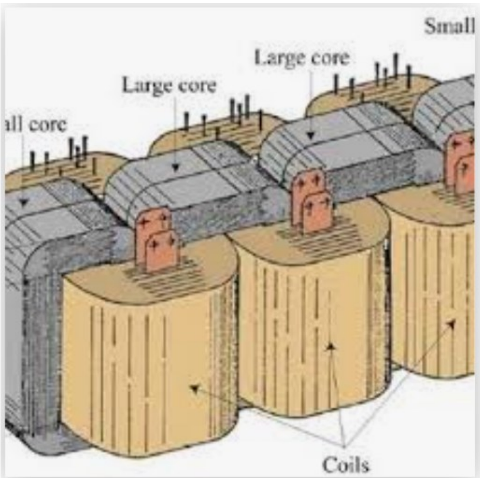


Figure 2. 5 Windings of DT.

All types of transformers have two windings, and the distribution transformer is the same. It is divided into the primary and the secondary winding. The primary one has a function of drawing power from the source. The secondary winding transfers electric power to electrical equipment

d. Core

Figure 2.6 shows core of DT

Figure 2. 6 Core of DT.

The transformer core provides a path that controls the magnetic flux created in the transformer. Typically, the core is not a solid bar of steel. It includes many laminated steel sheets, or layers folded neatly. This design is to eliminate or decrease heating. The transformer's cores have two types used according to your demand: core type and shell type. The main difference of these types is how the primary and secondary coils folded around the steel core.

When the input voltage gets into the primary winding, alternating current starts to flow in this winding. As the current goes through it, a continuously changing and alternating flux is created in the transformer's core. When this magnetic field runs across the secondary winding, a new alternating voltage is formed in that one. The main manor to determine the transformer types and the output voltage [17] is the ratio of actual turns of wire in each coil. Say the number of turns of the primary and secondary winding is N1 and N2, the voltage in the two windings call U1 and U2; we have a formula: $N1/N2 = U1/U2$. If the output winding voltage is higher than the input voltage, then the secondary winding has more wire turns than the primary one. So, the output voltage increased higher, also called "a step-up transformer." Whereas, if the output voltage is less than the input voltage, it's called "a step-down transformer. Usually, a distribution transformer is also a step-down transformer.

Figure 2.7 shows electric power system in phases

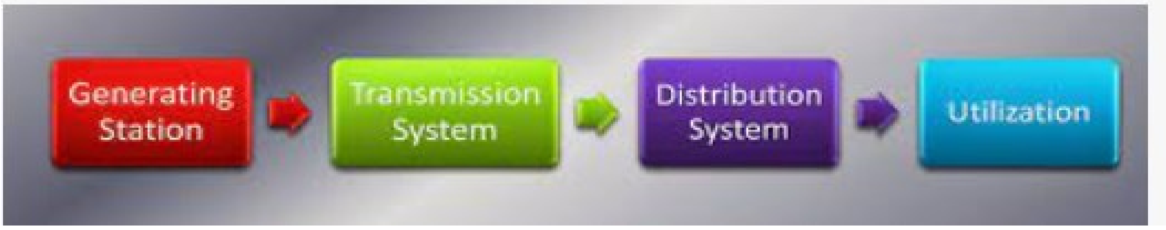


Figure 2. 7 Electric power system in phases.

In electric power system; power is generated by power generation stations, transmitted by transmission network systems and distributed to consumers by distribution network systems. Solar, hydro, wind, gas, etc. are source of energy and using the appropriate generators and associated equipment; you generate the power. Transmission lines and power transformers (step up) compose transmission network systems. Distribution lines and distribution transformers (step down) compose distribution network systems

2.3 RELATED WORKS

There are existing different methods that have been used to monitor and control power systems using IoT. They are focusing on how to collect and generate essential technical parameters, perform their analytics to have a real time decision making of what to do in terms of control, protection, quick interventions and avoiding further incidents.
GSM-Based Distribution Transformer Monitoring System is a conference paper published in 2004 by A.R. Al-Ali, Abdul Khaliq and Mohammad Arshad from School of Engineering, American University of Sharjah [18]. This paper presents the design and implementation of a mobile embedded system to monitor and record key operation indictors of a distribution transformer like load currents, transformer oil and ambient temperatures. The proposed on-line monitoring system integrates a Global Service Mobile (GSM) Modem, with stand alone single chip microcontroller and sensor packages. It is installed at the distribution transformer site and the above-mentioned parameters are recorded using the built-in 8-channel analog to digital converter of the embedded system. The acquired parameters are processed and recorded in the system memory. If there is any abnormality or an emergency situation the system sends SMS (Short Message Service) messages to designated mobile telephones containing information about the abnormality according to some predefined instructions and policies that are stored on the embedded system EEPROM. Also, it sends SMS to a central database via the GSM modem for further

processing. This mobile system will help the utilities to optimally utilize transformers and identify problems before any catastrophic failure.

Kumar et al. [19] proposed methods for live monitoring and fault recognition of intelligent power transformer to ensure the safety and reliability of the power function of a transformer. The important intention was to meet the requirements for the fast measurement and to inspect the parameters like voltage and current of the transformer, temperature of oil, level of oil in the transformer and also frequently check whether there is any spark, flame or smoke and send the alert message accordingly. The system consists of various elements such as voltage sensing instrument, current sensing instrument and temperature sensing instrument and an oil level sensing instrument for monitoring various parameters of a transformer. All of the parameter changes are notified with the help of IOT using Blynk App. An alarm is ON if any changes occur. Current and voltage sensors have been used to monitor voltage and current parameter changes. Arduino UNO was used as well to share all the information to the required person.

Tiago et al. [20] talks about the development and application of overhead transformers of the distribution grid, as well as the different technologies used for the gathering of electrical quantities, in the field of a monitoring solution. The solution reports the values of the quantities and alarms of operation remotely and almost in real-time. The development of this solution seeks to provide an electrical grid with greater reliability, proposing the reduction of KPIs (Key Performance Indicator), such as SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index), through more transparent monitoring of the behavior of the electrical distribution grid and its equipment. The data generated by the RTU are sent to the modem, which in turn sends to the Cloud service. Seljeseth, Helge[21] talks about the overvoltage immunity of electrical appliances laboratory test results from 60 appliances.

Road, Outer Ring[22] presented how any damages in transformers adversely affects the balance of a power system. The damages are mainly occurring due to overloading and inefficient cooling, hence the main objective of the real time monitoring of the health conditions of the distribution transformer using IOT technology.

Roy, Pallavi Misra, Pritam Saharia, Paramananda Sarma, Rituraj Pathak, Santanu [23] discussed how to acquire real-time data of transformer remotely over the internet falling under the category of Internet of Things (IOT). For this real-time aspect, they take one temperature sensor, one potential transformer and one current transformer for monitoring temperature, voltage and current data of the transformer and then send them to a remote location. Mali Dnyaneshwar Jadhav, Vinod A Dethe, Kajal P Shivpuje, Dhananjay B [24] talked about how to protect transformer against different types of faults. Various methods get used. In this system, overload protection is established for protection of transformer. Relay connected to the microcontroller is used to protect transformer. Mrs. A. P. Khandait Swapnil Kadaskar Girish Thakare [25] in their work presented the design and execution of real time monitoring and fault detection of transformer and record key operation indictors of a dispersion transformer like load current, voltage, transformer oil and encompassing temperatures and humidity. Monika Thakor, Hardik Shah, Yash Shah, Parmar Bhavin, Hitarth Joshi [26]. The aim of the project is to design a IOT based smart transformer monitoring and control system. The system would also provide the real-time monitoring of the parameters of the transformer like voltage, current, temperature etc on the android device and personal computers and get notifications in the cases of faults. Mahanta, Deba Kumar Rahman, Iftikar [27] presented the main objective of the real time monitoring of the health conditions of the distribution transformer using IOT technology. The parameters such as temperature, voltage, current, and oil level of a transformer are monitored, processed and recorded in servers. This helps in identifying human dependency, and solving a problem before a failure without human monitoring. Kore, Pustaraj Ambare, Vrushabh Dalne, Avinash Amane, Ganesh Kapse, Shubham [28] presented the system designed based upon online monitoring of key Operational parameters of distribution transformers that can provide useful Information about the health of transformers which will help the utilities to optimally use their transformers and keep the asset in operation for a longer period. Dwarakesh, K Jeyasekar, C Engineering, Electronics [29]. This paper is about design and implementation of low-cost remote monitoring of distribution transformer's key parameters like current, voltage, oil level, oil temperature and winding temperature with remote recording of consumer's energy consumption, load shedding of non-vital consumers during overload / cold load pickup period, energy theft detection in the distribution network and alerting during un-balanced load conditions. The parameters are sent to the IoT cloud and concern maintenance engineer will be alerted during energy theft and for any abnormal conditions using a dedicated mobile app. Shaikh, Abrar Nannewar, Payal Mangate, Diksha Gajapure, Rupali Tirpude, Swinal [30] talked about the remote monitoring of transformer health over internet system is. Also it proposed to send the central database via Wi-Fi module for further process. The real time monitoring system consist of embedded system. Wi-Fi and sensors are installed at transformer site which reads and measure the physical quantity from the distribution transformer and further it converts into the analog signal.

2.3 GAPS

From the existing implemented technics and as per the reviewed literatures; there is live DT monitoring and fault recognition to control the availability of power supply. However, there is not an IoT solution to immediately detect and safeguard the customer's load and DT itself from fluctuations/anomalies originating on the secondary side of DT and there is not remote reclosing for testing if the issue on secondary side of DT has been fixed to reduce power restoration time with related losses. In addition, there is not monitoring and prevention of vandalism where those malpractices are nowadays becoming enormous and affect the good service delivery, standards, safety and revenues.

2.4 PROPOSED SYSTEM

The developed system performs fast measurement and inspection of three technical parameters of DT (voltage, current and temperature), then sends the alert message when there is abnormality, cuts of the secondary side of DT to safeguard DT itself with customer's equipment. It detects also the vandalism of DT equipment by generating audio signaling (buzzer) when there is a disturbing movement in the DT compound and sends the related picture to the utility with the corresponding sms.

2.5 SUMMARY OF WEAKNESSES IDENTIFICATION AND OUR SCIENTIFIC CONTRIBUTION

Based on related work, Monitoring and Control of DTs systems have been created using different technologies as cited in the related works above. However, weaknesses have been identified and, through this research, a scientific and technological contribution is made to reinforce the system in a perfect way as shown in the Table 1.1Key research papers and gaps identified.

S/N	Author	Title	Description	Gap	Mitigation
1	Al-Ali, Abdul Rahman Khaliq, Abdul Arshad, Muhammad	GSM-based distribution transformer monitoring system	mobile embedded system to monitor and record key operation indictors of a distribution	-Voltage fluctuations were not monitored. -No action to safeguard DT -No vandalism detected	-Voltage was controlled -switch on/off remotely -Send notifications about sensed movements
2	Kumar, R Krishna Thilagaraj, M Vengatesh, P Rajalakshmi, J Mohamed, M I Farsin, Babul Nandhini, K	Remote Transformer Faults Analyzing System using IoT	Fast measurement and inspection of voltage and current of the transformer, temperature of oil, level of oil in the transformer	-No action to safeguard DT and customer loads -No vandalism detected	-Switch on/off remotely -Motion detector sends the notifications about sensed movements
3	Roy, Pallavi Misra, Pritam Saharia, Paramananda Sarma, Rituraj Pathak, Santanu	A Study of Remote Monitoring of a Transformer using IoT	Acquire real-time data of transformer remotely over the internet falling under the category of Internet of Things	-No theft detection -No remote switching of DT and buzzer	-ESP cam was used to take related pictures - Interfaces for remote action on DT and buzzer were provided
4	Monika Thakor, Hardik Shah,	IRJET- IoT based Smart Transformer	Real-time monitoring of the parameters of the	-No human malpractices	-Movements were controlled

	Yash Shah, Parmar Bhavin, Hitarth Joshi	Monitoring and its Control	transformer like voltage, current, temperature etc on the android device and personal computers	on DT detected -No remote reclosing of DT	-Remote operations of DT were provided
5	Dwarakesh, K Jeyasekar, C Engineering, Electronics	Low-cost Remote Monitoring of Distribution Transformer with Consumer wise Energy recording , Load control & Power theft detection using Internet of Things	Remote monitoring of distribution transformer's key parameters	-Site alarm when there are prohibited access -Remote operation of DT	-Site access was monitored and controlled -Distant action on DT with the help of NodeMcu

Table 1. 1 Key research papers and gaps identified.

