UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION

KUMASI

REMOTE MONITORING OF A DISTRIBUTION TRANSFORMER

GODFRED KWASI SARPONG

AUGUST, 2016

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GODFRED KWASI SARPONG

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AUGUST, 2016

DECLARATION

STUDENT'S DECLARATION

I, GODFRED KWASI SARPONG, declare that this Dissertation, with the exception of quotation and references contained in the published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in parts or whole, for another degree elsewhere.

SIGNATURE……………………………………………………………………

DATE……………………………………………………………………………

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of the work was supervised in accordance with the guidelines for supervision of Dissertation as laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: PROF. WILLIE K. OFOSU

SIGNATURE: ……………………………………………………………........

DATE: …………………………………………………………………………..

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"No Achievement is by one Man's Effort"

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DEDICATION

This dissertation is dedicated to my FAMILY AND FRIENDS.

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LIST OF ABBREVIATIONS

NEDCo	Northern Electricity Distribution Company
GSM	Global System Mobile
SMS	short message service
LCD	liquid crystal display
AI	artificial intelligence
RF	Radio Frequency
GPRS	General Packet radio service
PT	Potential Transformer
CT	Current Transformer
I/O	Input/Output
ANNEPS	Artificial Neural Network Expert System
DGA	Dissolved Gas Analysis
SRAM	Static Random Access Memory
RTU	Remote Terminal Unit
EEPROM	Electrical Erasable Programmable Read-Only Memory
PIC	Peripheral Interface Controller
PC	Personal Computer
AVR	Advanced Virtual RISC

ADC	Analogue-to-Digital Converter
IC	Integrated Circuit
AC	Alternating current
SCADA	Supervisory Control and Data Acquisition
DC	Direct Current
RMS	Root mean value
RISC	Reduced instruction set computer
IDE	integrated development environment
AT	attention command
LED	light emitting diode
GND	ground

ABSTRACT

The main objective of this project is to develop a simple low cost microcontroller based remote distribution transformer monitoring system using wireless technology which acquires key transformer parameters like temperature, voltage and load current using various sensors to display the real-time values on LCD and forwards them to a cell phone in a remote location by SMS. This project was developed by using Arduino board with ATMEGA328 Microcontroller, SIM 900 GSM Module, LCD display, voltage sensor (PT), current transformer (CT), a thermistor as temperature sensor and a GSM based communication network which covered almost every nook and cranny of the country.

The preliminary level of fault or abnormality details was reported to the pre-assigned operator through an SMS service. The circuit model was set up and has been working satisfactorily. This embedded system can be very useful to the electricity supply authorities to monitor their transformers at remote locations without being physically present there.

CHAPTER 1

INTRODUCTION

1.1. Background to the Study

Power transformer is regarded as the heart of any electrical transmission and distribution system. At the output of the generator, they are used for stepping up voltage for transmission. In addition, at certain sections of the transmission system, they are used to either step-up or step-down the system voltage. Distribution utility companies require power transformers to step-down voltage to the required level for utilization by consumers (Li, D., Serizawa, Y., and Kiuchi, M., 2002).

However, there are several challenges that confront power transformers. Some of these include overheating, overloading and overvoltage. Non-monitoring and control of these parameters can lead to flashover between terminals, deterioration of insulation of transformer oil, burning of winding insulation, shortening of transformer life span and total breakdown of the power transformer. These can cause interruptions in the supply of power to consumers and subsequently an unreliable power system (Solomon Nunu and Edward Kofi Mahama 2013).

Moreover, distribution transformer downtime in the absence of any condition monitoring can be as high as 20% of its life span. This can be reduced to less than 2% when proper condition monitoring techniques are adopted. Online condition monitoring helps to detect incipient faults and increases the overall efficiency equipment. Furthermore, continuous monitoring help prevent catastrophic failures. (www.masplantiz.com).

According to Chan (1999), distribution transformer is an electrical equipment which distributes power to low-voltage users directly and its operating condition is a vital part of the operation of distribution network.

The distribution transformer is a critical equipment in power systems and its correct functioning is essential to the reliable operation of the system. It is therefore necessary to monitor the operating condition and performance of distribution transformers in order to reduce its running cost by optimizing maintenance schedules and hence avoid or reduce disruption due to sudden or unexpected failure (Barnes M. F, 1996).

Therefore, reliability of operation of distribution networks can be increased by using automatic monitoring systems for transformers – not only for power transformers but also for distribution transformers. Remote monitoring can provide selective sharing of data among multiple sites in the most efficient and cost effective manner (Bengtsson T. Kols 1996).

1.2. Statement of the Problem

In Ghana, Distribution transformers are currently monitored manually where a person periodically visits a transformer site for maintenance and records the respective transformer's parameters (i.e. current, voltage and temperature). This type of monitoring cannot provide information about occasional overloads and overheating of transformer oil and windings. It is also expensive, time consuming and has very low accuracy. Furthermore, substations in rural areas are even more difficult to monitor manually and hence require more time to take respective actions. There is therefore the need for a novel technique to monitor these remote transformers (Prof. KunalV.Ranvir, Mayuri A. and Solanke, 2015).

Figure 1.1: A NEDCo Staff Monitoring a Transformer Load Current Manually

(Source: TechimanNEDCo Diary)

There are different types of proper monitoring methods to evaluate the condition and possible incipient failures of a power transformer. For distribution transformer monitoring, the methods are usually too expensive and/or time consuming to use. However, cost-efficient methods for distribution transformer monitoring are needed (Banupriya M, et al. 2013).

One such method is using an embedded system for monitoring important parameters of a distribution transformer, and then transmitting the values to a mobile phone using GSM-SMS technology. This will help to identify problems before any serious system failure occurs and hence significantly save cost and ensure greater reliability (Prof. KunalV.Ranvir, et. al. 2015).

1.3. Aim and Objectives of the study

The aim of this project is to design and implement a low cost microcontroller based transformer monitoring system using GSM.

The specific objectives of the research are to:

i. Design and build a microcontroller based monitoring system to monitor the voltage, current and oil temperature of the transformer.

ii. Provide continuous monitoring and LCD display.

iii. Send the status of the sensors to a mobile phone via GSM network

iv. Alert the electricity company by SMS when pre-set voltage, current and temperature are exceeded.

v. Permit the status of the remote sensors to be queried from the mobile phone.

1.4 Research Questions

The design was guided by the following research questions:

1. What is the significance of remote monitoring of the distribution transformer?
2. How efficient will the remote monitoring of the distributiontransformer be to electricity power supply authorities?
3. How will this system be different from the already exited systems?

1.5 Significance of the Study

A distribution transformer real-time monitoring system is extremely essential to detect all operating parameters of a distribution transformer, so this information can be sent on time to monitoring centres. It ensures online monitoring of key operational parameters of distribution transformers which can provide useful information about their health which will help utility companies to optimally use their transformers and keep it in operation for a longer period. This will help to identify problems before any serious failure which will save cost significantly and provide greater reliability. Widespread use of mobile networks and GSM devices such as GSM modems and their decreasing costs have made them an attractive option not only for audio and video communication but for other wide area network applications. (Ansuman S. and Rajesh B, 2013)

1.6 Organization of Chapters

This study is organised into six Chapters. Chapter One comprises the background to the study, statement of the problem, purpose of the study, objectives of the study and significance of the study.

Chapter Two presents literature review where previous researches in this area are analysed and the loop holes that this research will fill is also presented

Descriptions of the system architecture, hardware requirements of the design, and explanations of circuitry and block diagrams with some design calculations are discussed in Chapter Three.

Furthermore, Chapter Four comprises of detailed information on hardware and software design and implementation.

Test and results of the circuit design are then presented in Chapter five while the Sixth Chapter contains the conclusion and recommendation for other systems to be designed in the future.

CHAPTER 2

LITERATURE REVIEW

This chapter presents a review of researches performed in the area of remote transformer monitoring and other related areas. The technologies reviewed are artificial intelligence (AI), Supervisory Control and Data Acquisition (SCADA), Radio Frequency (RF), General Packet Radio Service (GPRS), ZigbeeTecnology, and Global System Mobile (GSM).

2.1. Remote Monitoring of Transformers

A transformer monitoring system is a system that provides observation of the status of a transformer or a number of transformers remotely. The performance of the transformer will be determined according to the data monitored variables such as voltage, current, temperature and power of a power transformer. The data of these monitored variables are obtained with the application of specific sensors such as temperature sensors, Potential Transformers (PTs) and Current Transformers (CTs), etc. Through a remote monitoring system, the user such as the maintenance crew or operator is able to detect abnormal conditions or current status of the transformer conveniently at any time, and anywhere (Rocha, G., Dolezilek, D., Ayello, F., and Oliveira, C., 2011).

Shoureshi, Norick, and Swartzendruber (2004); proposed a design which was based on a study on three single-phase 166MVA transformers that aimed at providing an alternative for periodic on-site checking. The system provided monitoring of temperature, current and vibration of a power transformer. These collected data of monitored variables were further transmitted to the substation computer for storage and as a reference to a scheduled on-site monitoring and maintenance. Artificial intelligent technique using Neuro-fuzzy logic is applied together with the monitoring system to detect abnormal condition of the transformer (Shoureshi, R., Norick.,T., &Swartzendruber, R., 2004).

Also, Yishan Liang (2005) considered a monitoring and diagnostic system with an application of ANNEPS v4.0 software. The system detects the presence of dissolved gas such as Nitrogen (N2), Oxygen (O2), Hydrogen (H2), Carbon dioxide (CO2), Carbon monoxide (CO), Methane (CH4), Ethane (C2H6), Ethylene (C2H4), and Acetylene (C2H2) within the oil of a liquid- immersed transformer. A diagnostic technique called Dissolved Gas-in-oil Analysis (DGA) was applied to detect the above mentioned dissolved gases. Once the diagnosis result showed that the transformer condition was abnormal, an alarm procedure was started. An alarm email message with fault information was sent to the user via internet.

The performance of the proposed systems above were examined and from the experimental readings and observations, it was established that the system had high accuracy in monitoring the transformer when there was any fault but it posed a setback as it required high-level computational skills. (Bashi et al 2007).

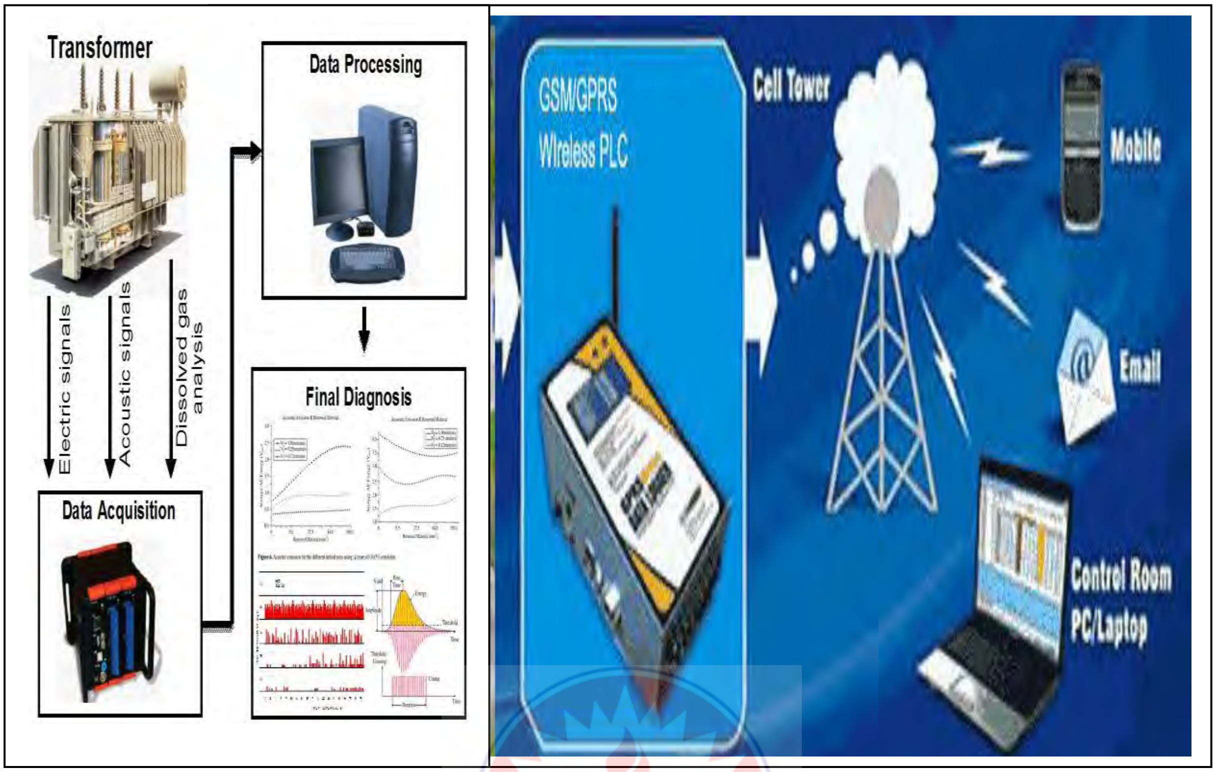


Figure 2.1: Power Transformer Monitoring Using Artificial Intelligence (Neuro-fuzzy and DGA). (Source: https://www.scribd.com)

Furthermore, Nunoo and Mahama, (2013) investigated the use of Internet-based Supervisory Control and Data Acquisition (SCADA) system to monitor temperature, load, bushing condition and line voltage of a power transformer remotely. Current transformer, thermistor or thermocouple, bushing monitor and voltage transformer are used for sensing the concerned parameters. A remote Terminal Unit (RTU) polls the sensed parameters from the output of the sensors. The read values are then compared with the set point of the parameters based on the configuration of the RTU. If the readings are above the preset values, a signal is sent via the internet to the master station for corrective action to be taken. Internet Protocol Security (IPSec) Virtual Private Network (VPN) is used in securing the SCADA network. The system was found to have a longer lifespan, more accurate and provided security against hackers but was very expensive and bulky (*S*olomon Nunoo& Edward Kofi Mahama, 2013).