CHAPTER 3: RESEARCH METHODOLOGY

The systematic process of conducting this project was:

- Problem definition: Understanding the situation and gaps to be addressed

- Project planning and gathering information: Addressing how to complete a project in a certain timeframe, usually with defined stages and designated resources

- Field study: For feasibility analysis and requirements specifications

- Design conception: The core idea driving the design of a product, explained via a collection of sketches, images, and a written statement. Translates the requirements specifications into the model

- Coding and Implementation of the prototype: Creation of the actual prototype

The primary research method for monitoring and control system of distribution transformers is literature review and theoretical modeling. For literature review, we used the survey of scholarly sources on a specific topic that provided an overview of current knowledge and systems, allowing us to identify relevant theories, methods, and gaps in the existing system for monitoring and control of distribution transformers. Theoretical frameworks were often used to define concepts and explained phenomena of this system like working system of transformer, sensor, microcontrollers, gateway device and other related to this IoT system.

For the implementation, we used literature review model and theoretical modeling in order to implement this monitoring and control system of distribution transformers.

The first step was to connect calibrated sensors (current, voltage and temperature sensors) to the transformer. it means all sensors measure real value and send data to microcontroller. Then collected data were processed by microcontroller and uploaded to the cloud storage for further analysis. The system makes data analysis according to real time data collected on transformer and once the abnormality is found, the system cut off automatically the secondary side of DT and isolate the customers load in 2 seconds and send notifications to authorized person in 5 seconds. In case of movements around the DT (related to vandalism); the related sms is sent, the picture is taken and sent to the cloud and siren/buzzer makes loud noise. If there is no abnormality detected, the system keeps sensing without sending the data to the cloud.

Normally the allowed operating limits of technical parameters (current, voltage and temperature) of DTs are written on their nameplates depending on their type and capacity. Going beyond those operating limits means that there is abnormality/fluctuations or faults exerted on distribution transformer.

The admissible nominal voltage range between line/phase and neutral (L-N) on secondary side (low voltage) of distribution transformers is 230Volts ± 5% (218.5 volts- 241.5volts), while is 400volts ±5% (380volts-420volts) between two different lines/phases (L1-L2; L1-L3; L2-L3).

The maximum current depends on the transformer capacity. For example, a distribution transformer with capacity of 250KVA (kilo volts Amperes) as rated power, operating on medium voltage (input/primary side) of 15KV (kilo volts) has a maximum current of 400 Amperes on secondary side while a 100KVA, 15KV distribution transformer has a maximum current of 160 Amperes on secondary side.

The temperature rise depends on the type of transformer and it is written on its nameplate. For example, dry-type transformers are available in three standard temperature rises: 80ºC, 115ºC, or 150ºC. Liquid-filled transformers come in standard rises of 55ºC and 65ºC. These values are based on a maximum ambient temperature of 40ºC.

The sampling rate or frequency for sensing technical parameters data (current, voltage, temperature) and taking action of cutting off the secondary side of DT when there is anomaly is in 2 seconds for protecting the customer's loads and avoid the damage of DT itself. Sending the corresponding notification to the cloud and authorized person is in 5 seconds. If there is no abnormality detected, the system keeps sensing without sending the data to the cloud.

3.1 SYSTEMATIC PROCESS

The system of monitoring and control of distribution transformers identifies and acts clearly on the problem of monitoring and controlling daily working of distribution transformer problems: short circuit, overload, over voltage, under voltage, vandalism that may be caused by destruction or theft of electricity infrastructures.

All data on distribution transformer parameters such as working temperature, voltage, current, and motion detected are monitored.

The implemented system gives the following solutions:

- When there are unconditional faults, the authorized electrical engineer gets notifications from the system.

- The system is able to cut-off transformer automatically, when there is a fault in order to protect loads of consumers

- For security issues, we have surveillance cameras and motion sensor. *S*ystem takes photos automatically when there is someone moving around the transformer in order to protect against theft of electricity infrastructures and we have alarm system to let the offender be intimidated and inform neighborhood whenever there is an emergency.

- The system takes decision automatically according to data we have and it is done by analyzing real time data

- Authorized person in control station has ability to turn ON/OFF without reaching where transformer is.

- Authorized person in control station will able to monitor all different transformers in different location by using transformer ID.
- System generates report and graphs of monitored data.

IoT monitoring and control system of distribution transformers comprises of two subsections, which are hardware part and software part. This research was concerned with three major issues: Effective measurement of electrical power parameters, Monitoring, Control, Ease of access and data analysis.

I. **Effective measurement of electrical power parameters:** The designed system has the sensor module that includes current sensors, voltage sensors and temperature sensor. These sensors are connected to a microcontroller and are used for detecting any abnormalities of technical parameters of the transformer, which are current, voltage and temperature.

II. **Monitoring:** The sensor data is real time monitoring using the hosted website.

III. **Control:** Based on the sensor data and threshold values our transformer can be controlled remotely.

IV. **Ease of access:** the data can be effectively accessed using the cloud, it can be observed and controlled using the web application, and when a fault occurred on distribution transformer; the system send a sms notification to an authorized person. Alarm can be on when there is a motion detected in the surrounding area of the distribution transformer.

V. **Data analysis:** The purpose of this data analysis is to extract useful information from data collected in different sensors and take the decision based upon the data analysis.

CHAPTER 4: SYSTEM ANALYSIS AND DESIGN

4.1 SYSTEM DESIGN

The developed IoT system automatically detects three technical parameters of DT (voltage, current and temperature) and checks if they are in the admissible operating limits. Once one or all of those technical parameters are becoming abnormal, the system cut off automatically the secondary side of DT and isolate the customers load in 2 seconds, and sends the corresponding short message service (sms) to the authorized person in 5 seconds. PIR sensor detects motion when there is vandalism of DT equipment and , ESP 32 CAM (camera) takes a picture to be sent to the utility with a corresponding sms. A buzzer gives an alert warning on the site as well. If there is no abnormality detected, the system keeps sensing without sending the data to the cloud.

The system has four modules, which are: power module, sensors (input) module, controller module, output module. It is built using current sensors, voltage sensors, and temperature sensor with ATMEGA 328P Microcontroller to collect and process data from sensors connected to DT system. GSM/GPRS module uploads all the data sensed to the cloud storage, displays them on web application and sends sms to authorized persons. Relay cut off automatically the secondary side of DT and it can be reclosed remotely. A web-based application was developed using PHP, HTML, CSS, and Java Script as the user interface for information visualization. The database for storing sensed data was developed using Mysql and this application was hosted to Afriregister Rwanda. This IoT system will be powered by rechargeable battery where the main supply from DT charges the batteries.

4.1.1 BLOCK DIAGRAM

Figure 4.1 shows the block diagram of the developed system.

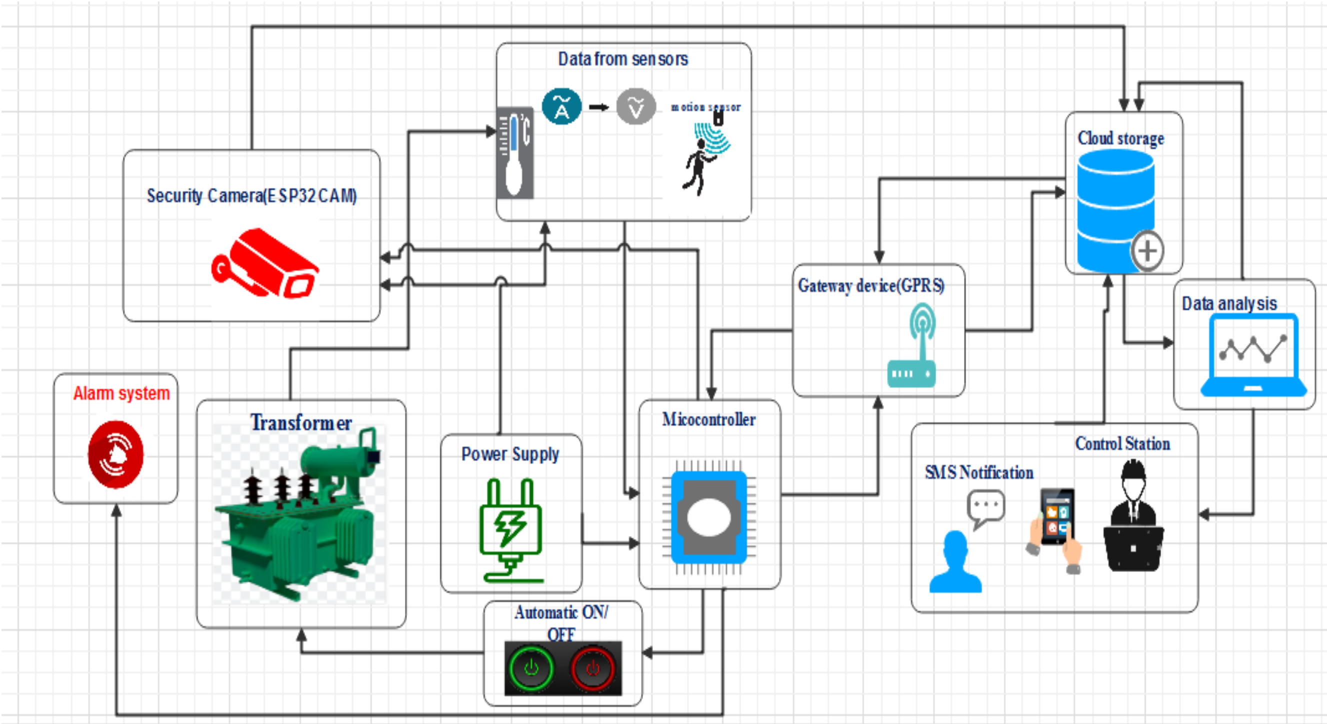


Figure 4. 1 Block diagram of the developed system.