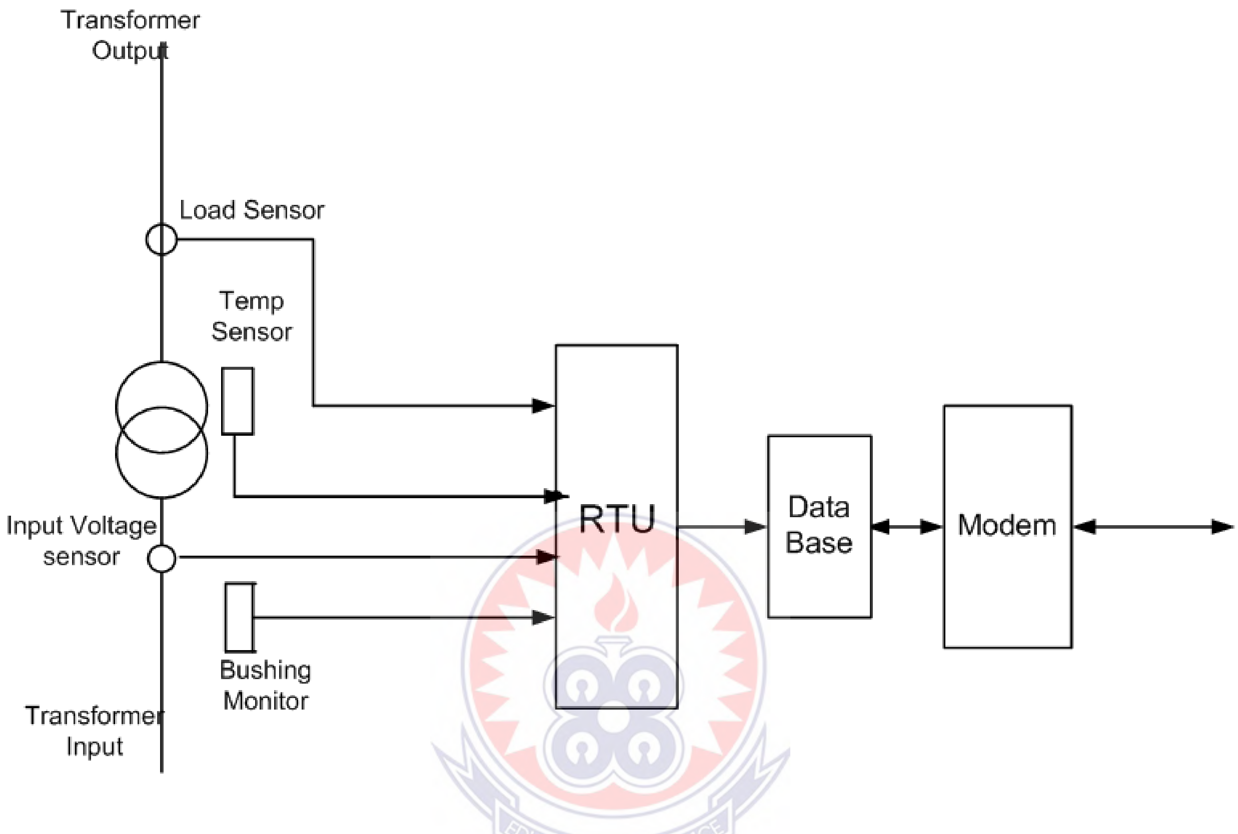


Figure 2.2: Power Transformer Monitoring Using SCADA (Remote Site Architecture)
(Source: www.academicpub.org)

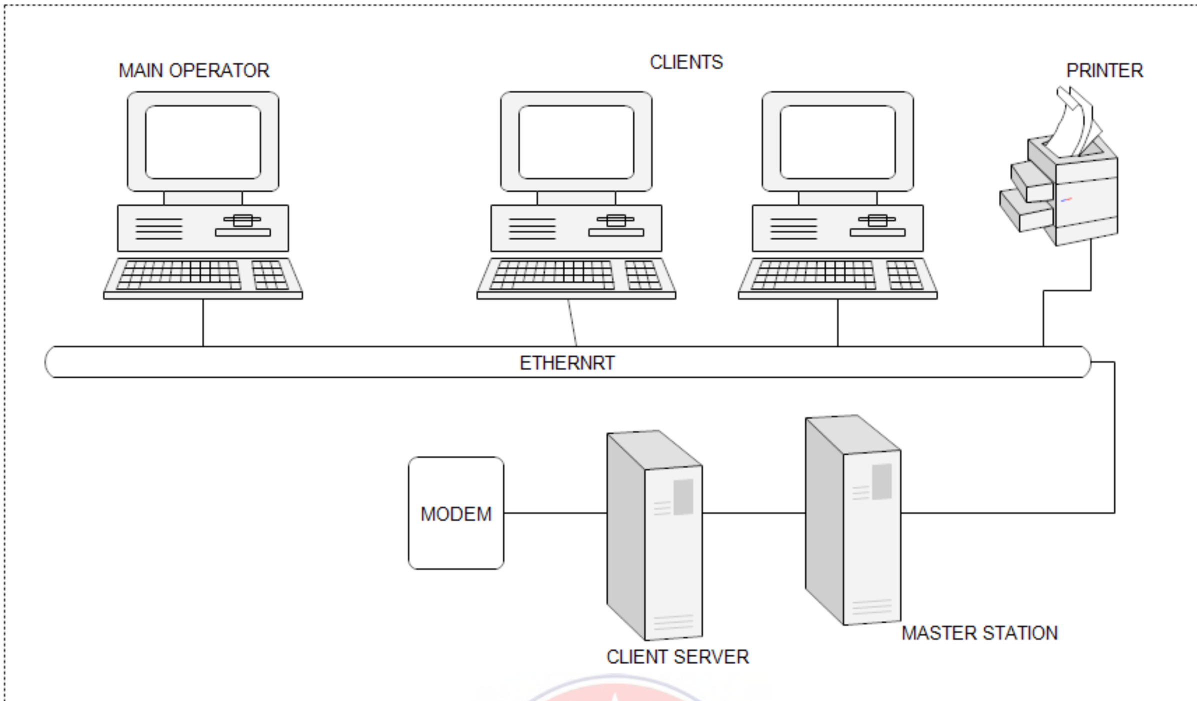


Figure 2.3: Power Transformer Monitoring Using SCADA (Master Station Architecture)

(Source: www.academicpub.org)

In addition, Thiyagarajan&Palanivel(2010) proposed an innovative design to develop a system based on AVR microcontroller that was used for monitoring the current of a distribution transformer in a substation and to protect the system from the rise in current due to overloading. The protection of the distribution transformer was accomplished by shutting down the entire unit with the aid of radio frequency communication. Whenever an over current was sensed by the system while monitoring the transformer, it directed the main station to shut down the transformer and thus guarded the unit from any serious damages (V. Thiyagarajan& T.G. Palanivel, 2010).

Radio Frequency communication is based on ISM band (Industrial Scientific and Medical) are very useful in sending and receiving real time data when monitoring transformers in remote locations. A transformer can be monitored from a personal computer by use of radio frequency. This online monitoring technique plays an important role in a smart grid. **(**Deshpande V.S., Kulkarni A.R., Kulkarni G.K & Mahajan S.K., 2016)

Faults such as over- current, over-voltage and over-heating can be avoided by using this monitoring technique. As pre-fault indication can be observed using RF signal so fault can be prevented and system failure can be avoided. This system is good for long range monitoring and also provides protection for the transformer. However, the system is complex and suffers from noise (Vaibhav et al. 2016).

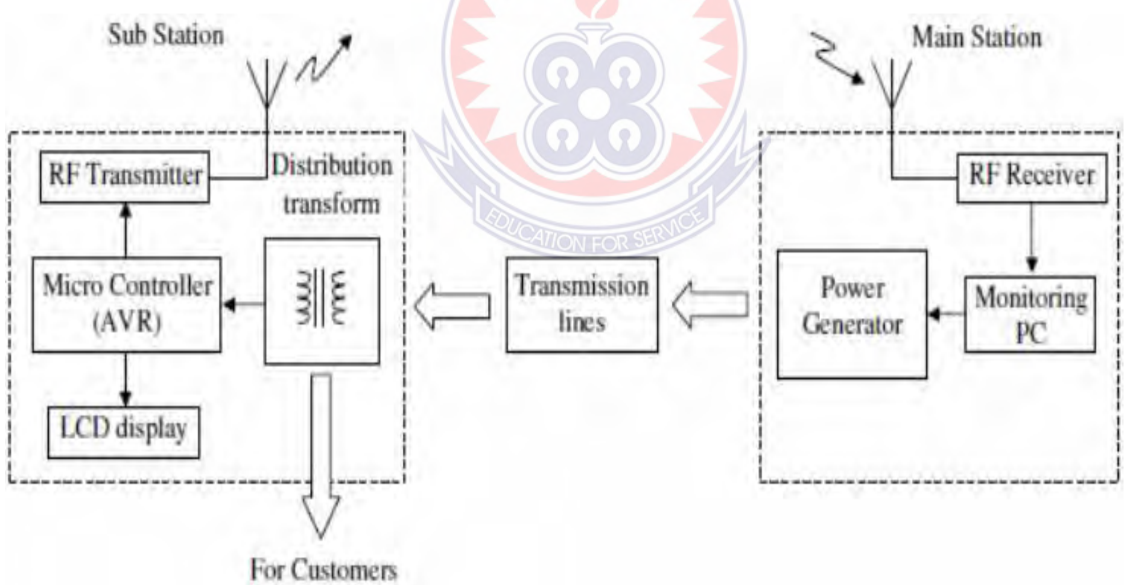


Figure 2.4: Distribution Transformer Monitoring Using RF Communication

(Source: www.arpapress.com)

In June 2013, Dr. J. Jayakumar et al presented a system which worked on a wireless, real time, multi-object monitoring system of Distribution Transformer depending on General Packet Radio Service (GPRS) network. A design based on PIC Microcontroller was developed for monitoring the key parameters of Distribution Transformer in a substation. An algorithm for monitoring the voltage, current and temperature was developed and programmed to the microcontroller. It was observed that the proposed system was effective in monitoring and displaying data using wireless communication network.It was fast and provided back up for transformer data but suffered from security threats and was expensive. (Dr.J.Jayakumar, J.Hephzibah Jose Queen, Thanu James, G.Hemalatha & NeethuLonappan, 2013).

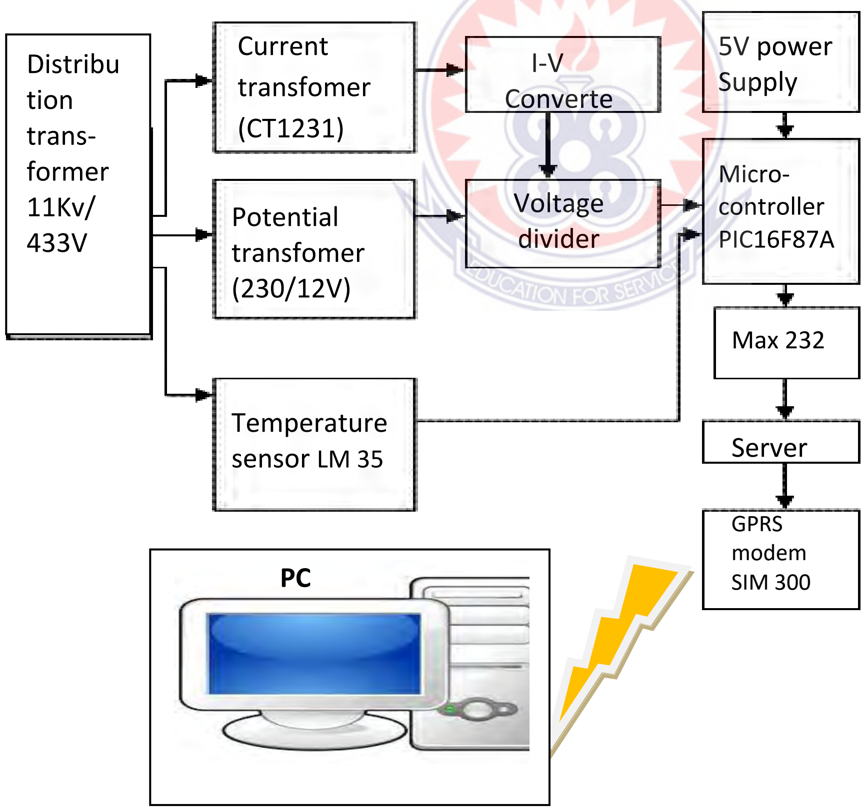


Figure 2.5: Distribution Transformer Monitoring Using GPRS

(Source: www.ijser.org)

Finally, aninnovative design about the development of remote monitoring system for a three-phase 10-kVA Switchable Distribution transformer with the help of a PIC microcontroller and Zigbee-based Wireless device was also proposed byDr. Rani Thottungal et al, (2014).

The PIC microcontroller from microchip helps in controlling the switching devices and monitors the current, voltage and temperature of the transformer. The Zigbee-based wireless device is used as long range wireless communication between the modules. The information is transmitted point by point using Zigbee transmitter and receiver and is sent to the server module to check the state of the transformer. Zigbee technology is simple, consumes less power and has low cost but cannot be used for very long range monitoring. (Dinesh, S., Kumar, R., Suresh Kumar & Dr.RaniThottungal. 2014).

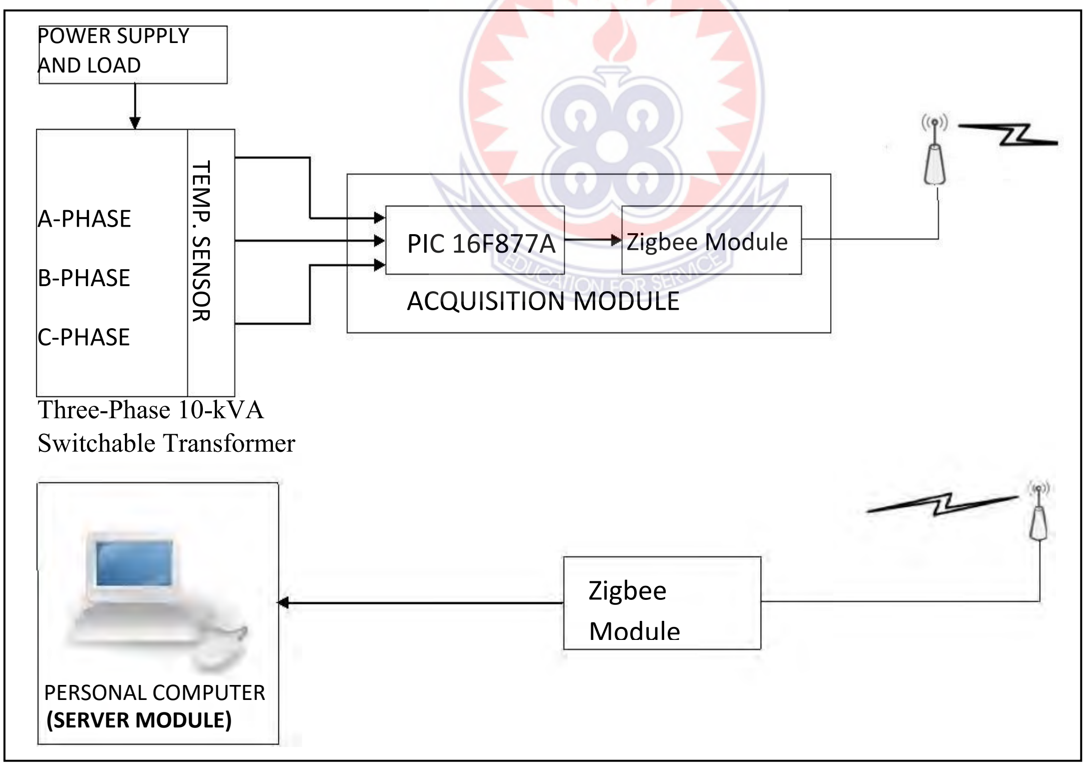


Figure 2.6: Distribution Transformer Monitoring Using Zigbee Technology

(Source: http://www.ijret.rg)

2.3 Comparing the Existed Systems to the Proposed System

The above researches has a number of deficiencies, however, a microcontroller based remote distribution transformer monitoring system using GSM Application has quite a number of merits which serves as remedy to the existed technologies deficiencies. That is:

- **Deficiencies of the Existed Technologies**

  i. Monitoring using artificial intelligence requires high-level computational skills.

  ii. The SCADA system has comparable higher cost and a bulky modeling.

  iii. Radio Frequency (RF) system is complex and suffers from frequency interference and noise in the network

  iv. GPRS Technology suffers from security threats and has higher cost

  v. Zigbee Technology cannot be used for very long range monitoring.

- **Merits of the Proposed System (Microcontroller Based GSM Application)**

  i. Prompt speedy notifications on over-current, over-voltage and rise in temperature.

  ii. Widespread use of mobile networks and GSM devices such as GSM modems and their decreasing costs have made them an attractive option not only for voice media but also for other wide area network applications.

  iii. With the help of this GSM module it is possible to send information whenever a fault is discovered. i.e. send text SMS to the service engineers' mobile phone.

  iv. GSM technology has the advantage of saving on cable costs and aid rapid installation of the communication infrastructure.

  v. It has a wider range of network coverage

  vi. It does not require web service for data transmission,

vii. Easy to implement since it makes use of existing networks and is portable. For instance, Ghana has a lot of mobile network operators and their combined operations have covered almost the whole country. This makes it possible for all the operators or assigned technicians to have access (network) to monitor transformers in different remote areas.

viii. GSM technology has flexibility. This means that a device and its associated communication equipment can be relocated at no additional cost of rewiring and excessive downtime. A new device and its associated communication equipment can also be installed easily, especially those remote pole-mounted transformers which cannot be reached by PLC and Optical Fiber Technology mainly due to their prohibitive cost.

Based on the above merits, it can be concluded that the system will enhanced the monitoring process and result in better protection of distribution transformers and hence ensure reliable power supply to consumers.

2.3 Theoretical Framework

This project plans to design and implement the hardware and its corresponding software of a low cost microcontroller based transformer monitoring system using GSM. This system will be mainly constructed with sensors, Peripheral Interface Controller (PIC) and GSM modem. The sensors sense the voltage, current and temperature and the sensed data are sent to thePIC. PIC receives the sensed data and checks for overload, overvoltage or overheating according to the programming. If there is over voltage, overload or overheating, the microcontroller sends a message to the user mobile phone from the GSM modem. This system is relatively cheap and has a wider range of network coverage, it does not require web service for data transmission, easy to implement since it makes use of existing networks and is portable. However, the number of SMS messages that can be processed by a GSM modem per minute is very low - only about six to ten SMS messages per minute. (Dr.HlaMyoTun&Win TunOo, 2014).

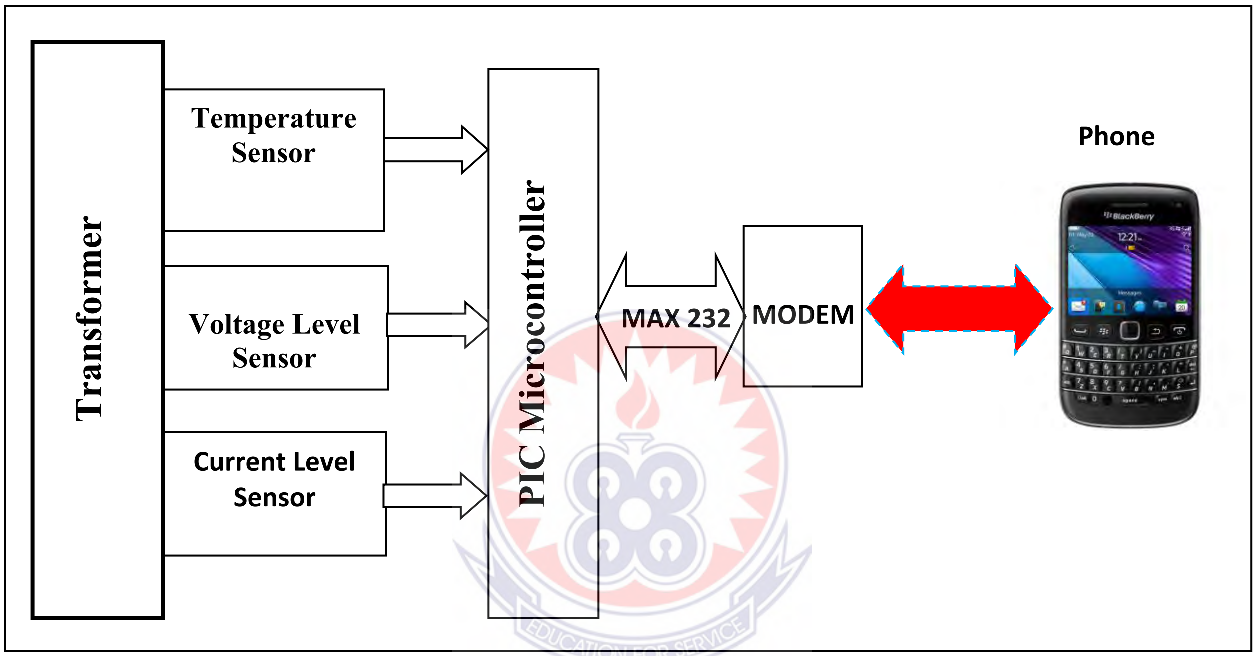


Figure 2.7: Distribution Transformer Monitoring Using GSM-SMS Technology

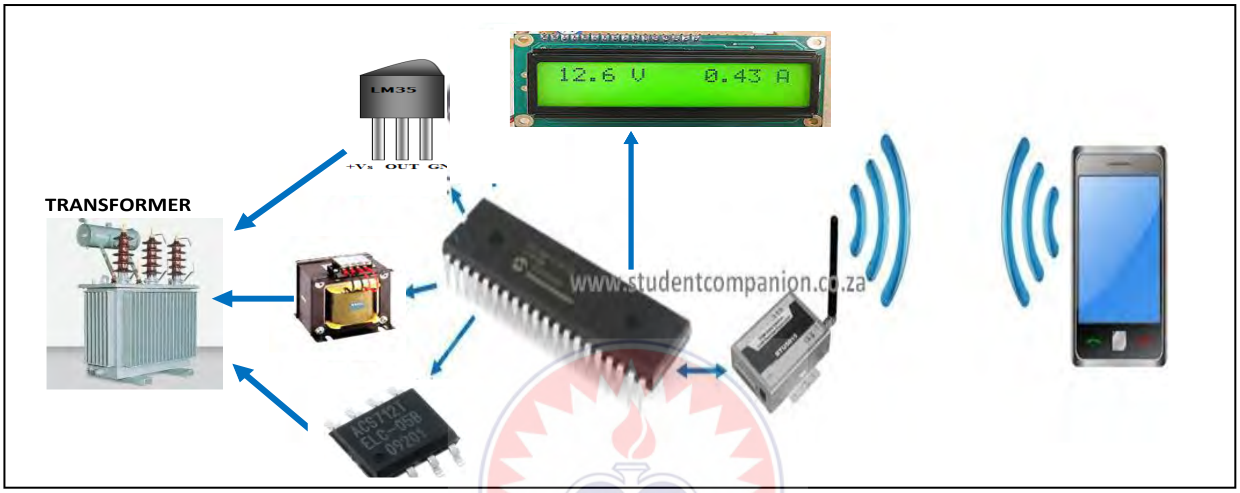
(Source: http://www.ijsrp.org/research-paper-0614/ijsrp-p3014.pdf)

CHAPTER 3

METHODOLOGY

3.1. Proposed System Design

Figure 3.1 shows the proposed system design.



The design consist of three sensors; voltage, current and temperature sensors installed at the secondary side of the transformer that reads the parameters (i.e. voltage, load current and oil temperature) of the distribution transformer respectively. The microcontroller continuously monitors the parameters and displays the values on an LCD. The displayed parameters are passed on to the GSM modem, which transmits the values in the form of SMS to the mobile phone.

This system is designed to automatically send real time electrical parameters periodically (based on time settings) in the form of SMS. Also, it is designed to send SMS alerts whenever the voltage, current or temperature exceeds predefined limits.

Users can also send commands in the form of SMS messages to read the remote electrical parameters.