In case of movements around the DT (related to vandalism); PIR sensor detects the human motion then camera takes a picture to be sent to the utility with a corresponding sms. In addition, a Buzzer gives an alert warning on the site. If there is no abnormality detected, the system keeps sensing without sending the data to the cloud. This system is also built using current sensors, voltage sensors, and temperature sensor with ATmega 328P Microcontroller to collect and process data from sensors connected to DT system. GSM/GPRS module uploads all the data sensed to the cloud storage and displays them on web application and also sends sms to authorized person. Once there is abnormality, the power relay cut off automatically the secondary side of DT and it can be reclosed remotely to test if the fault has been cleared. This system is powered using a rechargeable battery. A web-based application was developed using PHP, HTML, CSS, and Java Script as the user interface for information visualization. The database for storing sensed data was developed using Mysql and this application was hosted to Afriregister Rwanda

4.1.2 COMPONENTS/MODULES USED

Table 4.1 shows the main Components/Modules used

S/N	Component/ Modules	Usage
1	Power module	The power module has a rectifier as AC to DC converter and battery power bank. The battery is used to keep constant power supply when there is no main power. A power supply is there to give the capacity to scale sensor and controller modules
2	Sensor module	The sensor module comprises by current sensors, voltage sensors, waterproofed temperature sensor and PIR sensor. These sensors are connected to a microcontroller as input part and are used for detecting the power utility parameters from time to time.
3	Controller module	Microcontroller is considered as brain of this architecture, GSM and Wifi module as gateway devices. This control unit provides a bridge for data to travel across mobile networks and the Internet
4	Output module	Monitoring and control system of DTs has web application as the first output part by using mobile phone, tablet or computers. The authorized person in control station will receive SMS notifications and collected data. The second output part is camera module that will be used for taking pictures if movements are around. The third part is alarm system/buzzer to make loud noise when movements (vandalism) are occurred on the transformer. The last ones are actuators to isolate the load/consumers from the secondary side of DT if faults occur and buzzer. Those actuators are relays. They can be also used to reconnect back the buzzer and the loads/customers to the transformer.
5	Storage module	we have clouds storage as server, it is a service model in which data is transmitted and stored on remote storage systems before and after data analysis, where it is maintained, managed, backed up and made available to users over a network, and it will store

		all data collected and transmitted by GSM/GPRS and Wifi module

Table 4. 1 Main Components/Modules used.

4.1.3 CIRCUIT DIAGRAM

Circuit diagram in Figure 4.2 shows the real connection of all components of our system.

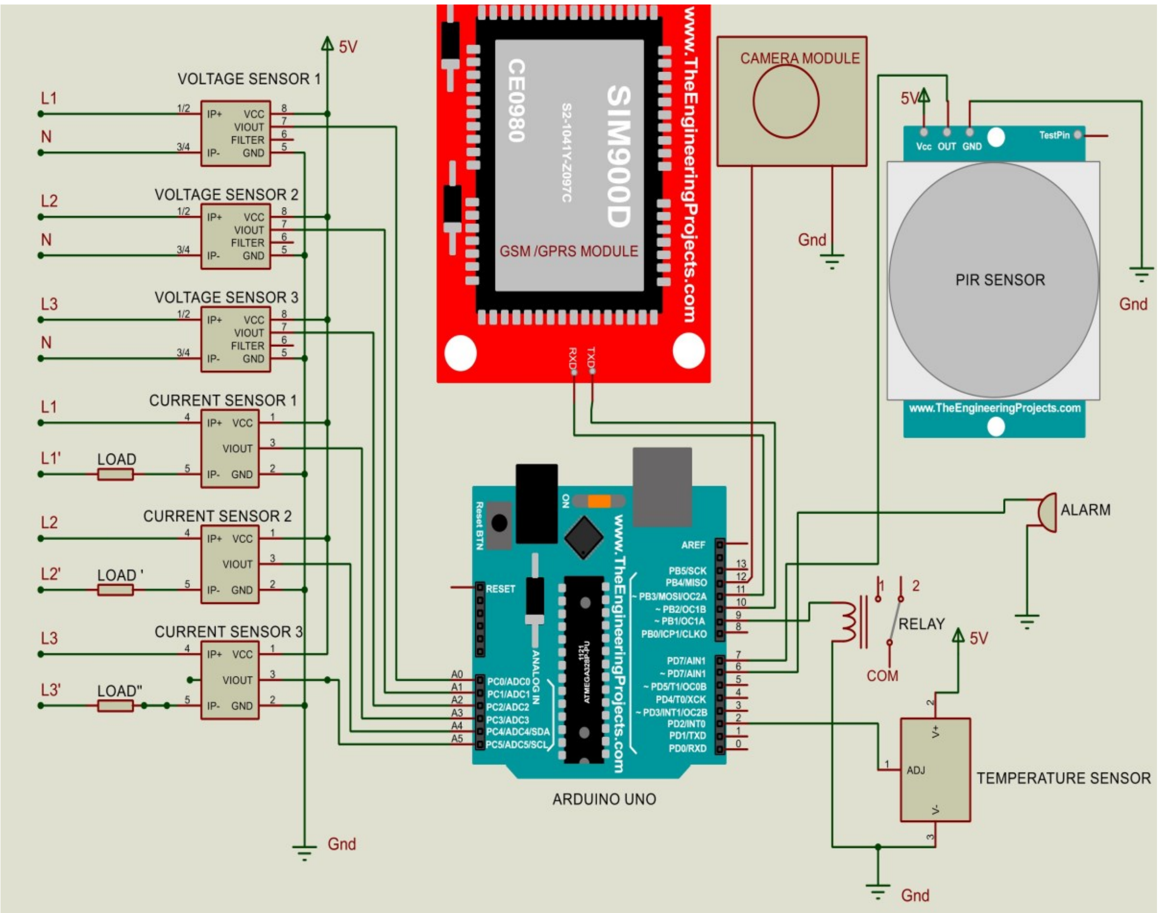


Figure 4. 2 Circuit diagram of IoT monitoring and control system of DT.

Three voltage sensors are supplied by 5volts from power supply and connected to analog pins A0, A1 and A2 of microcontroller respectively to measure the main three phase line voltage of secondary side of DT. Three current sensors are supplied by 5volts from power supply and connected to analog pins A3, A4 and A5 of microcontroller respectively to measure the main three phase line current consumed by customers (load). The temperature sensor is supplied by 5volts from power supply and connected to digital pin 2 of microcontroller to measure the operating temperature of DT. The motion sensor is supplied by 5volts from power supply and its output pin is connected to digital pin 7 of microcontroller to detect any human motion around the DT and activate the camera (connected on output digital pin 12) to take a picture and buzzer alarm (connected on output digital pin 6) will give a sound alert. For abnormal situation, power relay that is connected on output digital pin 9 will cut off automatically the secondary side of DT. All the information will be sent by using GSM/GPRS module that is connected on transmitter pin 10 and receiver pin 11.

4.2 SOFTWARE REQUIREMENTS

To program the hardware system that containing the ATmega 328P microcontroller, sensors, actuators and communication module; we used Arduino IDE environment to write the code and upload it in the microcontroller from personnel computer using universal serial bus cable. Proteus was used to simulate the functionality of each module by sketching the circuit diagram and uploading the written code from Arduino IDE then run to see the result. A web-based application (a user interface for information visualization and control the remote system) was developed using PHP, HTML, CSS, and Java Script programs. The database for storing sensed data was developed using Mysql and this application was hosted to Afriregister Rwanda hosting company. The cloud is http://www.transformer.iot.rw/

4.2.1 FLOWCHART

Figure 4.3 shows the Flowchart of IoT monitoring and control system of DT.
It describes how our system works from the beginning where it starts by initialization and reading data from sensors (current, temperature and voltage). The data read are temporally stored in the memory of microcontroller waiting to be executed. Various calculations are done to verify if the sensed data are in the normal range of thresholds of technical parameters (current, voltage and temperature) set and human motion detection, else the action will be taken to send sms notification, cut off the secondary side of DT and when human motion is detected the picture will be taken and buzzer gives an alert. The operator can cut off or close remotely the buzzer and the secondary side of DT. The process is endless loop.

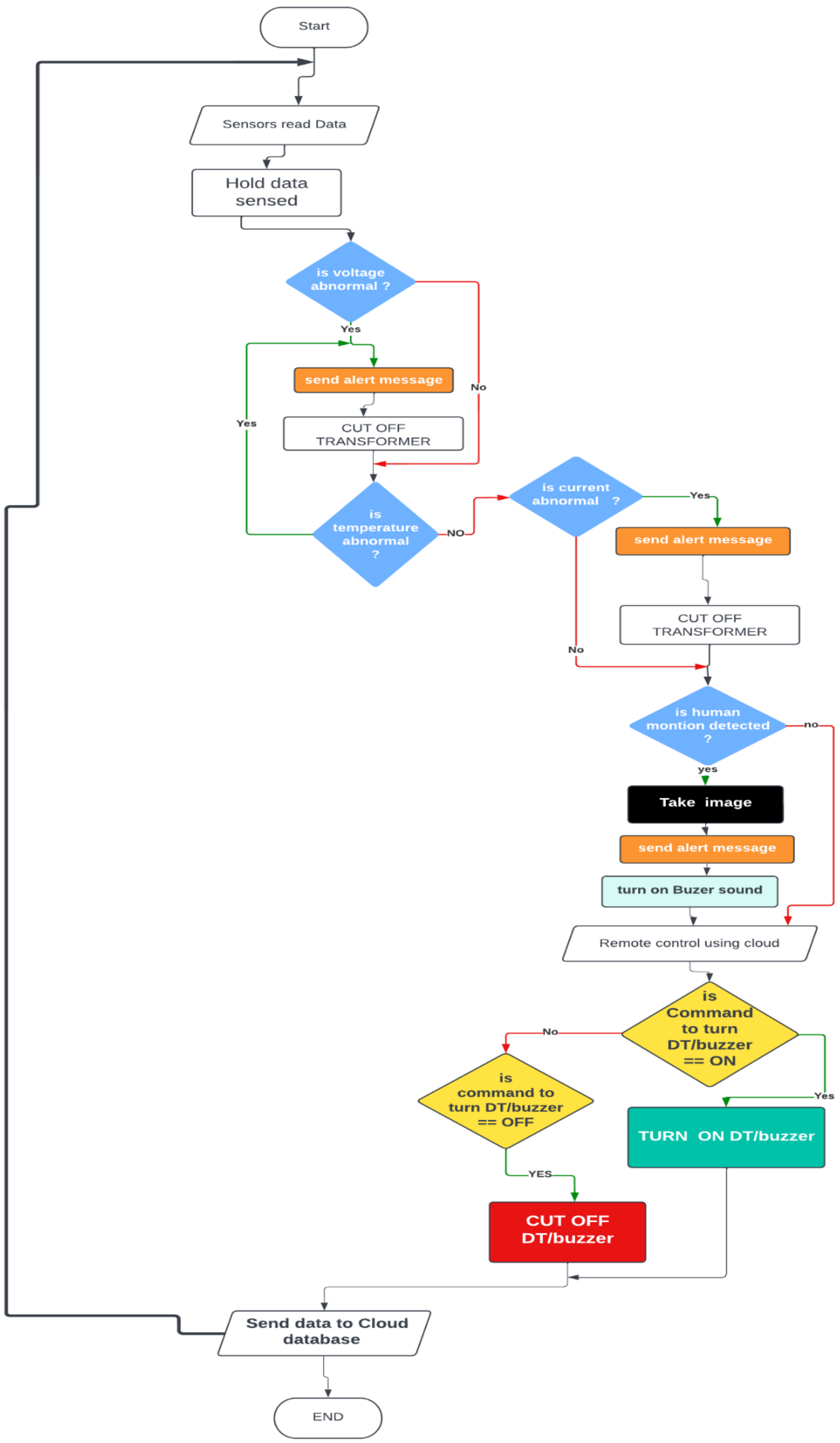


Figure 4. 3 Flowchart of IoT monitoring and control system of DT.

CHAPTER 5: RESULTS AND ANALYSIS

5.1 INTRODUCTION

This chapter describes the implementation of the system prototype, finally displaying the results of the device and rationalization of finding and the graphs of effects.