3.2. Block Diagram of the System

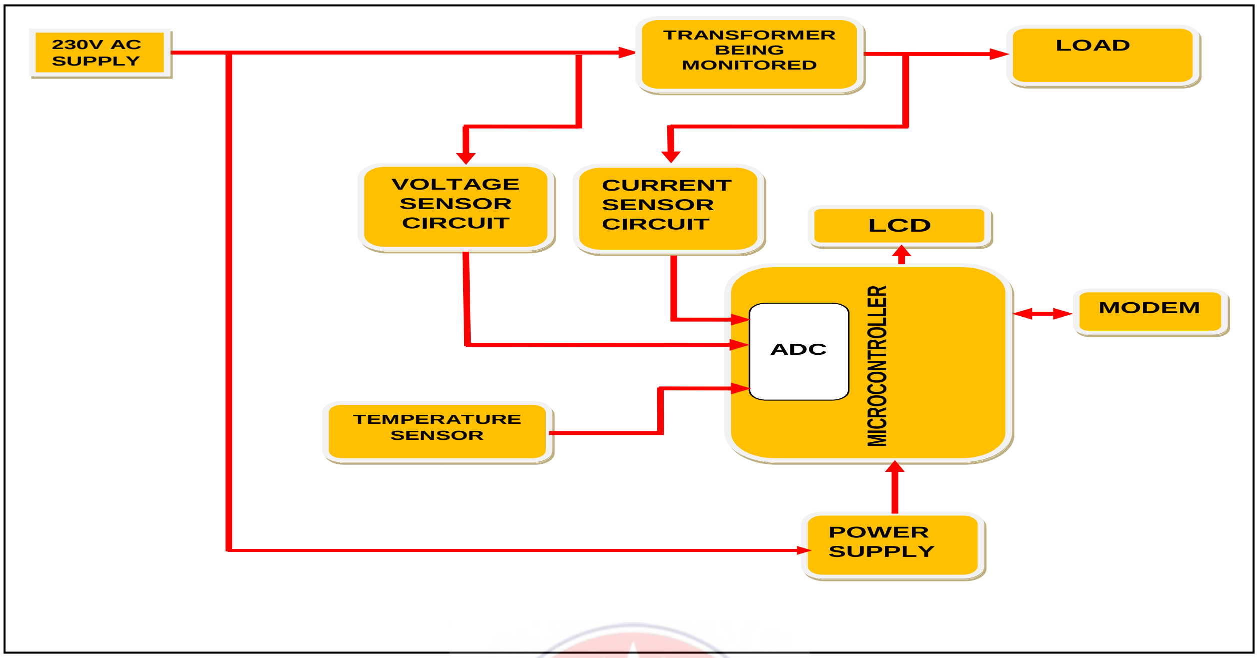


Figure 3.2: System Block diagram

Fig 3.2 shows a block diagram of GSM based condition monitoring and reporting system using microcontroller. Arduino Uno board with AVR (ATmega328) microcontroller is chosen for the implementation of this system since the desire for the microcontroller is to perform a lot of programmed functions; its large memory enables storage of all data readings in its memory space and finally its fast processor speed makes it efficient.

Three sensors are also mounted at the transformer station and it senses the voltage, current and temperature of the transformer. The transformer's primary input voltage is connected through a voltage sensing circuit to the microcontroller ADC pin for monitoring. The voltage sensing circuit consists of a 230V/12V step-down transformer, a bridge rectifier, capacitor filter and a voltage divider which ensures the input to the ADC does not exceed 5V.

The Voltage regulator is used to simulate the low voltage by adjusting its output to a value lower than the threshold voltage (170V). As the voltage falls below the set threshold voltage, a message is sent to the phone reporting a low voltage on the system

At the secondary side of the transformer, a current sensor is connected in series between the load and the transformer secondary terminal for sensing the load current. The output of the current sensor has a burden resistor, a diode rectifier and a filter before being fed to the microcontroller ADC pin for monitoring. The threshold current is set to 1Ampere, and the loads (4- 60 W incandescent light bulbs) are turned on simultaneously. As the load are switched on, the current rises and eventually goes pass the threshold current. The system reports with a test message indicating an overload.

A temperature sensor monitors the oil temperature and its output is connected to the ADC.
For overheating test, the threshold is set to 45ºC and using the incandescent lights as the source of heat, the system sends an SMS alert indicating overheating when the threshold temperature is reached.
The transmission to the phone is made possible by interfacing the microcontroller with a GSM modem.

This design can be divided into several units or modules. These are the sensor unit, processing unit and power unit. There are some devices, technology and components used in the design to implement each unit.

The devices are voltage sensor, voltage divdider, current sensor, temperature sensor, AVR(AT mega 328) microcontroller, GSM modem, liquid diplay unit,(LCD), power supply unit and Wireless Technolopgy.

3.3. DESIGN CONSIDERATIONS

3.3.1. Wireless Technology

A monitoring system must be safe, reliable, easy to use or implement, and cost effective. However, based on the literature reviews done on various existed remote monitoring technologies, the following deficiencies were realised:

i. Monitoring using artificial intelligence requires high-level computational skills.
ii. The SCADA system has comparable higher cost and a bulky modeling.
iii. J Radio Frequency (RF) system is complex and suffers from frequency interference and noise in the network
iv. GPRS Technology suffers from security threats and has higher cost
v. Zigbee Technology cannot be used for very long range monitoring.

With respect to the drawbacks outlined above, there was a need for a real-time electrical parameters monitoring system to detect all operating parameters and send it to the monitoring centre on time. It leads to online monitoring of operational parameters of distribution transformer which can provide useful information about the health of transformers which will help the utility companies to optimally use their transformers and keep it in operation for a longer period of time. This will help to identify problems before they become serious thus ensuring reliable power supply. In view of this, GSM Technology has been chosen based on the following intrinsic worth:

i. Widespread use of mobile networks and GSM devices such as GSM modems and their decreasing costs have made them an attractive option not only for voice media but also for other wide area network applications.

ii. With the help of this GSM module it is possible to send information whenever a fault is discovered i.e. send text SMS to the service engineers' mobile phone.

iii. GSM technology has the advantage of saving on cable costs and aid rapid installation of the communication infrastructure.

iv. It has a wider range of network coverage

v. It does not require web service for data transmission,

vi. Easy to implement since it makes use of existing networks and is portable. For instance, Ghana has a lot of mobile network operators and their combined operations have covered almost the whole country. This makes it possible for all the operators or assigned technicians to have access (network) to monitor transformers in different remote areas.

vii. GSM technology has flexibility. This means that a device and its associated communication equipment can be relocated at no additional cost of rewiring and excessive downtime. A new device and its associated communication equipment can also be installed easily, especially those remote pole-mounted transformers which cannot be reached by PLC and Optical Fiber Technology mainly due to their prohibitive cost.

The above qualities of GSM Technology caused it to be chosen, however, the number of SMS messages that can be processed by a GSM modem per minute is very low - only about six to ten SMS messages per minute.

3.3.2. Voltage Sensor

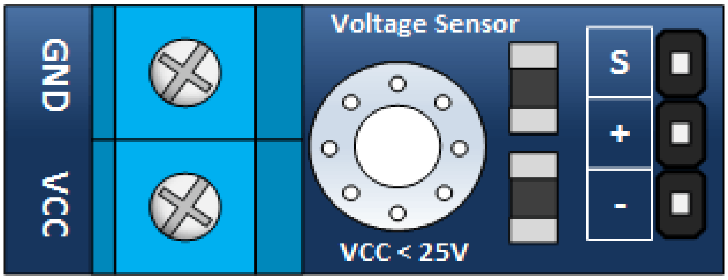


Figure 3.3: B25 Voltage Sensor Module

Fig. 3.3 shows the actual features of B25 arduino voltage sensor. The arduino analog input is limited to a 5 VDC input; however, a voltage divider could be used to regulate the input voltages to the arduino analogue input terminal.

It is fundamentally a 5:1 voltage divider using a 30KΩ and a 7.5KΩ resistor.

Note that, the voltage sensor is restricted to voltages that are less than 25 volts, above this will damage the board.

3.3.2.1. Basic Connection of the 25V Voltage Sensor to Arduino board

The **input** section consist of two terminals with one marked **GND** which is the same electrical point as the Arduino ground where the low side of the voltage to be measured is connected and the terminal **VCC** where the high side of the voltage to be measured is connected

The output side also has three terminal which is indicated as **S** which serve as the Arduino analog input, the Negative Terminal(-) as the Arduino ground and Positive terminal**(+)** which does absolutely nothing (normally not connected)

3.3.2.2. Schematic Diagram of the Voltage Sensor

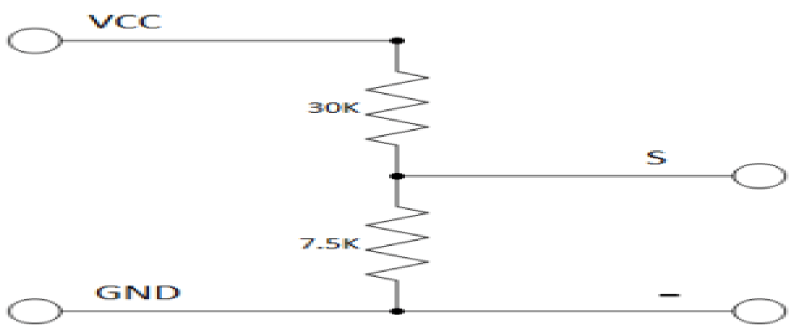


Figure 3.4: Schematic Diagram of voltage Sensor

The schematic diagram for the B25 voltage sensors is straight forward. As previously mentioned, it is a couple of resistors connected as shown in figure 3.4

3.3.2.3. Voltage Sensing Circuit

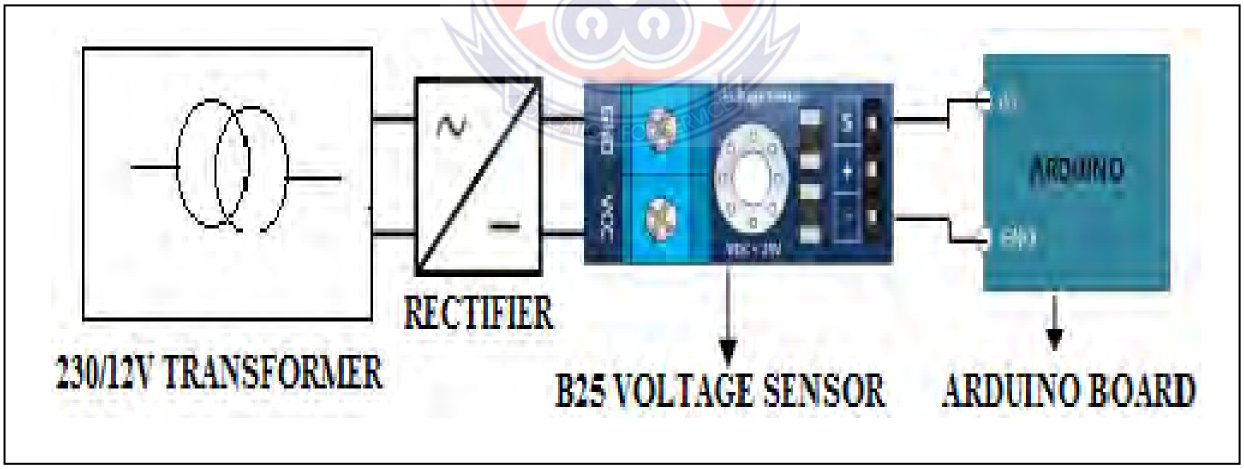


Figure 3.5: Voltage Sensor Circuit

Figure 3.5 shows the interconnection of the potential transformer with Arduino board. The Step down transformer is 230/12V. The output of the potential transformer is fed into the bridge rectifier for the rectification purpose and the rectified output from the bridge rectifier is again fed into the filter circuit in order to remove the ripples. The output of the filter goes through a voltage divider (B25 Voltage sensor) before it is fed to the analogue port of the microcontroller on the arduino board. **(**Dr.Jayakumar, J. et al. 2013)

3.3.2.4. Schematic Diagram of Voltage sensor Circuit

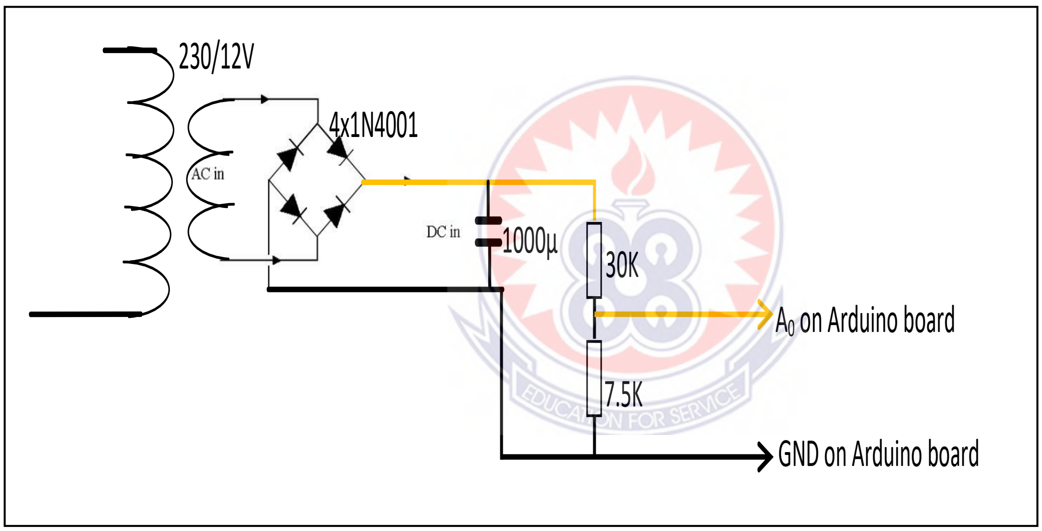


Figure 3.6: Schematic Diagram of Voltage Sensor Circuit

The respective connections are shown in fig. 3.6. The secondary voltage of the transformer is 12VAC and connectedto a bridge rectifier, therefore the DC output(V_{DC}) is approximately *16V* as shown in Appendix A.