The system automatically detects the abnormality/fluctuations of three technical parameters of DT (voltage, current and temperature). Once one or all of those technical parameters are becoming abnormal, the system cut off automatically the secondary side of DT and isolate the customers load in 2 seconds, and sends the corresponding short message service (sms) to the authorized person in 5 seconds. PIR sensor detects motion when there is vandalism of DT equipment and camera takes a picture to be sent to the utility with a corresponding sms. A buzzer gives an alert warning on the site as well. If there is no abnormality detected, the system keeps sensing without sending the data to the cloud. This system is also built using current sensors, voltage sensors, temperature sensor with the ATmega 328P microcontroller to collect and process data from sensors connected to DT system. GSM/GPRS module uploads all the data sensed to the cloud storage, displays them on web application and sends sms to authorized persons. Power relay cut off automatically the secondary side of DT and it can be reclosed remotely. A web-based application was developed using PHP, HTML, CSS, and Java Script as the user interface for information visualization. The database for storing sensed data was developed using Mysql and this application was hosted to Afriregister Rwanda.

With the developed system you can detect faults on distribution transformer such as short circuit, overload, over voltage, under voltage, over heat and vandalism/theft of transformer equipment.

This system improves the reliability and efficiency of electricity service delivery by timely interventions and safeguarding the DT itself with appliances/equipment of customers connected on that DT against frequent power cuts/fluctuations, breakdown services that might be originated in electricity distribution network. It prevents as well the vandalism of DT equipment.

5.2 DATA COLLECTION

Sensors, actuators and gateway devices are connected to ATmega 328P microcontroller; the programs' codes were uploaded into the real ATmega 328P microcontroller board hardware (Arduino Uno) using Arduino IDE software.

Figure 5.1 shows uploaded code in ATmega 328P.

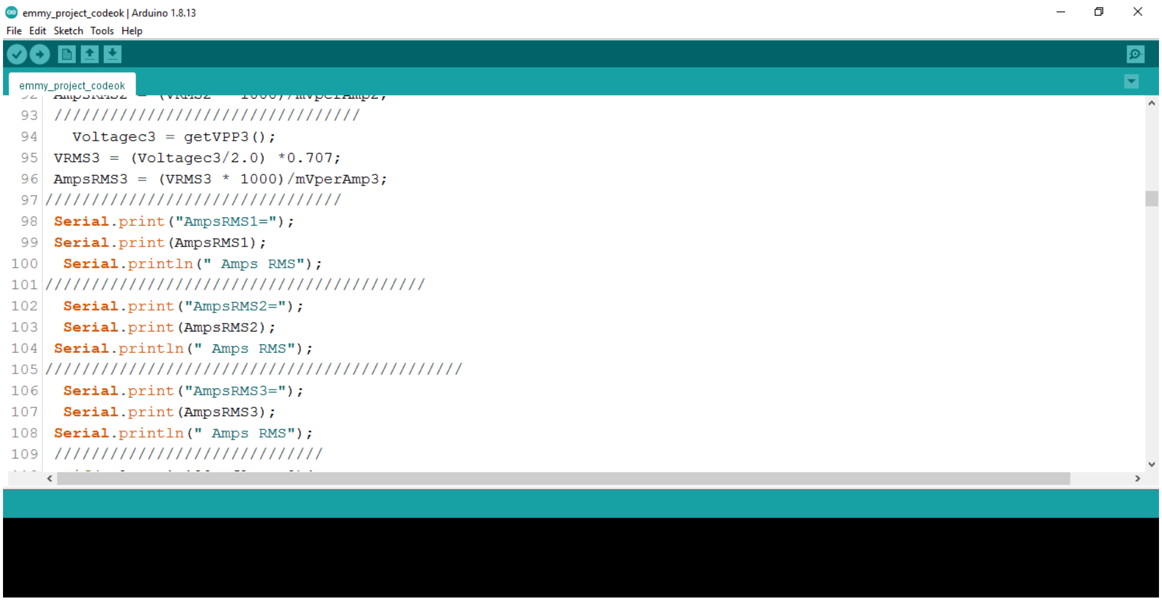


Figure 5. 1 Uploading code in ATmega 328P microcontroller using Arduino IDE.

Figure 5.2 shows the integration of IoT monitoring and control system of DT *components*

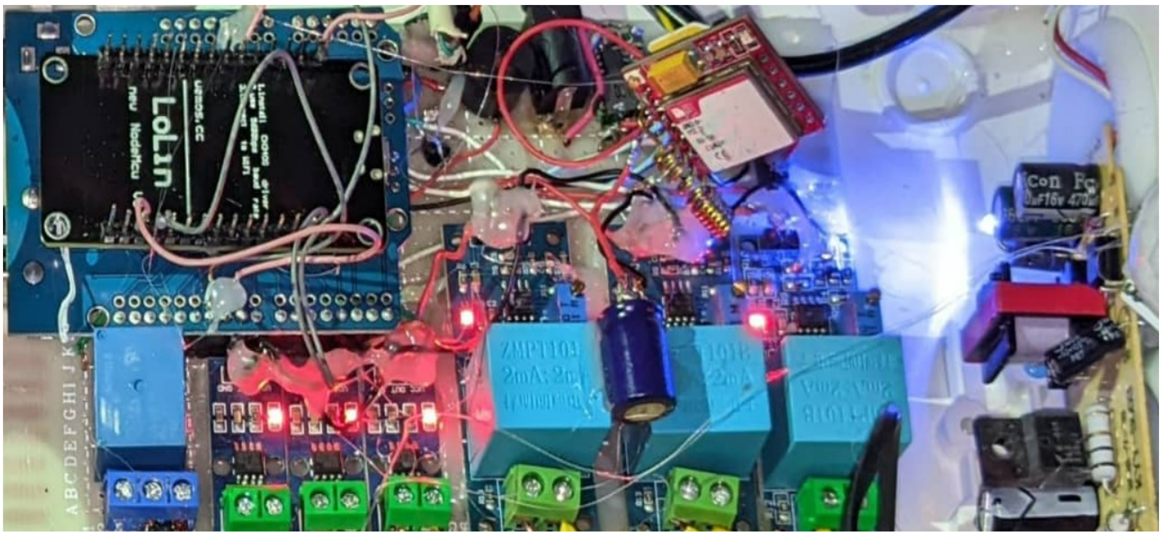


Figure 5. 2 Integration of IoT monitoring and control system of DT components.

5.3 SYSTEM VISUALIZATION

The developed web-based application is used to visualize the transformer information which helps the administrator and the operator to get information about the operations of the transformer. The visualized information is represented in a number of the dashboard and by the graph, which shows the data of the transformer. If there is no abnormality detected, the system keeps sensing without sending the data to the cloud except when the system is initialized and starts to operate for showing the initial status.

This figure 5.3 shows the dashboard used to register in the system the details and technical parameters of DT

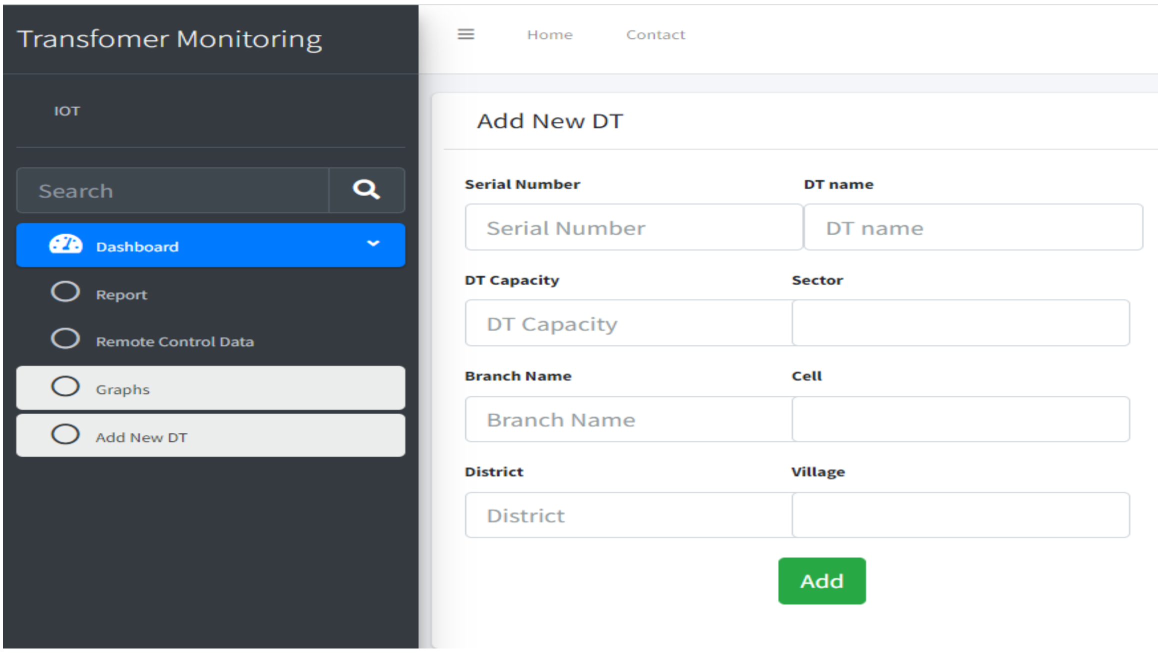


Figure 5. 3 System dashboard for registration

This figure 5.4 shows system dashboard for remote control menu used to switch on/off the secondary side of DT and buzzer.

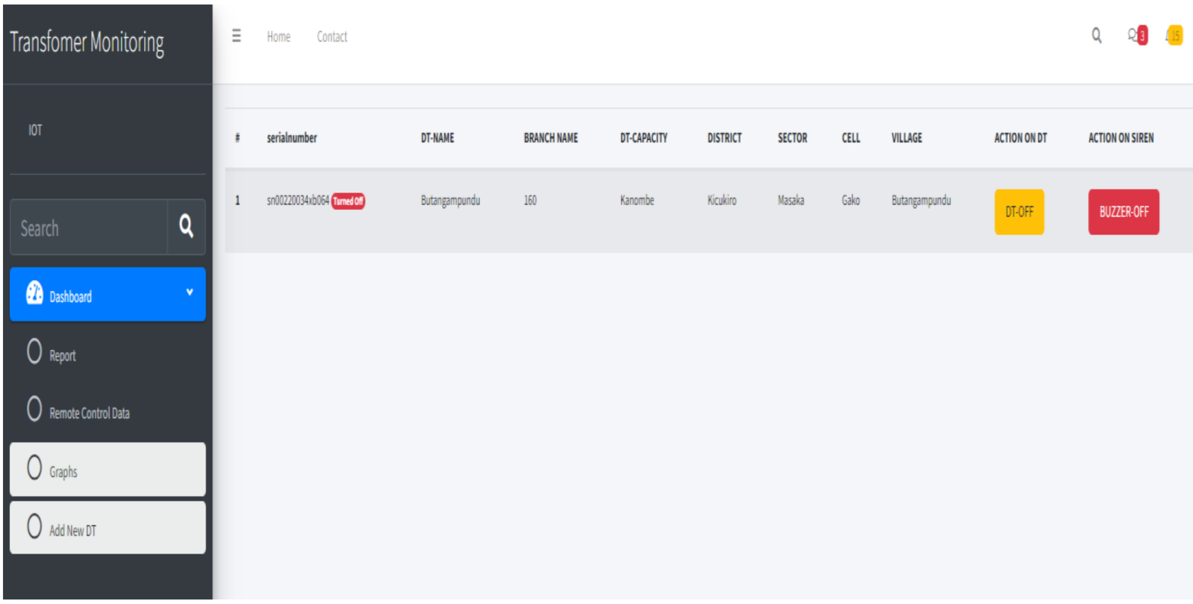


Figure 5. 4 System dashboard for remote control menu.

This figure 5.5 shows system dashboard: graph

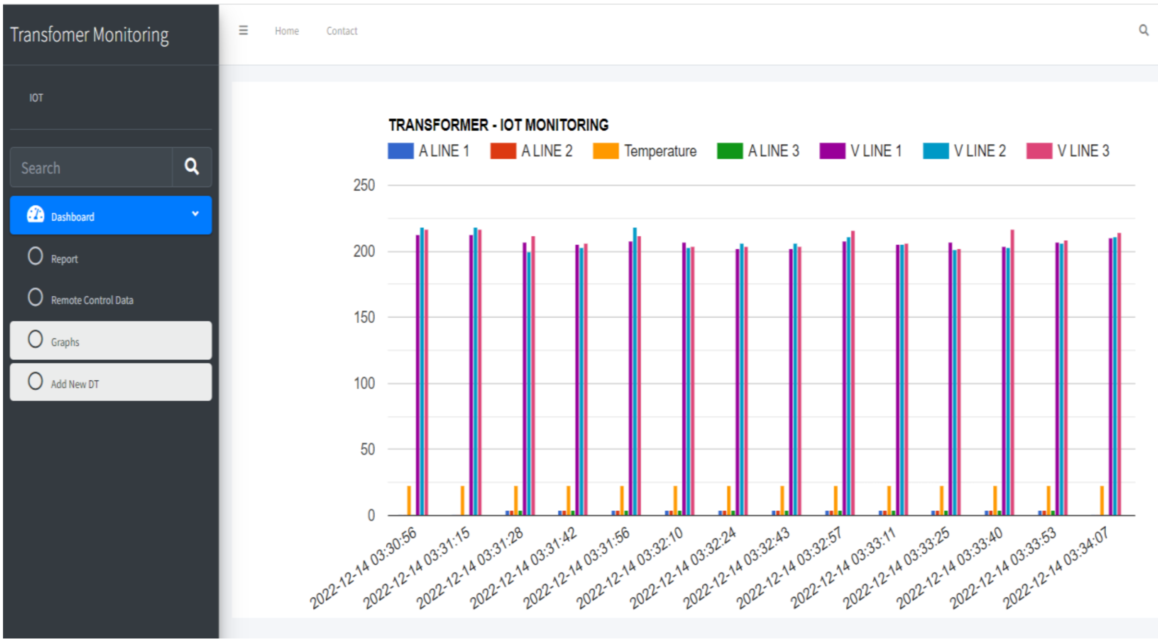


Figure 5. 5 System dashboard for graph.

This figure 5.6 shows system data collected in tabular form.

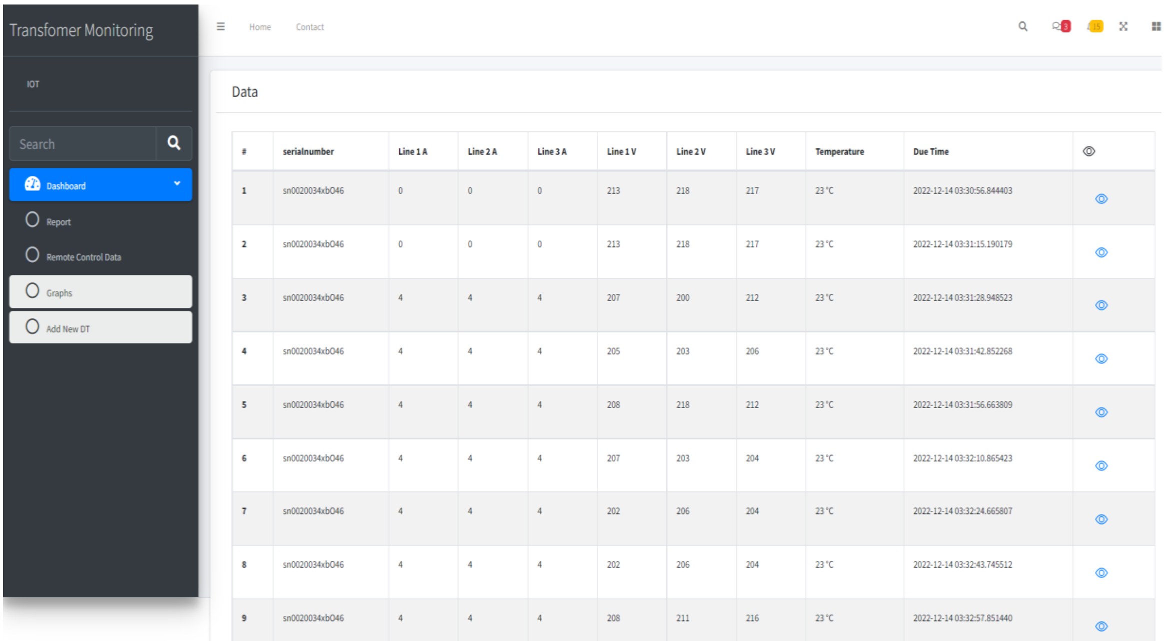


Figure 5. 6 System data in tabular form.

5.4 APPLICATION TESTING OF SENSORS

The project utilized both unit testing and integration testing methodologies to ensure that the prototype device functioned as per the user requirements. The results of test were presented in a scorecard in table layout as illustrated in table 5.1 Application testing of sensors.

S/N	FUNCTION	EXPECTED RESULT	SCORE
Voltage sensor one	Measure voltage of Line one of transformer	Accurately measure the Voltage of Line one of transformer	Pass
Voltage sensor two	Measure voltage of Line two of transformer	Accurately measure the Voltage of Line two of transformer	Pass
Voltage sensor three	Measure voltage of Line three of transformer	Accurately measure the Voltage of Line three of transformer	Pass

Current sensor one	Measure current of Line one of transformer	Accurately measure the current of Line one of transformer	Pass
Current sensor two	Measure Current of Line two of transformer	Accurately measure the Current of Line two of transformer	Pass
Current sensor three	Measure Current of Line three of transformer	Accurately measure the Current of Line three of transformer	Pass
Temperature sensor	Measure Temperature of transformer	Accurately measure the of transformer	Pass
Motion sensor(PIR)	Detect someone around the transformer	Accurately Detect someone around the transformer	Pass

Table 5. 1 Application testing of sensors.

5.5 FIELD TESTING AND DISCUSSIONS

The real distribution transformer (DT) used during testing is a 160KVA, 15KV/0.4KV located in REG Kanombe Branch. It means that its capacity is 160KVA, the input voltage on primary side (medium voltage side) is 15KV=15000volts, the output voltage on secondary side (low voltage side) is 0.4KV=400volts between line and line (L-L) and 230volts between line and neutral (L-N), the maximum current/load on secondary side is 250 Amperes and the maximum temperature rise is 65ºC.

During the tests, REG suggested us to not setting in our system the actual technical parameters (current, voltage and temperature) of DT that are written on the nameplate, instead they suggested to set the minimum threshold values to perform our experiments and see the results without causing DT to go into real abnormal conditions (overload, overheat, overvoltage and under voltage). In additional, our prototype has the current sensors not exceeding 30Amperes of input alternating current, hence the acceptable thresholds we have set in our system for trial are:

-Maximum current: 5Amperes

- Maximum voltage: 230volts

-Minimum voltage: 180volts

-Maximum temperature:30ºC

Setting those squeezed/reduced range as nominal values of technical parameters of DT helped us to observe the abnormal conditions and system reacted according but really the DT did not go into trouble.

To connect our system, the three lines (L1, L2, L3) from the secondary side of DT were used as inputs on our three current sensors (each line per current sensor) using the corresponding wires where input terminal 1 of each current sensor is linked with secondary side of DT and input terminal 2 of each current sensor is connected with the customers/load. We gradually added the customers/load but we did not reach 30 Amperes since our current sensors do not exceed 30Amperes. The voltage sensors were also connected using line and neutral (L-N) from the secondary side of DT. The input voltage range of our voltage sensors is 220V-250V. The output of current and voltage sensors is a signal goes to microcontroller. The waterproof temperature sensor was fixed on the tank of DT to measure the temperature of DT. The motion sensor was adjusted to capture the movement in 4meters at 110 degrees.

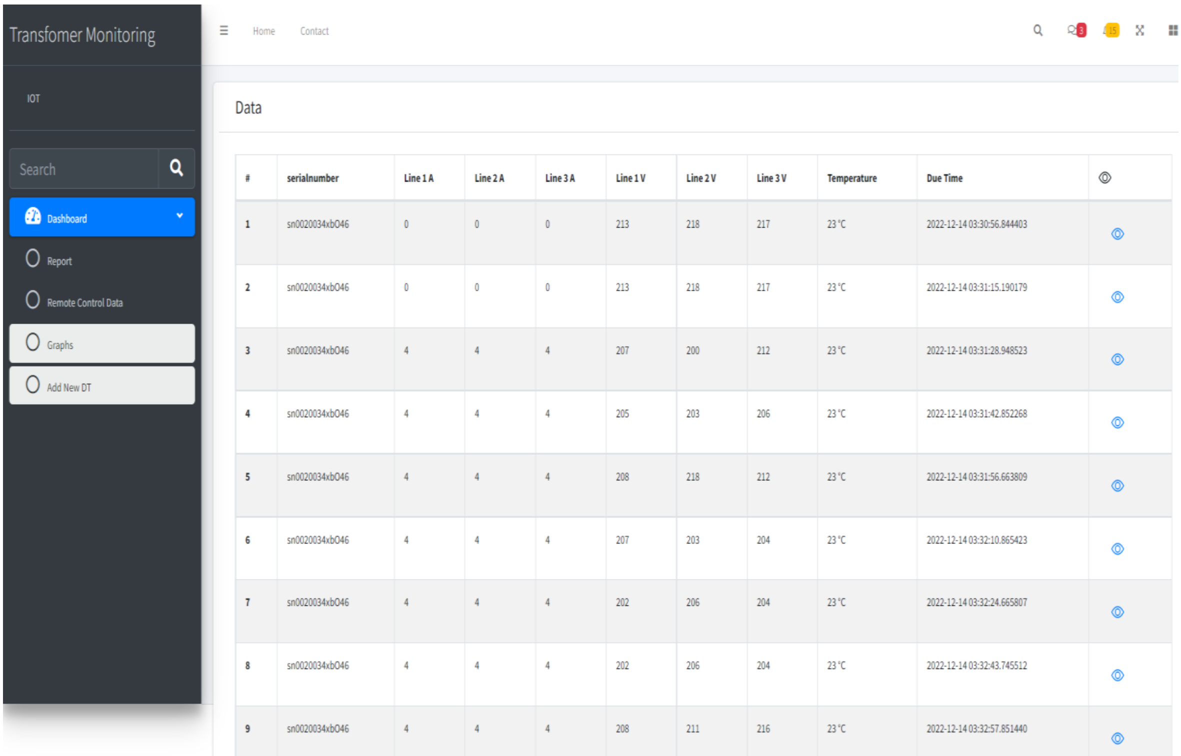
Going beyond those operating limits meaning that there is abnormality or faults exerted on distribution transformer. Those operating limits of technical parameters (current, voltage and temperature) of DT were set/configured in the developed application and the system keep comparing them to the actual values available on DT at each time.

5.5.1 VOLTAGE

The first major role of our system is that it can monitor the voltage of distribution transformer. By monitoring the voltage, you can protect overvoltage and under voltage of our transformer and also protect device of our consumers. When overvoltage or under voltage happen the system has the ability to cut off the secondary side of DT for safety purpose as well as save that action occurred to our power system for more analysis and reports.

For normal condition, voltage is in the range of 180V-230V per each phase/line and neutral of transformer.