The V_{AC} is the RMS transformer voltage and the 0.7V is the voltage drop across the rectifier. As there are two diodes conducting for each half cycle, there will be two rectifier voltage drops. This voltage V_{DC} is fed into the potential divider.

The B25 voltage sensor module shown in figure 3.4 is used. This ensures the maximum voltage fed to the Arduino analogue terminal is 3.2V.

3.3.3. Current Sensor

Current transformers (CTs) are sensors that are used for measuring alternating current.

The split core type such as the CT in Figure 3.7 is used for this project; it is particularly suitable for DIY use as it can be clipped straight on to either the live or neutral wire coming into the building without having to do any high voltage electrical work.

Figure 3.7: YHDC SCT-013-000 CT Sensor

3.3.3.1. Features of the YHDC SCT-013-000:

The YHDC SCT-013-000 CT Sensor has an input current range from 0A to 100A A.C with an output mode ranged from 0A to 50mA. It also has Non-linearity tolerance of ±3% with a turn ratio of 100A : 0.05A and a resistance grade of B.

Furthermore, it has a work temperature from 25°C to 70°C with dielectric strength (between shell and output) of 1000V AC/1min 5mA. The length of the Leading Wire is 1m and has a 13mm x 13mm in size.

3.3.3.2. Current Sensor Circuit

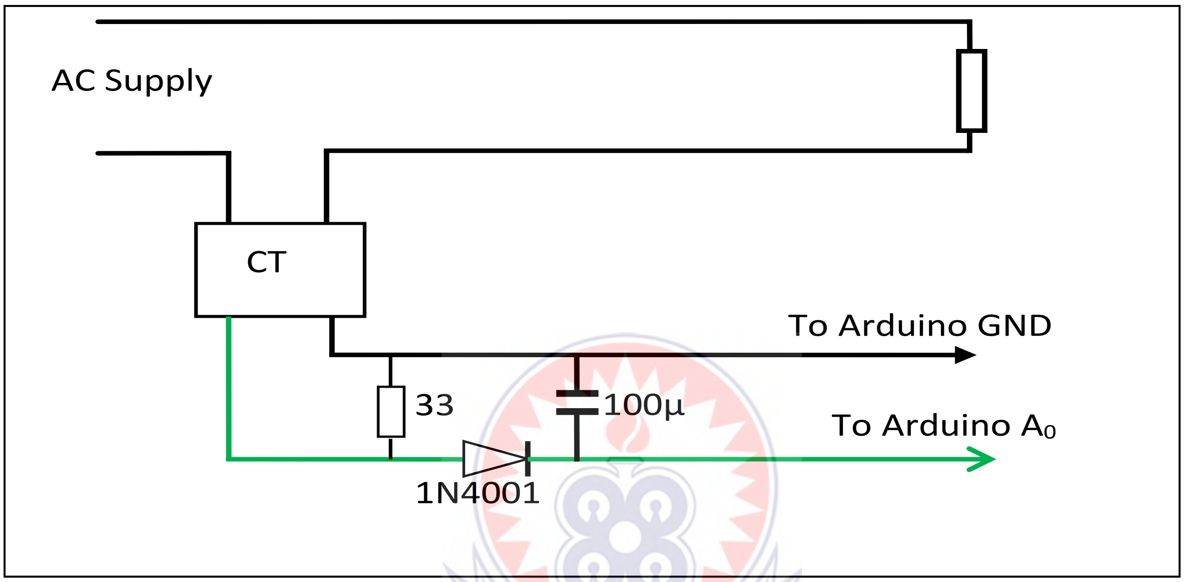


Figure 3.8: Current Sensor Circuit

Figure 3.8 depicts the interconnection between the current transformer and the Arduino board. Interfacing Current transformer with Arduino board is the same as interfacing potential transformer to the Arduino board as stated above except that a burden resistor is connected in parallel at the output in to convert the current to voltage since the microcontroller accepts only voltage as its input. The voltage generated is rectified and filtered before fed into the analogue input of the Arduino.

Calculating a suitable burden resistor size

If the CT sensor is a "current output" type such as the *YHDC SCT-013-000*, the current signal needs to be converted to a voltage signal with a burden resistor. If it is a voltage output CT; then this step can be skipped and the burden resistor can be left out. For this design, however, a burden resistor is needed.

Choosing the Burden Resistor

The YHDC SCT-013-000 CT has a current range of 0 to 100 A. Hence a 100A was chosen as the maximum current and was multiplied by √2 to Convert maximum RMS current to peak-current.

Also, the YHDC SCT-013-000 CT has 2000 turns; therefore the peak-current was divided by the number of turns in the CT to get the peak-current in the secondary coil.

Furthermore, Arduino running at 5V was used (AREF = 5) and to maximise measurement resolution, the voltage across the burden resistor at peak-current was to be equal to one-half of the Arduino analogue reference voltage. Thus: AREF / 2 = 2.5volts. Hence, the Ideal burden resistance is 35.4 Ω.

Note: The 35.4 Ω is not a common resistor value, hence the nearest common resistor value of either 33Ω or 39Ω can be used

Finally, In other for the maximum load current not to create a voltage higher than AREF, the smaller value of resistor was chosen thus; 33 Ω ±1% burden. Note that, in some cases, using 2 resistors in series will be closer to the ideal burden value. The further from the ideal value, the lower the accuracy will be. The detail calculations are shown in appendix A.

3.3.4. Temperature Sensor

Figure 3.9: TPT-32 Temperature Sensor

For sensing the transformer oil temperature, a sensor is chosen based on the following requirements: sensitivity, accuracy, temperature range, desired life of sensor, and budget. Temperature sensors used in practice are: Resistance Temperature Detector (RTD), Thermistor, Thermocouple and Semiconductor Temperature Sensors (LM34, LM35 or LM335). (www.bipom.com).

The thermistor, TPT-32, a temperature sensor for oil-filled transformers is employed in this project. (www.fiso.com). Thermistors are special solid temperature sensors that behave like temperature-sensitive electrical resistors.

There are basically two broad types, NTC-Negative Temperature used mostly in temperature sensing and PTC-Positive Temperature Coefficient, used mostly in electric current control. Thermistors are inexpensive and easy to use for temperature measurement. (Vadirajacharya K., AshishKharche, Harish Kulakarni, VivekLandage, 2012).

3.3.5. Microcontroller

The microcontroller is required to serve the purpose of monitoring the transformer information such as temperature, voltage and current through the LCD display, and then send an SMS through the modem to a mobile phone.

The microcontroller is chosen considering processing speed, memory size, power consumption, and ease of interfacing with other peripherals.

The main types of microcontroller are Advanced Virtual RISC (AVR) Microcontroller, Peripheral Interface Controller (PIC) Microcontroller and Advanced RISC Machines (ARM) Microcontroller. (Thiyagarajan, V.&Palanivel, T.G., 2010).

An Arduino Uno board with AVR (ATmega328) microcontroller is chosen for the implementation of this system for the following reasons:

1. It is not expensive
2. It comes with an open source hardware feature which enables users to develop their own kit using it as a source of reference.
3. The Arduino software is compatible with all types of operating systems like Windows, Linux, and Macintosh etc.
4. It also comes with an open source software feature which enables experienced software developers to use the Arduino code to merge with the existing programming language libraries and can also be extended and modified.
5. It is easy to use even by beginners.
6. Stand-alone Arduino based project can be wholly developed.

7. It comes with an easy provision of connecting with the CPU of the computer using serial communication over USB as it contains built in power and reset circuitry.

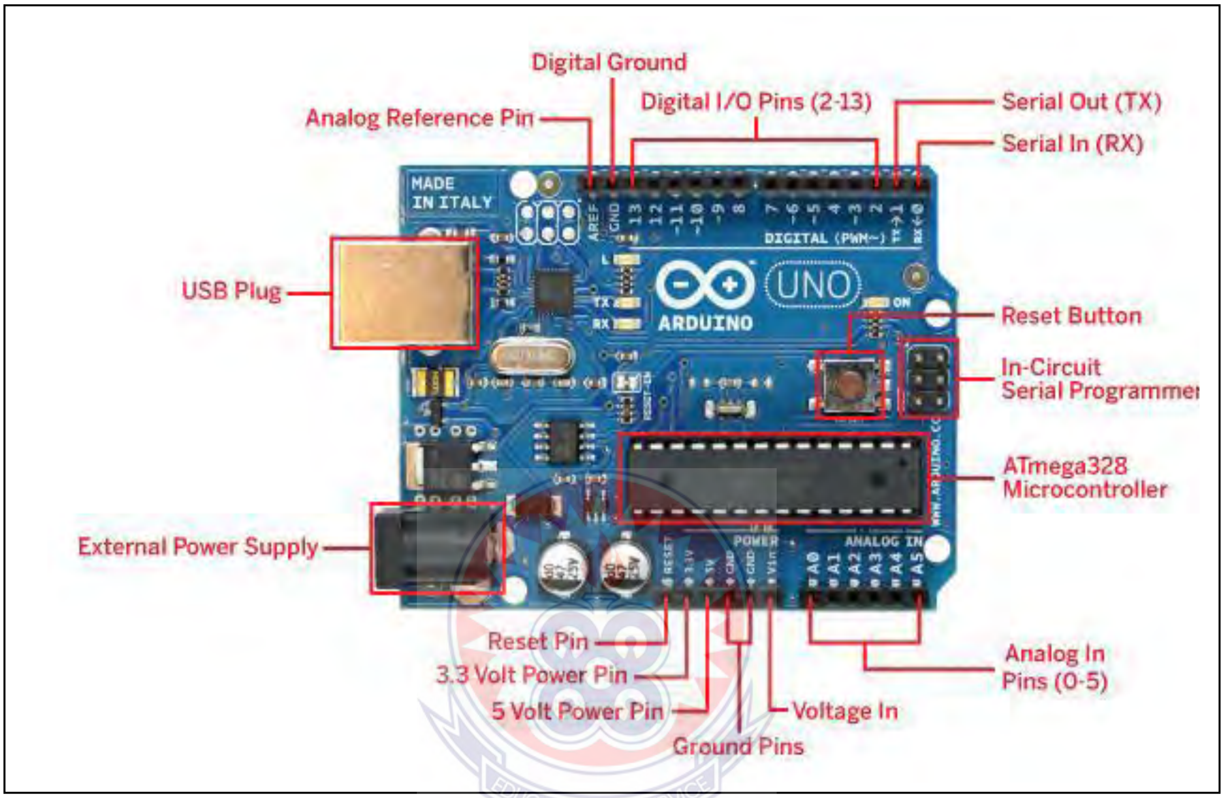


Figure 3.10: Arduino UNO Board

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on computer, and is used to write and upload computer code to the physical board.

The Arduino platform has become quite popular with electronic designs, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new codes onto the board; a USB cable can simply be used. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package.

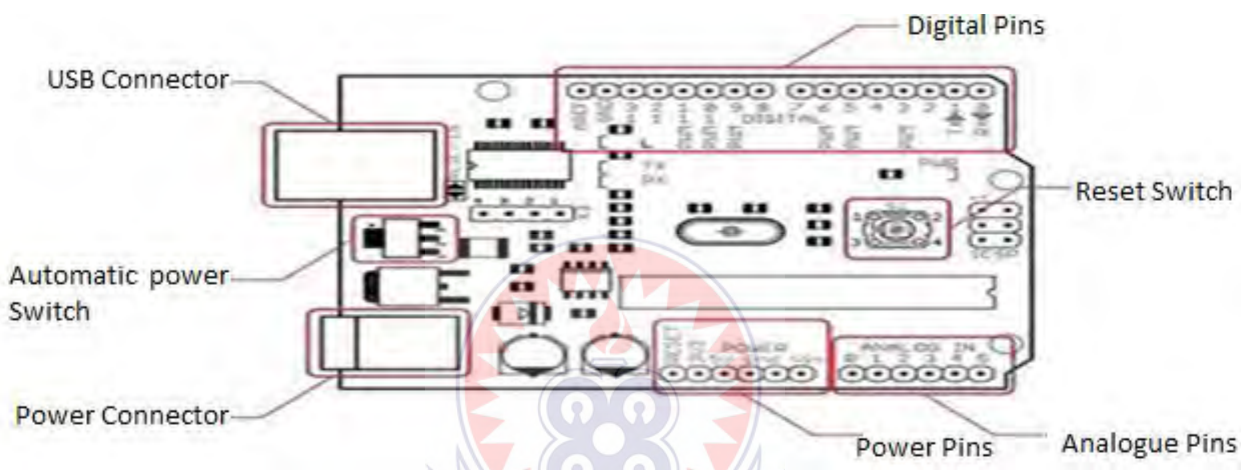


Fig 3.11: Arduino Pin Diagram

Fig 3.11 shows the most important parts on the arduino boardPower Pins

The Uno is one of the most popular boards in the Arduino family, it consists of 14 digital input/output pins out of which 6 can be used as Pulse-Width Modulation (PWM) outputs, 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an in-circuit serial programming (ICSP) header, and a reset button.