Figure 5.7 shows normal voltage



#	serialnumber	Line 1 A	Line 2 A	Line 3 A	Line 1 V	Line 2 V	Line 3 V	Temperature	Due Time	
1	sn0020034xbO46	0	0	0	213	218	217	23 °C	2022-12-14 03:30:56.844403	
2	sn0020034xbO46	0	0	0	213	218	217	23 °C	2022-12-14 03:31:15.190179	
3	sn0020034xbO46	4	4	4	207	200	212	23 °C	2022-12-14 03:31:28.948523	
4	sn0020034xbO46	4	4	4	205	203	206	23 °C	2022-12-14 03:31:42.852268	
5	sn0020034xbO46	4	4	4	208	218	212	23 °C	2022-12-14 03:31:56.663809	
6	sn0020034xbO46	4	4	4	207	203	204	23 °C	2022-12-14 03:32:10.865423	
7	sn0020034xbO46	4	4	4	202	206	204	23 °C	2022-12-14 03:32:24.665807	
8	sn0020034xbO46	4	4	4	202	206	204	23 °C	2022-12-14 03:32:43.745512	
9	sn0020034xbO46	4	4	4	208	211	216	23 °C	2022-12-14 03:32:57.851440	

Figure 5. 7 Normal voltage.

For abnormal condition high, voltage is above 230V for any phase and neutral of transformer.

Figure 5.8 and 5.9 shows abnormal voltage high (over voltage).

#	serial Number	Line 1 A	Line 2 A	Line 3 A	Line 1 V	Line 2 V	Line 3 V	Temperature	Due Time	
91	sn0020034xbO46	7	6	8	230	230	230	29 °C	2022-10-24 08:51:00.239911	
92	sn0020034xbO46	7	6	8	230	230	230	29 °C	2022-10-24 08:51:05.029575	
93	sn0020034xbO46	7	6	8	231	232	230	29 °C	2022-10-24 08:51:15.485376	
94	sn0020034xbO46	7	6	8	231	232	230	29 °C	2022-10-24 08:51:19.737755	
95	sn0020034xbO46	7	6	8	231	232	230	29 °C	2022-10-24 08:51:23.878924	
96	sn0020034xbO46	7	8	8	231	232	230	29 °C	2022-10-24 08:51:36.013125	
97	sn0020034xbO46	7	8	8	231	232	230	29 °C	2022-10-24 08:51:40.885428	

Figure 5. 8 Abnormal voltage high.

Transfomer with
sn00220034xb064
located at MASAKA branch,
Masaka Sector,Gako
cell,Butangampundu village
has overvoltage

Figure 5. 9 sms of abnormal voltage high.

For abnormal condition low, voltage is below 180V for any phase and neutral of transformer.

Figure 5.10 and 5.11 shows abnormal voltage low (under voltage).

21	sn0020034xbO46	0	0	0	0	211	230	26 °C	2022-12-14 03:46:18.449403	
22	sn0020034xbO46	0	0	0	0	0	0	35 °C	2022-12-14 03:46:44.305342	
23	sn0020034xbO46	0	0	0	0	0	0	35 °C	2022-12-14 03:47:11.872067	
24	sn0020034xbO46	0	0	0	0	0	0	54 °C	2022-12-14 03:47:37.931044	
25	sn0020034xbO46	0	0	0	0	0	0	54 °C	2022-12-14 03:48:04.767618	

Figure 5. 10 Abnormal voltage low.

Transfomer with
sn00220034xb064
located at MASAKA branch,
Masaka Sector,Gako
cell,Butangampundu village
has over undervoltgae

Figure 5. 11 sms of abnormal voltage low.

5.5.2 CURRENT

The second major role of our system is that it can monitor the overcurrent of distribution transformer means the transformer is overloaded or short circuit is happened. By monitoring the overcurrent of the transformer, you are protecting the transformer and devices of our consumers by disconnecting the loads from transformer for more analysis and action. For normal condition of current is set to be below 5A.

Figure 5.12 shows normal current

#	serialnumber	Line 1 A	Line 2 A	Line 3 A	Line 1 V	Line 2 V	Line 3 V	Temperature	Due Time	
1	sn0020034xbO46	0	0	0	213	218	217	23 °C	2022-12-14 03:30:56.844403	
2	sn0020034xbO46	0	0	0	213	218	217	23 °C	2022-12-14 03:31:15.190179	
3	sn0020034xbO46	4	4	4	207	200	212	23 °C	2022-12-14 03:31:28.948523	
4	sn0020034xbO46	4	4	4	205	203	206	23 °C	2022-12-14 03:31:42.852268	
5	sn0020034xbO46	4	4	4	208	218	212	23 °C	2022-12-14 03:31:56.663809	
6	sn0020034xbO46	4	4	4	207	203	204	23 °C	2022-12-14 03:32:10.865423	

Figure 5. 12 Normal current.

For abnormal condition, current is set to be above 5A for any phase/line.

Figure 5.13 and 5.14 shows abnormal current-high (over current/ overload)

#	serial Number	Line 1 A	Line 2 A	Line 3 A	Line 1 V	Line 2 V	Line 3 V	Temperature	Due Time	
98	sn0020034xbO46	11	11	11	220	220	220	30 ℃	2022-10-24 08:54:21.859052	
99	sn0020034xbO46	11	11	11	220	220	220	30 ℃	2022-10-24 08:54:24.498999	
100	sn0020034xbO46	11	11	11	220	221	221	30 ℃	2022-10-24 08:54:39.324924	
101	sn0020034xbO46	10	11	11	220	221	221	30 ℃	2022-10-24 08:54:40.954575	
102	sn0020034xbO46	10	11	11	220	221	221	31 ℃	2022-10-24 08:54:49.496859	
103	sn0020034xbO46	10	11	11	220	222	221	31 ℃	2022-10-24 08:55:05.630581	
104	sn0020034xbO46	11	11	11	220	222	221	31 ℃	2022-10-24 08:55:14.733426	

Figure 5. 13 Abnormal current-high.

Figure 5. 14 sms of abnormal current-high.

5.5.3 TEMPERATURE

The third major role of our system is that it can monitor the over temperature of distribution transformer means the transformer is overloaded, short circuit happened or transformer has other problems related to its internal functionality. By monitoring the over temperature of the transformer, you can protect the transformer and devices of our consumers by disconnecting the loads from the transformer for more analysis and action.

For normal condition of temperature is set to be below 30ºC.

Figure 5.15 shows normal temperature

117	sn0020034xb046	6	6	6	222	222	222	27 ℃	2022-10-25 07:47:03.804717	
118	sn0020034xb046	6	6	6	222	222	222	27 ℃	2022-10-25 07:47:11.060294	
119	sn0020034xb046	5	5	5	222	222	222	27 ℃	2022-10-25 07:47:24.702881	
120	sn0020034xb046	5	5	5	222	222	222	27 ℃	2022-10-25 07:47:53.415667	
121	sn0020034xb046	6	5	5	222	222	222	27 ℃	2022-10-25 07:48:00.355374	
122	sn0020034xb046	6	5	5	222	222	222	27 ℃	2022-10-25 07:48:05.154640	
#	serial Number	Line 1 A	Line 2 A	Line 3 A	Line 1 V	Line 2 V	Line 3 V	Temperature	Due Time	

Figure 5. 15 Normal temperature.

For abnormal condition of temperature is set to be above 30 ^{0}C because of overheat produced by overload or overcurrent.

Figure 5.16 and 5.17 shows abnormal temperature-high (over heat)

#	serial Number	Line 1 A	Line 2 A	Line 3 A	Line 1 V	Line 2 V	Line 3 V	Temperature	Due Time	
23	sn0020034xbO46	0	0	0	0	0	0	35 °C	2022-12-14 03:47:11.872067	
24	sn0020034xbO46	0	0	0	0	0	0	54 °C	2022-12-14 03:47:37.931044	
25	sn0020034xbO46	0	0	0	0	0	0	54 °C	2022-12-14 03:48:04.767618	
26	sn0020034xbO46	0	0	0	0	0	0	43 °C	2022-12-14 03:48:31.629070	
27	sn0020034xbO46	0	0	0	0	0	0	43 °C	2022-12-14 03:48:58.688440	
28	sn0020034xbO46	0	0	0	0	0	0	40 °C	2022-12-14 03:49:26.710245	
29	sn0020034xbO46	0	0	0	0	0	0	43 °C	2022-12-14 03:49:56.322004	

Figure 5. 16 Abnormal temperature-high.

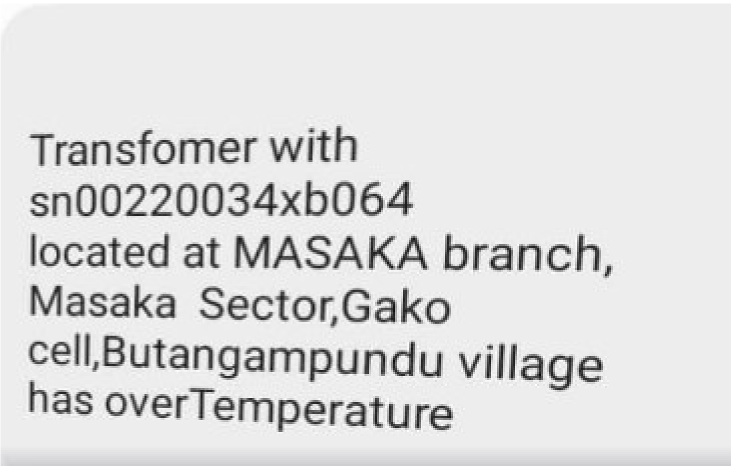


Figure 5. 17 sms of abnormal temperature-high.

Figure 5.18 and 5.19 shows the DT on site with someone around the DT

Figure 5. 18 DT on site with someone around the DT.

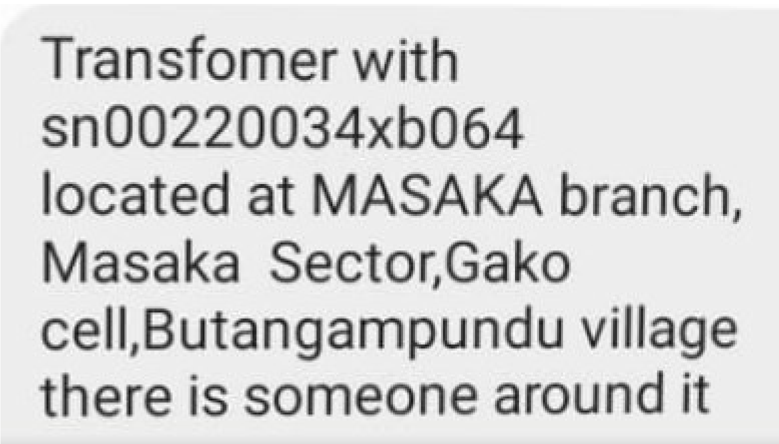


Figure 5. 19 sms of DT on site with someone around the DT.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

The project model was designed and developed based on real data. The model focused on three technical parameters of DT namely: the voltage, current and temperature. Distribution transformers need to be in normal condition where operated voltage, current and temperature don't exceed those on nameplate. The changes in either of the technical parameters affects DT and connected devices as well as vandalism of DT equipment hence, the need for constant monitoring and timely communication. Once one or all of those technical parameters become abnormal, the system cut off automatically the secondary side of DT and isolate the customers load in 2 seconds, and sends the corresponding short message service (sms) to the authorized person in 5 seconds. In case of movements around the DT (related to vandalism); the camera takes a picture to be sent to the utility with a corresponding sms. In addition, a buzzer gives an alert warning on the site. If there is no abnormality detected, the system keeps sensing without sending the data to the cloud.

With the developed system you can detect faults on secondary side of DT such as short circuit, overload, over voltage, under voltage, over heat and vandalism/theft of transformer equipment. This system maximizes the security and efficiency of electricity distributed to consumers in the power utility. This project research focused on 3 key main technical parameters (voltage, current and temperature) of DT that are frequently affect the normal operations of DT but there are other different parameters on DT that can be researched in the future projects in order to capture all possible faults.

The testing done on a distribution transformer located in Masaka Sector, Gako Cell, Butangampundu Village provided interesting results and suggests that the use of such a system throughout the grid would be beneficial.

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APPENDIXES

1. Hardware code

```
#include <SoftwareSerial.h>
SoftwareSerial gprs(3,4);//(Tx,Rx)
#include <OneWire.h>
#include <DallasTemperature.h>
/****************************************************************/
// Data wire is plugged into pin 2 on the Arduino
#define ONE_WIRE_BUS 5
/****************************************************************/
// Setup a oneWire instance to communicate with any OneWire devices
// (not just Maxim/Dallas temperature ICs)
OneWire oneWire(ONE_WIRE_BUS);
/****************************************************************/
// Pass our oneWire reference to Dallas Temperature.
DallasTemperature sensors(&oneWire);
/////////////////////////////////////////
int buzzer =6;
int camera =7;
int motion =8;
int relay =12;
const int sensorIn1 = A0;
const int sensorIn2 = A1;
const int sensorIn3 = A2;
int mVperAmp1 = 100;
int mVperAmp2 = 100;
int mVperAmp3 = 100;
////////////////////////////////////////////
double Voltagec1 = 0;
double VRMS1 = 0;
double AmpsRMS1 = 0;
```

```
double Voltagec2 = 0;
double VRMS2 = 0;
double AmpsRMS2 = 0;
double Voltagec3 = 0;
double VRMS3 = 0;
double AmpsRMS3 = 0;
//////////////////////////////////////
double sensorValue1 = 0;
int val1[100];
int max_v1 = 0;
double VmaxD1 = 0;
double VeffD1 = 0;
double Veff1 = 0;
int Voltage1 = 0;
///////////////////////////////////////
double sensorValue2 = 0;
int val2[100];
int max_v2 = 0;
double VmaxD2 = 0;
double VeffD2 = 0;
double Veff2 = 0;
int Voltage2 = 0;
///////////////////////
double sensorValue3 = 0;
int val3[100];
int max_v3 = 0;
double VmaxD3 = 0;
double VeffD3 = 0;
double Veff3 = 0;
int Voltage3 = 0;
int flag=0;
```

```
//////////////////////////////////
void setup() {
 gprs.begin(9600);
  Serial.begin(9600);
  pinMode(relay, OUTPUT);
    pinMode(buzzer, OUTPUT);
      pinMode(camera, OUTPUT);
        pinMode(motion,INPUT);
  Serial.begin(9600);
 Serial.println("Dallas Temperature IC Control Library Demo");
 // Start up the library
 sensors.begin();
}

void loop() {
  overcurrentMessage();
  undervoltageMessage();
  overvoltageMessage();
  overtemperatureMessage();
  motionMessage();
  temperature();
  voltage1();
  voltage2();
  voltage3();
    Voltagec1 = getVPP1();
 VRMS1 = (Voltagec1/2.0) *0.707;
 AmpsRMS1 = ((VRMS1 * 1000)/mVperAmp1);
//////////////////////////////////
  Voltagec2 = getVPP2();
 VRMS2 = (Voltagec2/2.0) *0.707;
 AmpsRMS2 = (VRMS2 * 1000)/mVperAmp2;
```

```
 ////////////////////////////////
  Voltagec3 = getVPP3();
 VRMS3 = (Voltagec3/2.0) *0.707;
 AmpsRMS3 = (VRMS3 * 1000)/mVperAmp3;
////////////////////////////////
 Serial.print("AmpsRMS1=");
 Serial.print(AmpsRMS1);
  Serial.println(" Amps RMS");
////////////////////////////////////////
  Serial.print("AmpsRMS2=");
  Serial.print(AmpsRMS2);
 Serial.println(" Amps RMS");
////////////////////////////////////////////
  Serial.print("AmpsRMS3=");
  Serial.print(AmpsRMS3);
 Serial.println(" Amps RMS");
 ////////////////////////////
  if(Voltage1<180&&flag==0){
  // motionMessage();
}
      else if(Voltage2<180&&flag==0){
   //motionMessage();
    flag=1;}
      else if(Voltage3<180&&flag==0){
   //motionMessage();
    flag=1;}
    else if(Voltage1<180){
      //analogWrite(relay,255);
      }
      else if(Voltage2<180){
      //analogWrite(relay,255);
```

```
    }
     else if(Voltage3<180){
    //analogWrite(relay,255);
    }

  else{Serial.println("okoko");

   //analogWrite(relay,0);
   }

}
 ///////////////
    void voltage1(){
     for ( int i = 0; i < 100; i++ ) {
         sensorValue1 = analogRead(A5);
  if (analogRead(A0) > 511) {
    val1[i] = sensorValue1;
  }
  else {
    val1[i] = 0;
  }
  delay(1);
 }

 max_v1 = 0;

 for ( int i = 0; i < 100; i++ )
 {
  if ( val1[i] > max_v1 )
  {
    max_v1 = val1[i];
```

```
  }
  val1[i] = 0;
 }
 if (max_v1 != 0) {
  VmaxD1 = max_v1;
  VeffD1 = VmaxD1 / sqrt(2);
  Veff1 = (((VeffD1 - 420.76) / -90.24) * -210.2);
   //Veff1 = (((VeffD1 - 420.76) / -90.24) * -210.2)+120 ;
 }
 else {
  Veff1 = 0;
 }
 VmaxD1 = 0;
 delay(400);
 if(Veff1<0){
  Voltage1=0;}
  else{
   Voltage1=Veff1+120;
   }
    Serial.print("Voltage1: ");
 Serial.println(Voltage1);}
/////////////////////////////
   void voltage2(){
    for ( int i = 0; i < 100; i++ ) {
  sensorValue2 = analogRead(A4);
  if (analogRead(A1) > 511) {
   val2[i] = sensorValue2;
  }
  else {
   val2[i] = 0;
  }
```

```
  delay(1);
}

max_v2 = 0;

for ( int i = 0; i < 100; i++ )
{
  if ( val2[i] > max_v2 )
  {
    max_v2 = val2[i];
  }
  val2[i] = 0;
}
if (max_v2 != 0) {
  VmaxD2 = max_v2;
  VeffD2 = VmaxD2 / sqrt(2);
  Veff2 = (((VeffD2 - 420.76) / -90.24) * -210.2);
  //Veff2 = (((VeffD2 - 420.76) / -90.24) * -210.2)+163;
}
else {
  Veff2 = 0;
}

VmaxD2 = 0;
delay(400);
if(Veff2<0){
  Voltage2=0;}
  else{
    Voltage2=Veff2+163;}
    Serial.print("Voltage2: ");
Serial.println(Voltage2);
```

```
//if(Voltage2<120){Serial.print("Voltage2nooo: ");}
}
///////////////////////////
void voltage3(){
    for ( int i = 0; i < 100; i++ ) {
  sensorValue3 = analogRead(A3);
  if (analogRead(A2) > 511) {
    val3[i] = sensorValue3;
  }
  else {
    val3[i] = 0;
  }
  delay(1);
}

max_v3 = 0;

for ( int i = 0; i < 100; i++ )
{
  if ( val3[i] > max_v3 )
  {
    max_v3 = val3[i];
  }
  val3[i] = 0;
}
if (max_v3 != 0) {
  VmaxD3 = max_v3;
  VeffD3 = VmaxD3 / sqrt(2);
  Veff3 = (((VeffD3 - 420.76) / -90.24) * -210.2) ;
  //Veff3 = (((VeffD3 - 420.76) / -90.24) * -210.2) ;
}
```

```
 else {
  Veff3 = 0;
 }

 VmaxD3 = 0;
 delay(400);
 if(Veff3<0){
  Voltage3=0;}
  else{
   Voltage3=Veff3+204;}
    Serial.print("Voltage3: ");
 Serial.println(Voltage3);}
 void temperature(){
  // call sensors.requestTemperatures() to issue a global temperature
// request to all devices on the bus
/********************************************************************/
Serial.print(" Requesting temperatures...");
sensors.requestTemperatures(); // Send the command to get temperature readings
Serial.println("DONE");
/********************************************************************/
Serial.print("Temperature is: ");
Serial.println(sensors.getTempCByIndex(0)); // Why "byIndex"?
  // You can have more than one DS18B20 on the same bus.
  // 0 refers to the first IC on the wire
  delay(1000); }

  void overcurrentMessage()
{
 gprs.println("AT+CMGF=1"); //Sets the GSM Module in Text Mode
 delay(1000);  // Delay of 1000 milli seconds or 1 second
```

```
  gprs.println("AT+CMGS=\"0788472885\"\r"); // Replace x with mobile number
  delay(1000);
  //mySerial.println("Dear Marc your device developed by Theophile which has
temperature of "temp" °C  is on this location");
 gprs.println("Transfomer with sn00220034xb064");
  gprs.println("located at MASAKA branch, Masaka  Sector,Gako cell,Butangampundu
village");
  gprs.println("has overcurrent ");
  delay(100);
 gprs.println((char)26);// ASCII code of CTRL+Z
  delay(1000);
}
void undervoltageMessage()
{
  gprs.println("AT+CMGF=1"); //Sets the GSM Module in Text Mode
  delay(1000);  // Delay of 1000 milli seconds or 1 second
  gprs.println("AT+CMGS=\"0788472885\"\r"); // Replace x with mobile number
  delay(1000);
  //mySerial.println("Dear Marc your device developed by Theophile which has
temperature of "temp" °C  is on this location");
  gprs.println("Transfomer with sn00220034xb064");
  gprs.println("located at MASAKA branch, Masaka  Sector,Gako cell,Butangampundu
village");
  gprs.println("has undervoltage ");
  delay(100);
 gprs.println((char)26);// ASCII code of CTRL+Z
  delay(1000);
}
void overvoltageMessage()
{
  gprs.println("AT+CMGF=1"); //Sets the GSM Module in Text Mode
```

```
  delay(1000);  // Delay of 1000 milli seconds or 1 second
  gprs.println("AT+CMGS=\"0788472885\"\r"); // Replace x with mobile number
  delay(1000);
  //mySerial.println("Dear Marc your device developed by Theophile which has
temperature of "temp" °C  is on this location");
 gprs.println("Transfomer with sn00220034xb064");
  gprs.println("located at MASAKA branch, Masaka  Sector,Gako cell,Butangampundu
village");
  gprs.println("has overvoltage ");
  delay(100);
  delay(100);
 gprs.println((char)26);// ASCII code of CTRL+Z
  delay(1000);
}
void overtemperatureMessage()
{
  gprs.println("AT+CMGF=1"); //Sets the GSM Module in Text Mode
  delay(1000);  // Delay of 1000 milli seconds or 1 second
  gprs.println("AT+CMGS=\"0788472885\"\r"); // Replace x with mobile number
  delay(1000);
  //mySerial.println("Dear Marc your device developed by Theophile which has
temperature of "temp" °C  is on this location");
 gprs.println("Transfomer with sn00220034xb064");
  gprs.println("located at MASAKA branch, Masaka  Sector,Gako cell,Butangampundu
village");
  gprs.println("has overtemperature ");
  delay(100);
  delay(100);
 gprs.println((char)26);// ASCII code of CTRL+Z
  delay(1000);
}
```

```
void motionMessage()
{
  gprs.println("AT+CMGF=1"); //Sets the GSM Module in Text Mode
  delay(1000);  // Delay of 1000 milli seconds or 1 second
  gprs.println("AT+CMGS=\"0788472885\"\r"); // Replace x with mobile number
  delay(1000);
  //mySerial.println("Dear Marc your device developed by Theophile which has
temperature of "temp" °C  is on this location");
 gprs.println("Transfomer with sn00220034xb064");
  gprs.println("located at MASAKA branch, Masaka  Sector,Gako cell,Butangampundu
village");
  gprs.println("there is someone around it");
  delay(100);
 gprs.println((char)26);// ASCII code of CTRL+Z
  delay(1000);
}
void sendData()
  {
     gprs.println("AT+CREG?");
     delay(100);
     gprs.println("AT+SAPBR=3,1,\"CONTYPE\",\"GPRS\"");
     delay(1000);//2000
     gprs.println("AT+SAPBR=3,1,\"APN\",\"MTN.internet\"");
     delay(1000);//2000
     gprs.println("AT+SAPBR=1,1");
     delay(1000);//2000
     gprs.println("AT+HTTPINIT");
     delay(1000);//2000
```

```
gprs.print("AT+HTTPPARA=\"URL\",\"http://kivufamilyboat.com/gprs_test/getdata.php
?");

   gprs.print("department=");
   gprs.print("123");
   gprs.print("&");
   gprs.print("issue=");
   gprs.print("99");
   gprs.print("&");
   gprs.print("status=");
   gprs.print("340");
   gprs.println("\"");
  delay(1000);//2000
  // set http action type 0 = GET, 1 = POST, 2 = HEAD
   gprs.println("AT+HTTPACTION=0");
  delay(1000);//5000
  // toSerial();
  // read server response
   gprs.println("AT+HTTPREAD");
  delay(500);//
  // toSerial()
   gprs.println("");
   gprs.println("AT+HTTPTERM");
  // toSerial();
 // delay(300);
   gprs.println("");
  delay(1000);//10000
  gprs.println("AT+CIPSHUT");

}
```

```
float getVPP1(){//this will caculate the peak to peak of sensor1
float result1;
  int readValue1;             //value read from the sensor1
  int maxValue1 = 0;          // store max value here
  int minValue1 = 1024;          // store min value here
   uint32_t start_time = millis();
   while((millis()-start_time) < 1000) //sample for 1 Sec
   { readValue1 = analogRead(sensorIn1);
       // see if you have a new maxValue
       if (readValue1 > maxValue1) {
           /*record the maximum s ensor value*/
           maxValue1 = readValue1; }
       if (readValue1 < minValue1)  {
           /*record the maximum sensor value*/
           minValue1 = readValue1;} }
    // Subtract min from max
   result1 = ((maxValue1 - minValue1) * 5.0)/1024.0;
   return result1;}

   float getVPP2() //this will caculate the peak to peak of sensor2
{float result2;
  int readValue2;             //value read from the sensor
  int maxValue2 = 0;          // store max value here
  int minValue2 = 1024;          // store min value here
   uint32_t start_time = millis();
   while((millis()-start_time) < 1000) //sample for 1 Sec
   { readValue2 = analogRead(sensorIn2);
       // see if you have a new maxValue
       if (readValue2 > maxValue2) {
           /*record the maximum sensor value*/
           maxValue2 = readValue2; }
```

```
    if (readValue2 < minValue2)  {
        /*record the maximum sensor value*/
        minValue2 = readValue2;} }
  // Subtract min from max
 result2 = ((maxValue2 - minValue2) * 5.0)/1024.0;
 return result2;}
 //////////////////////////////
   float getVPP3() //this will caculate the peak to peak of sensor2
{float result3;
 int readValue3;             //value read from the sensor
 int maxValue3 = 0;          // store max value here
 int minValue3 = 1024;          // store min value here
 uint32_t start_time = millis();
 while((millis()-start_time) < 1000) //sample for 1 Sec
 { readValue3 = analogRead(sensorIn3);
    // see if you have a new maxValue
    if (readValue3 > maxValue3) {
        /*record the maximum sensor value*/
        maxValue3 = readValue3; }
    if (readValue3 < minValue3)  {
        /*record the maximum sensor value*/
        minValue3 = readValue3;} }
  // Subtract min from max
 result3 = ((maxValue3 - minValue3) * 5.0)/1024.0;
 return result3;}
```