Arduino can be powered either from the pc through a USB or through external source like adaptor or a battery. It can operate on an external supply of 7 to 12V. Power can be applied externally through the pin Vin or by giving voltage reference through the I/O Ref pin. It also consists of 14 digital inputs/output pins; each provides or takes up 40mA current. Some of them have special functions like pins 0 and 1, which act as Rx and Tx respectively , for serial communication, pins 2 and 3-which are external interrupts, pins 3,5,6,9,11 which provides pwm output and pin 13 where LED is connected.

Again, It has 6 analog input/output pins, each providing a resolution of 10 bits and a reference port which provides reference to the analog inputs. The Arduino has a reset button. Pushing it will temporarily connect the reset pin to ground and restart any code that is loaded on the Arduino.

Arduino has the advantage of been very easy to get started, can be used for real-time applications, everything (both hardware, software and IDE) are open source and not much programming knowledge is needed

3.3.6. GSM Modem

Figure 3.12: SIM900 GSM Module

The GSM modem communicates with the user cell phone to initiate the condition obtained for the microcontroller. In choosing a modem, the considerations are: ease of interface with microcontroller, portability, ease of remote control and logging, universality, etc.

Some GSM modems used for remote monitoring are GM28, FARGO MAESTRO 20, SIM300, and SIM900 (Saravana, M.,Kumar, K. R.,Prasanna, S. D.&SundarsinghJebaseelan, 2014.).

3.3.7. Display Unit

Figure 3.13: Liquid Crystal Display (LCD)

Light Emitting Diodes (LEDs) and Liquid Crystal Displays (LCDs) can be used to display the monitored values.

A liquid crystal display (LCD) is a flat panel display, electronic visual display, or video display that uses the light modulate. LCDs do not emit light directly.

In recent years the LCD is finding widespread use replacing LED's. This is due to the following reasons:

1. Declining prices
2. Ability to display numbers, characters and graphics.
3. Incorporation of a refreshing controller into the LCD.
4. Ease of programming.
5. Ease of interfacing with microcontroller.

Fortunately, a very popular standard exists which allows us to communicate with the vast majority of LCDs regardless of their manufacturer. The standard is referred as HD44780U, which refers to the controller chip which receives data from an external source and communicates directly with the LCD.

The display used is 16x2 LCD (Liquid Crystal Display); which means 16 characters per line by 2 lines.

3.4. Software Requirements

The software design plays a very important role in the working of the entire system; the system will not operate without the software.

3.4.1 Arduino Integrated Development Environment

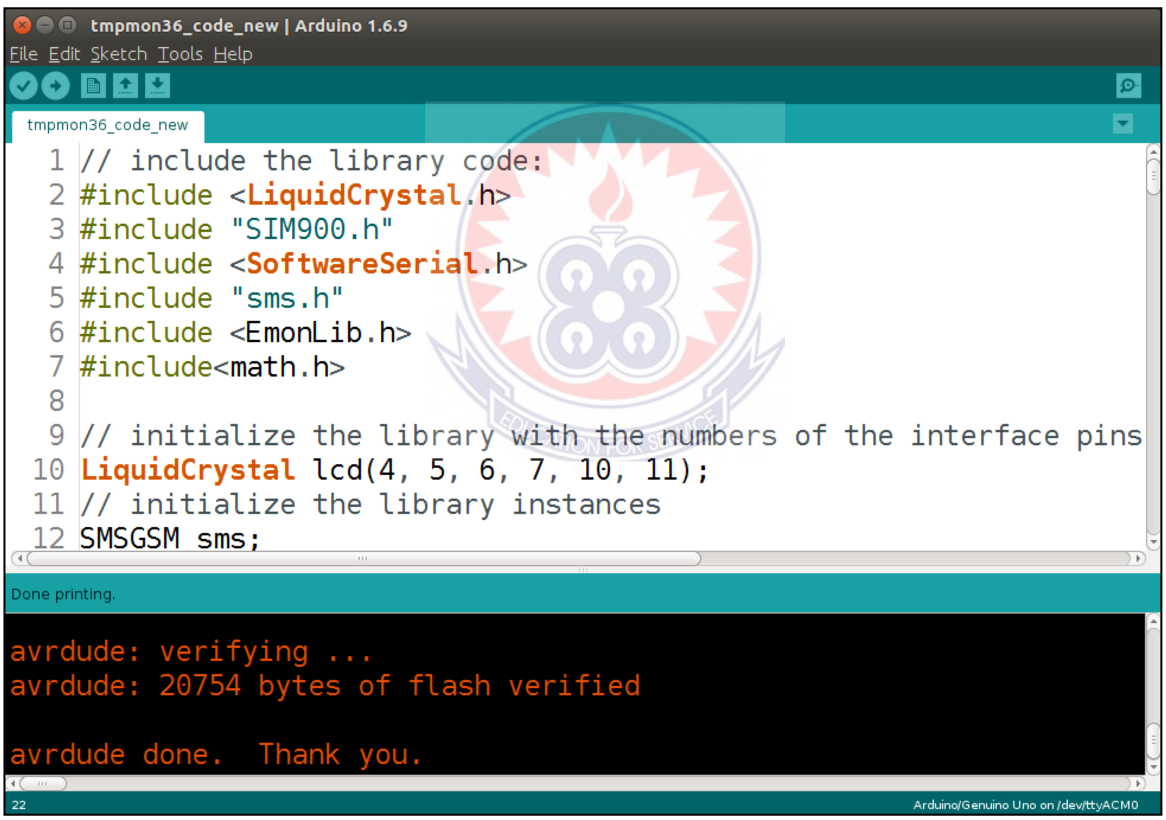


Figure 3.14: Arduino IDE

The Arduino Integrated Development Environment or Aduino Software consists of toolbar with the buttons like verify, upload, new, open, save, serial monitor. It also consists of a text editor to write the code, a message area which displays the feedback like showing the errors, the text console which displays the output and a series of menus like the File, Edit, and tools menu.

Fig 3.14 shows a screenshot of the Arduinosoftware. The white area is where the program is written. The programming language that the Arduino platform uses is

called C++ (pronounced *see plus plus*),

C++ programs are written as regular text. Arduino calls these programs*Sketches*. Then a utility called *compiler* reads the sketch and converts it to machine instructions that the Arduino understands.

The black area at the bottom of the Arduino software window is where status information appears. For example, if your C++ code has an error this is where you will see the details.

The Arduino software also has a toolbar with the verify button which runs the C++ compiler. If there are any errors it will be seen in the black status area. It also has upload button which ompiles the C++ program like the Verify button does, and if compilation is successful it uploads the resulting program to the Arduino board, which must be connected to the computer through the USB port.

Moreover, it has a new button which Clears the current loaded program and an open button that shows a dropdown with a long list of examples of programs that can be loaded or the option to load a sketch from disk.

Also it has a save button which Saves the current program to a file on disk and a serial Monitor: Opens the serial monitor console. This is used mostly for debugging.

The most important advantage with Arduino is that, the programs can be directly loaded to the device without requiring any hardware programmer to burn the program. This is done because of the presence of the 0.5KB of Boot loader which allows the program to be burned into the circuit. All that has to be done is to download the Arduino software and write the code

3.4.1 Flow chart of the software implementation

The flowchart gives a diagram representation of the program algorithm.

The flowchart below shows the initial description of the system program code and the printout of the code is attached as appendix 'A' and 'B'

The program initializes and reads the Analogue to Digital Converted (ADC) signals and the Universal Synchronous/Asynchronous Receiver/Transmitter (USART) pins, then sends the transformer parameters which are fed to the ADC to GSM Modem, then to the LCD display. The microcontroller ADC continuously captures the transformer parameters, and as soon as overvoltage, overcurrent or overheating is observed, an SMS is sent to a mobile phone via the GSM Modem. Also, when an AT commands (QUERY) is received from the mobile phone, the values displayed on the LCD are sent to the mobile phone. The system flowchart is designed as shown in fig 3.15.