2. Code used for camera

```
#include <Arduino.h>
#include <WiFi.h>
#include "soc/soc.h"
#include "soc/rtc_cntl_reg.h"
#include "esp_camera.h"
const char* ssid = "how??";
const char* password = "123456789";
String serverName = "security.vrt.rw";   // REPLACE WITH YOUR Raspberry Pi IP
ADDRESS
//String serverName = "example.com";   // OR REPLACE WITH YOUR DOMAIN
NAM
String serverPath = "/views/admin/uploads/upload.php";     // The default serverPath
should be upload.php
const int serverPort = 80;
WiFiClient client;
// CAMERA_MODEL_AI_THINKER
#define PWDN_GPIO_NUM     32
#define RESET_GPIO_NUM    -1
#define XCLK_GPIO_NUM      0
#define SIOD_GPIO_NUM     26
#define SIOC_GPIO_NUM     27
#define Y9_GPIO_NUM       35
#define Y8_GPIO_NUM       34
#define Y7_GPIO_NUM       39
#define Y6_GPIO_NUM       36
#define Y5_GPIO_NUM       21
#define Y4_GPIO_NUM       19
#define Y3_GPIO_NUM       18
#define Y2_GPIO_NUM        5
```

```
#define VSYNC_GPIO_NUM    25
#define HREF_GPIO_NUM     23
#define PCLK_GPIO_NUM     22
const int timerInterval = 30000;    // time between each HTTP POST image
unsigned long previousMillis = 0;   // last time image was sent
void setup() {
  WRITE_PERI_REG(RTC_CNTL_BROWN_OUT_REG, 0);
  Serial.begin(115200);
  WiFi.mode(WIFI_STA);
  Serial.println();
  Serial.print("Connecting to ");
  Serial.println(ssid);
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    Serial.print(".");
    delay(500);
  }
  Serial.println();
  Serial.print("ESP32-CAM IP Address: ");
  Serial.println(WiFi.localIP());

  camera_config_t config;
  config.ledc_channel = LEDC_CHANNEL_0;
  config.ledc_timer = LEDC_TIMER_0;
  config.pin_d0 = Y2_GPIO_NUM;
  config.pin_d1 = Y3_GPIO_NUM;
  config.pin_d2 = Y4_GPIO_NUM;
  config.pin_d3 = Y5_GPIO_NUM;
  config.pin_d4 = Y6_GPIO_NUM;
  config.pin_d5 = Y7_GPIO_NUM;
  config.pin_d6 = Y8_GPIO_NUM;
```

```
config.pin_d7 = Y9_GPIO_NUM;
config.pin_xclk = XCLK_GPIO_NUM;
config.pin_pclk = PCLK_GPIO_NUM;
config.pin_vsync = VSYNC_GPIO_NUM;
config.pin_href = HREF_GPIO_NUM;
config.pin_sscb_sda = SIOD_GPIO_NUM;
config.pin_sscb_scl = SIOC_GPIO_NUM;
config.pin_pwdn = PWDN_GPIO_NUM;
config.pin_reset = RESET_GPIO_NUM;
config.xclk_freq_hz = 20000000;
config.pixel_format = PIXFORMAT_JPEG;

// init with high specs to pre-allocate larger buffers
if(psramFound()){
  config.frame_size = FRAMESIZE_SVGA;
  config.jpeg_quality = 10;  //0-63 lower number means higher quality
  config.fb_count = 2;
} else {
  config.frame_size = FRAMESIZE_CIF;
  config.jpeg_quality = 12;  //0-63 lower number means higher quality
  config.fb_count = 1;
}

// camera init
esp_err_t err = esp_camera_init(&config);
if (err != ESP_OK) {
  Serial.printf("Camera init failed with error 0x%x", err);
  delay(1000);
  ESP.restart();
}
sendPhoto();
```

```
}
void loop() {
  //sendPhoto();
}
String sendPhoto() {
  String getAll;
  String getBody;

  camera_fb_t * fb = NULL;
  fb = esp_camera_fb_get();
  if(!fb) {
    Serial.println("Camera capture failed");
    delay(1000);
    ESP.restart();
  }
  Serial.println("Connecting to server: " + serverName);
  if (client.connect(serverName.c_str(), serverPort)) {
    Serial.println("Connection successful!");
    String head = "--RandomNerdTutorials\r\nContent-Disposition: form-data;
name=\"imageFile\"; filename=\"esp32-cam.jpg\"\r\nContent-Type: image/jpeg\r\n\r\n";
    String tail = "\r\n--RandomNerdTutorials--\r\n";
    uint32_t imageLen = fb->len;
    uint32_t extraLen = head.length() + tail.length();
    uint32_t totalLen = imageLen + extraLen;

    client.println("POST " + serverPath + " HTTP/1.1");
    client.println("Host: " + serverName);
    client.println("Content-Length: " + String(totalLen));
    client.println("Content-Type: multipart/form-data; boundary=RandomNerdTutorials");
    client.println();
    client.print(head);
```

```
uint8_t *fbBuf = fb->buf;
size_t fbLen = fb->len;
for (size_t n=0; n<fbLen; n=n+1024) {
  if (n+1024 < fbLen) {
    client.write(fbBuf, 1024);
    fbBuf += 1024;
  }
  else if (fbLen%1024>0) {
    size_t remainder = fbLen%1024;
    client.write(fbBuf, remainder);
  }
}
client.print(tail);
esp_camera_fb_return(fb);
int timoutTimer = 10000;
long startTimer = millis();
boolean state = false;
while ((startTimer + timoutTimer) > millis()) {
  Serial.print(".");
  delay(100);
  while (client.available()) {
    char c = client.read();
    if (c == '\n') {
      if (getAll.length()==0) { state=true; }
      getAll = "";
    }
    else if (c != '\r') { getAll += String(c); }
    if (state==true) { getBody += String(c); }
    startTimer = millis();
  }
  if (getBody.length()>0) { break; }
```

```
    }
    Serial.println();
    client.stop();
    Serial.println(getBody);
  }
  else {
    getBody = "Connection to " + serverName +  " failed.";
    Serial.println(getBody);
  }
  return getBody;
}
```

3. Code used to design web application

```
 <?php
      if($row['power']>="ON")
     {
     ?>
       <form action="storeTrasfomer.php" method="POST">
       <input type ="hidden"value="<?=$row['id']?>" name="idggg">
       <input type ="hidden"value="56" name="power">
     <input type="submit" class="btn btn-primary" value="DT-ON" style="font-size:11px">

       </form>
<?php
} else{
?>
       <form action="storeTrasfomer.php" method="POST">
       <input type ="hidden"value="<?=$row['id']?>" name="idggg">
       <input type ="hidden"value="56" name="powery">
      <input  type="submit" class="btn btn-warning"  value="DT-OFF" style="font-size:11px">

       </form>
      <?php
      }?>
       </td>
```

```
      <td>
    <?php
     if($row['siren']>="ON")
     {
     ?>

  <form action="storeTrasfomer.php" method="POST">
       <input type ="hidden"value="<?=$row['id']?>" name="idggg">
       <input type ="hidden"value="56" name="powersilen">
      <input  type="submit" class="btn btn-success"  value="DT-OFF" style="font-
size:11px">

       </form>
<?php
}
else{
?>

  <form action="storeTrasfomer.php" method="POST">
       <input type ="hidden"value="<?=$row['id']?>" name="idggg">
       <input type ="hidden"value="56" name="powersilen3">
      <input  type="submit" class="btn btn-danger"  value="DT-OFF" style="font-
size:11px">

       </form>
      <?php
      }
      ?>
       </td>
    <?php
}
?>
```