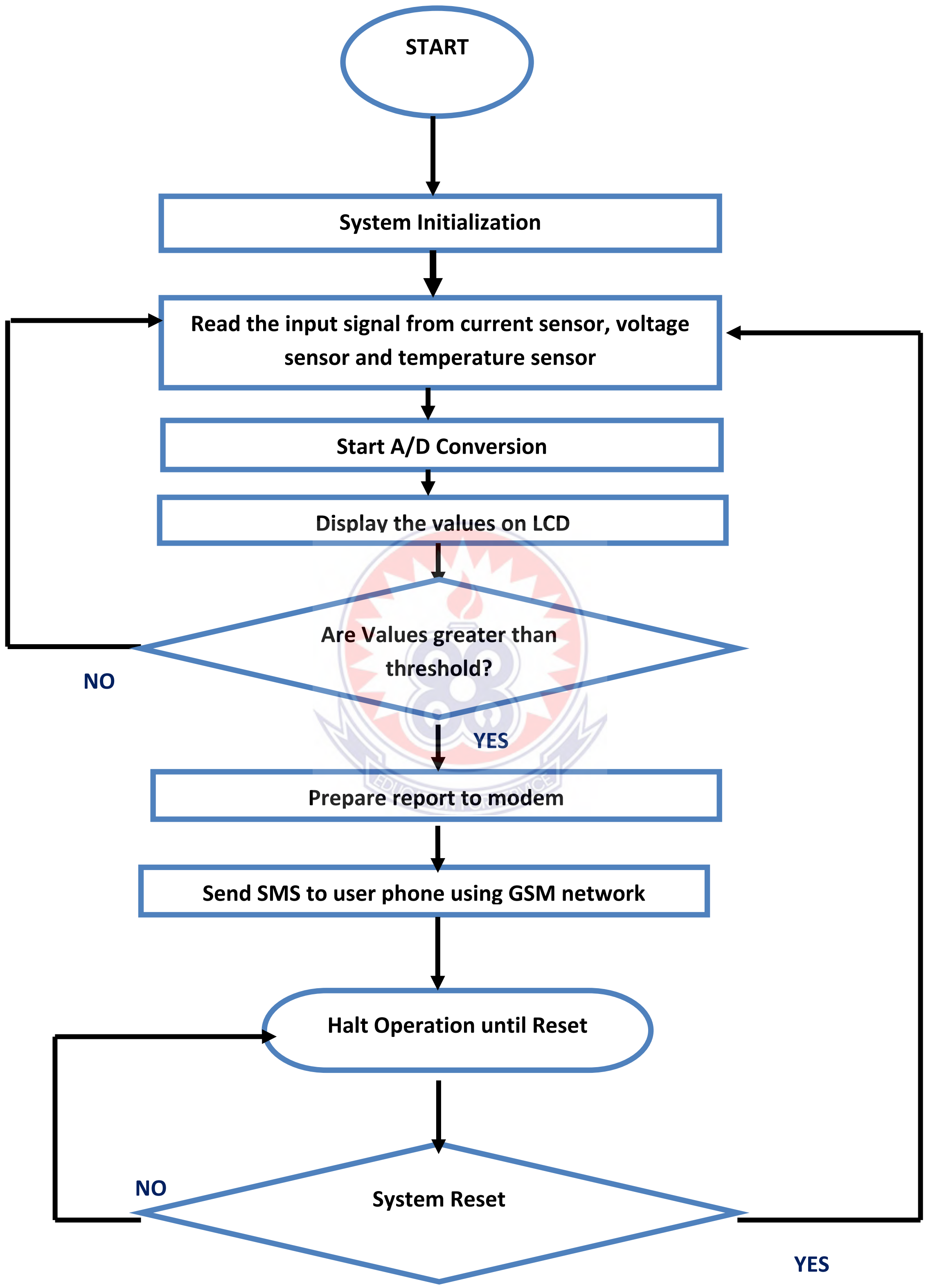


Figure 3.15: Software Flow Chart

3.5. Hardware Implementation

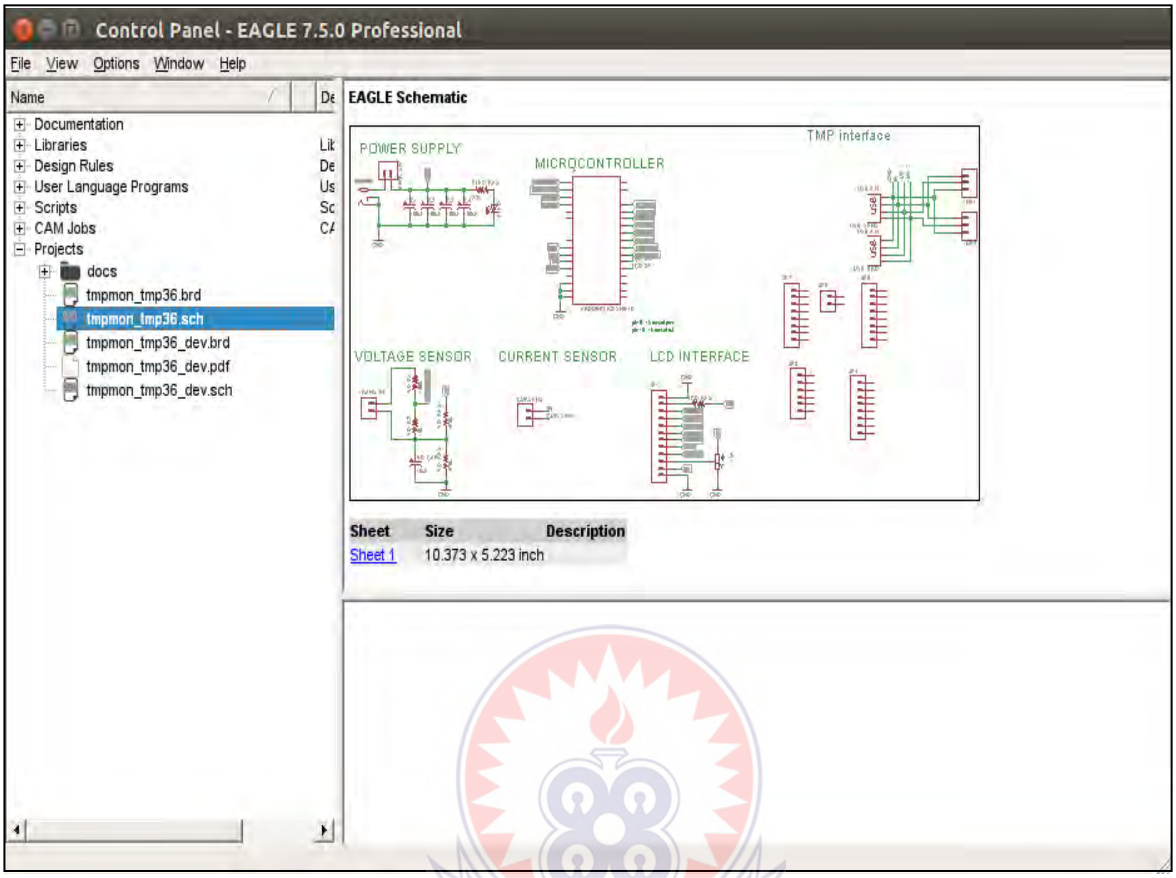


Fig 3.16: Arduino's UNO R3 Board Schematic Screenshot

There are many CAD developed to assist electronic designs during the drawing of PCBs and schematics; often they are integrated in complete suite to project, simulate and realize a whole electronic system. Besides the many commercial versions, Eaglecad was chosen to design the electronic schematic layout and the printed circuit board (PCB) as shown in fig 3.16

Eagle is the acronym of Easily Applicable Graphical Layout Editor made by Cadsoft. It was the preferred choice because it has a clean and easy to understand interfacethe right tools and a large component library. It is a professional software that has gained a lot of popularity due to the Arduino's success. One of the most important differences between Eaglecad and its competitorsis the availability of a version for every of the most common desktop OS: Windows, Linux, and Mac.

3.5.1 Complete Circuit Diagram of the Hardware Implementation

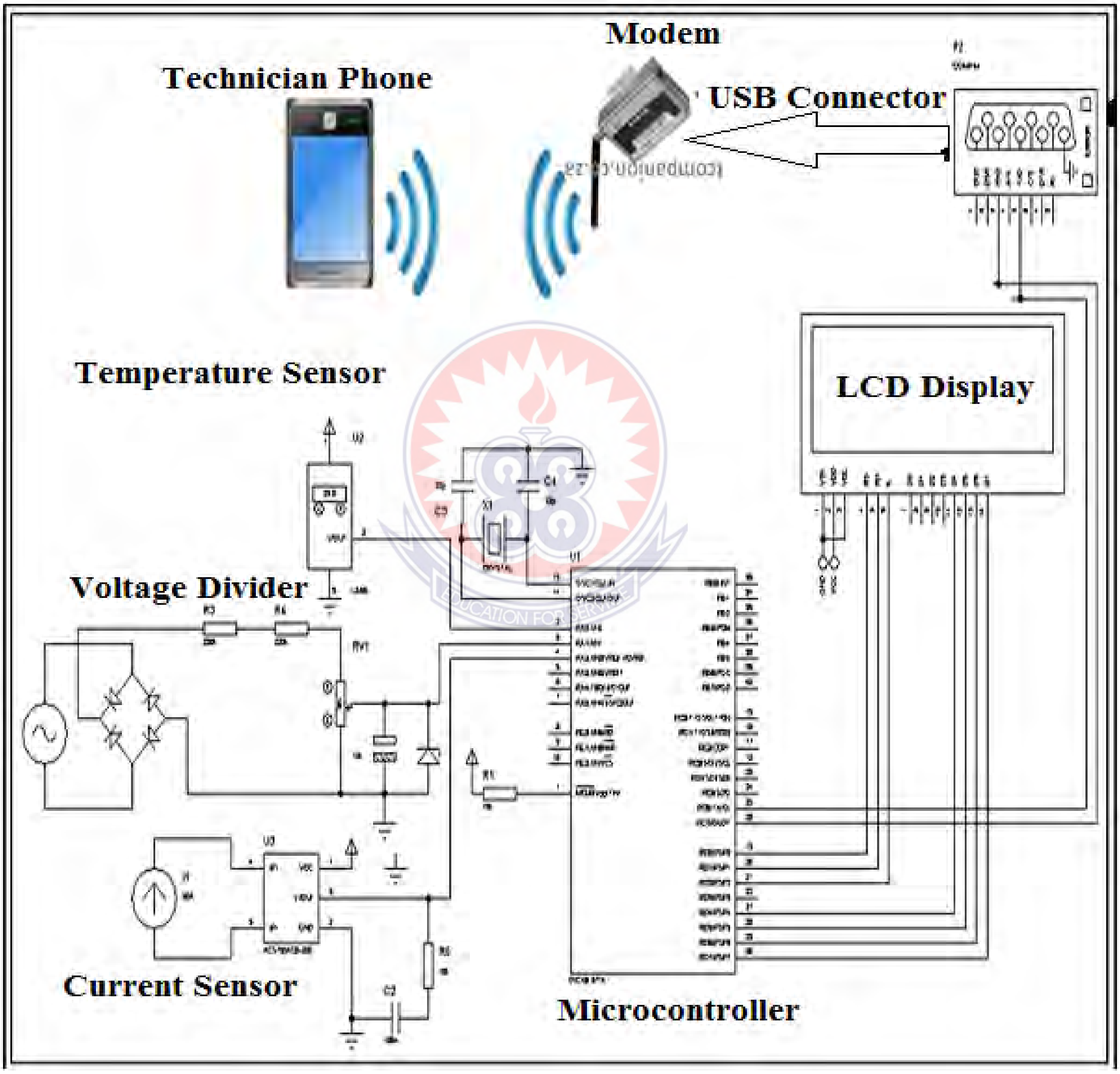


Figure 3.17: Complete Circuit Diagram of the System

3.5.2 Principle of Operation

Figure 3.17 shows the complete circuit diagram of the hardware implementation of a distribution transformer monitoring system using GSM.

The device is powered by a 9V, 1.5A power supply which takes its input from the AC lines and step it down to 9V working voltage. The power supply has fuse protection that ensures that the device is not destroyed by high current.

When the device is powered, it initializes the connected sensors and the GSM module. It then begins to monitor the temperature of the transformer, the voltage at which it operates, and the current being distributed. These data are recorded as analog electric signals by the tmp36 temperature sensor, voltage sensor and the ACS712 current sensor respectively. The analog signals are relayed to the 10 bit resolution digital Converter (ADC) of the arduino where the analog data is represented in the digital format for processing. The analog data is represented as an integer value between 0 and 1024 which corresponds to 0 V to 5 V. The digital values are slotted into the following formulas for computing the temperature, current and voltage from the sensors, to get the actual temperature, current and voltage readings:

i. Temperature = (Analog Reading/ 1024.0) * 5000.0) - 500.0) / 10.0

ii. Current = (((513 – Analog Reading) * 27.03)/1024.0) – 0.03

iii. The voltage is obtained through a series of operations outlined in the source code.

The actual readings are compared to a set threshold values. The current operating conditions are displayed on the LCD screen for quick lookup. When readings are higher than the threshold values recorded, they trigger the microprocessor to prepare a report which is sent to the operator via SMS. The system suspends its activities and displays an alert message on the screen, waiting for the operator to perform an action. After the operator has remedied the situation, he can perform a manual reset on the device by pressing the reset button or reset the device remotely via text messages by sending the RESET command. When the device receives the reset command, it resumes its monitoring activities.

At any point in time, the operator can query the state of the device remotely by sending the QUERY command via SMS. When the device receives this command, it prepares a report on the current systems operating conditions and relay it to the operator via SMS.

The circuit section consists of a microcontroller, circuit for voltage sensing, current sensing circuit, a temperature sensor, a GSM modem and an LCD display.

Voltage monitoring is achieved using a potential transformer.The Potential Transformer (PT) is a step down transformer of rating 230/12V. The output of the potential transformer is fed into the bridge rectifier for the rectification purpose and the rectified output from the bridge rectifier is again fed into the filter circuit in order to remove the ripples. The output of the filter goes through a voltage divider before it is fed to the analogue port of the microcontroller.

For the purpose of current sensing, a current transformer is used. To connect a CT sensor to an Arduino, the output signal from the CT sensor needs to be conditioned so it meets the input requirements of the Arduino analog inputs, that is a positive voltage between 0V and the ADC reference voltage. The CT output is a current signal and is converted to a voltage signal with a burden resistor. This voltage is rectified and filtered before fed into the ADC of the Arduino.

Oil temperature is monitored using a thermistor TPT-32 sensor immersed.

A 9V/2A AC-DC adaptor is used as power supply to the Arduino board.

The microcontroller sends the monitored parameters to LCD display and when the voltage, current or temperature exceeds the pre-set limits, a message is sent to a mobile phone. The transmission to the mobile phone is made possible by interfacing the microcontroller with a GSM modem.

CHAPTER 4

TEST AND RESULTS DISCUSSION

4.1. Constructed and Tested Project Prototype

4.1.1. Actual connection of the Voltage Regulator and the Sensors

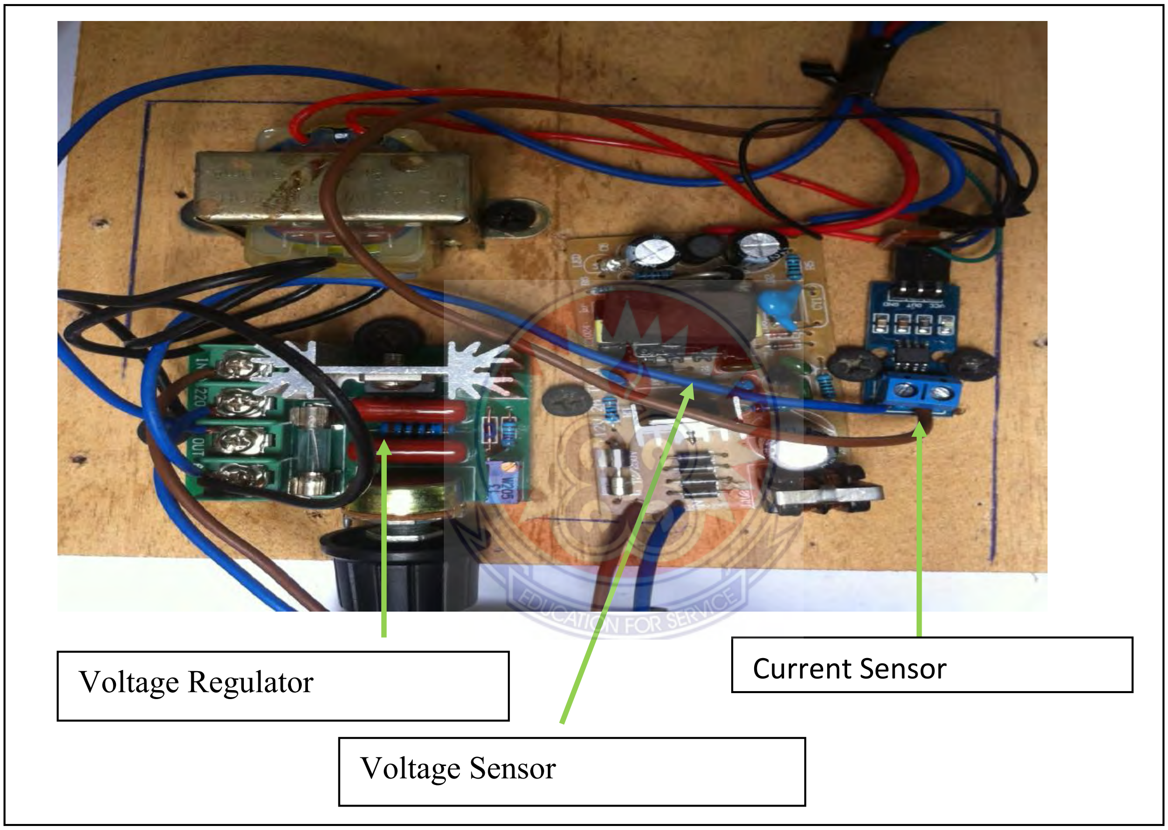


Figure 4.1: Actual Connection of Voltage Regulator and Sensors

Figure 4.1 shows the respective electronic components used in designing the various modules. Three sensors: voltage sensor, current sensor and temperature sensor were used to collect the distribution transformer's voltage, current and temperature respectively; also, a 230/12V voltage regulator was used to regulate the systems input supply.

4.1.2. Arrangement of the Systems Load and Temperature Sensor

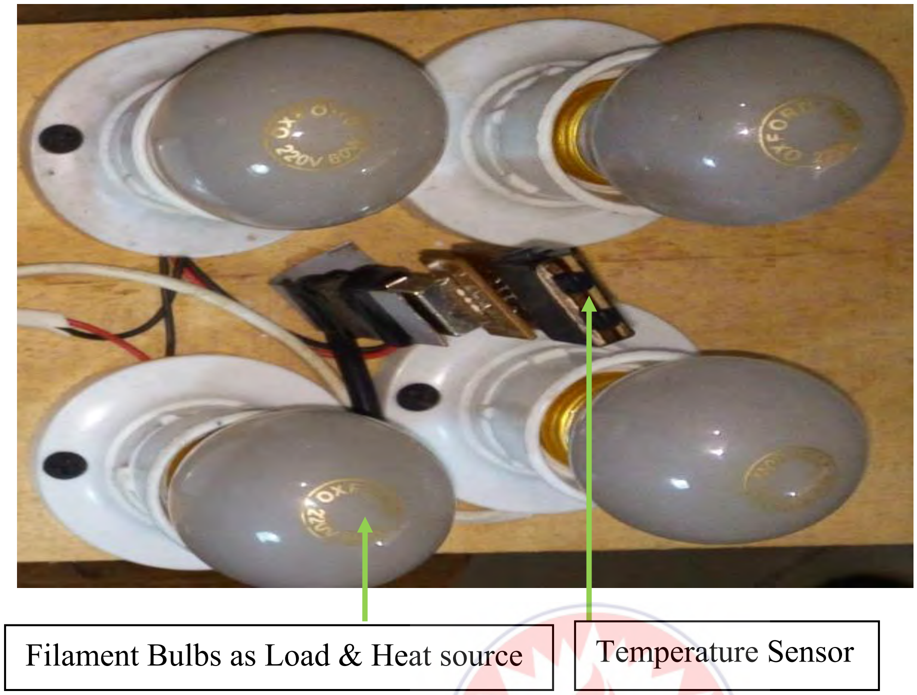


Figure 4.2: Connection of 60W Incandescent Bulbs and Temperature Sensor

Figure 4.2 shows the actual connection of four 60W incandescent bulbs connected in parallel and are used as load as well as the heat source for the temperature sensor which is inserted in the middle of the filament lamps. As the lamps are turned ON, it produces heat and that heat is sensed by the temperature sensor which sends a signal to the microcontroller.

4.1.3. Arrangement of the Actual Electronic Boards and the Display Unit

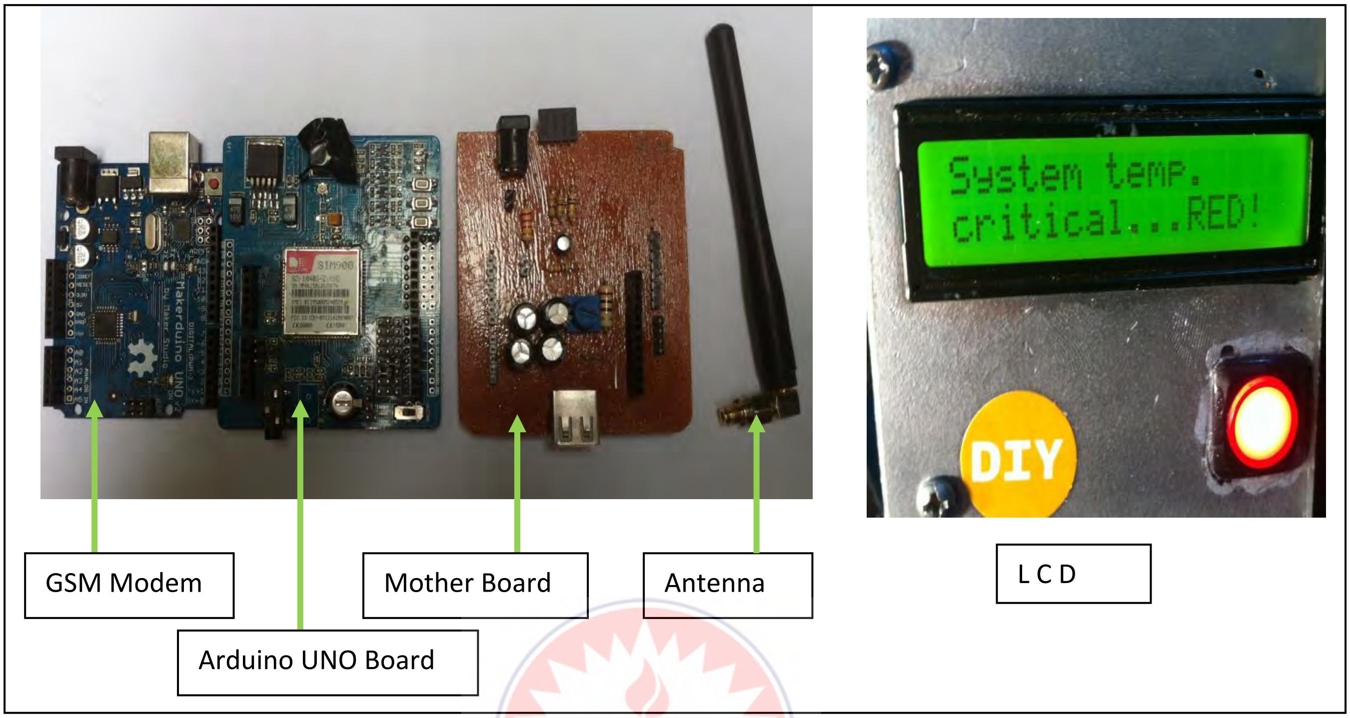


Figure 4.3: Electronic Boards and LCD

Figure 4.3 shows the various electronic boards used in designing the system. It involves the GSM Board, Arduino UNO Board, Mother Board, Modem's Antenna and the Liquid Crystal Display (LCD). The three electronic boards are designed to be interfaced and are programmed to function collectively.

The Arduino board which incorporates the microcontroller continuously monitors the sensed parameters and displays the values on an LCD. The displayed parameters are given to the GSM modem, which transmit the values in the form of SMS to the technician's mobile phone.

4.1.4. Hardware Module Identification and Operation

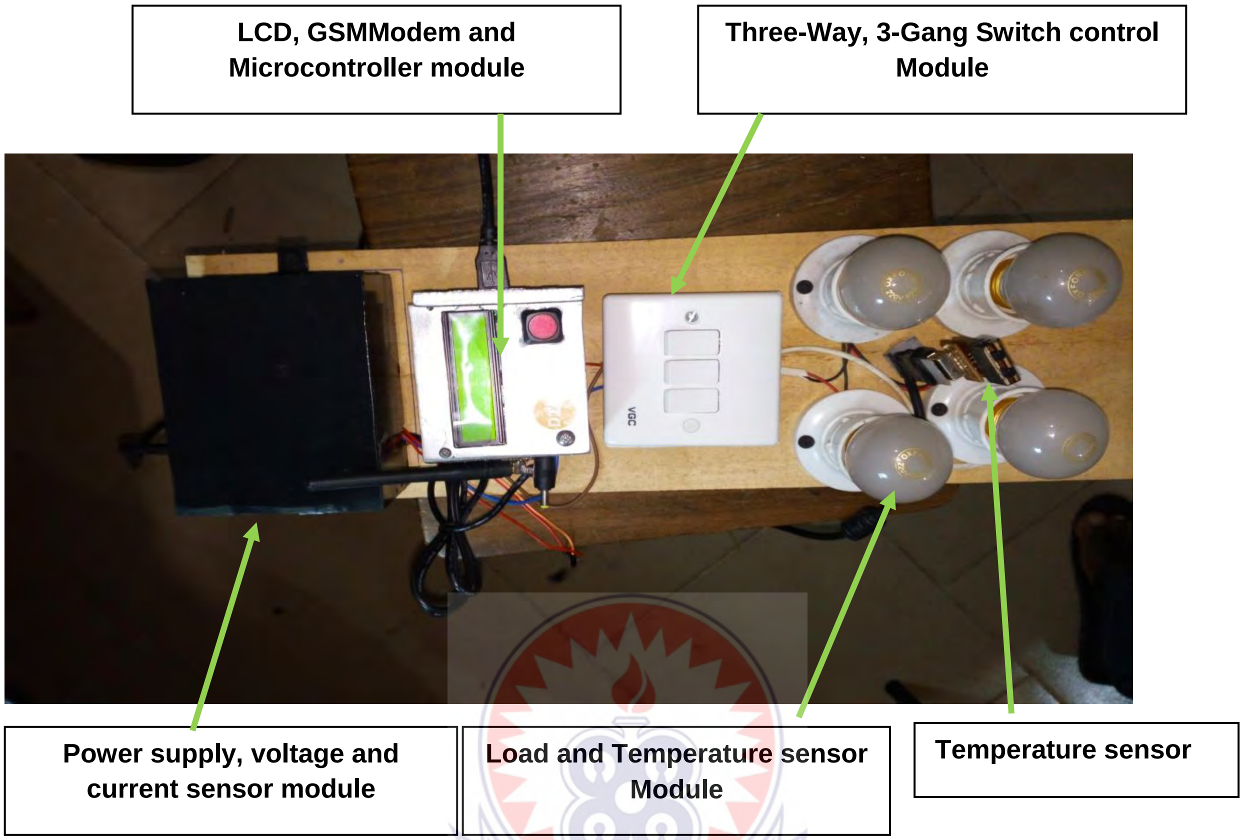


Figure 4.4: System Connection in Modules

The microcontroller based dedicated hardware unit (DHU) is constructed in this research as modules as shown in figure 4.4.

Thus:

- Power supply, voltage and current sensor module
- LCD, GSM Modem and Microcontroller module
- Load and Temperature Sensor Module
- Three-Way, 3-Gang Switch control Module

In this hardware construction, the temperature sensor, current sensor and voltage divider network sense the temperature, current and voltage respectively of the AC mains line instead of the power station equipment. Then the sensed data are transmitted to the GSM modem and the GSM modem then transmits the data to the operator's GSM mobile. A three-way, 3-gang switch was used as the load controller to regulate the number of loads that can be connected to the system at a particular time.

Actual System Design | Signals Displayed on LCD | SMS Received on Phone

Figure 4.5 Arrangement of Systems Operation Process

Figure 4.5 shows the Arrangement of the systems operation processes. The circuit can successfully monitor the distribution transformer, display the sensed parameters on LCD, transmit and receive SMS on temperature, current, voltage and query reports of the distribution transformer on a mobile Phone.

4.2 Test Results Analysis

4.2.1 Voltage Test

Voltage regulator was used to simulate low voltage by adjusting its output to a value lower than the threshold voltage (170V). As the voltage fell below the set threshold voltage, a message was sent to the phone reporting a low voltage on the system as shown in fig. 5.1.

The system uses any of the exited communication networks for its operation though the power supply authorities could adoupt their own network system.

Also the system will keep sending the fault messages until the fault is cleared then the system can be reset to work normal.

LCD Displaying Low Voltage

Low Voltage SMS Received on phone

Figure 5.1: System Reporting Low Voltage

4.2.2 Current Test

A similar test was conducted for current overload. The threshold current was set to 1 A, and the load (4- 60 W incandescent light bulbs) was turned on simultaneously. As the load was switched on, the current rose and eventually exceeded the threshold current. The system reported with a test message indicating an overload. Again, The system uses any of the exited communication networks for its operation though the power supply authorities could adoupt their own network system.

Also the system will keep sending the fault messages to the operators phone until the fault is cleared then the system can be reset to work normal.

LCD Displaying High Current

System Overloaded SMS Received

Figure 5.2: System Reporting Overload

4.2.3 Overheating Test

For the overheating test, the threshold was set to 45ºC and using the incandescent lights as the source of heat, the system sent an SMS alert indicating overheating when the threshold temperature wasexceeded.

Theis fault normally occurs when the distribution transformer is overloaded or when there are leakages which causes much higher demand on the transformer. Note that, this type of signal will need the urgent attention of the technician on duty or serous damage could result.

LCD Displaying System Overheated

System Overheated SMS Received

Figure 5.3: System Reporting Overheating

4.2.4 System Query

The device's temperature, voltage and current status can be accessed by sending "QUERY" via text message to the device and a report as shown in the Figure below will be received

This checks can be done at any point in time and at anywhere provided there is access to the communication network. Also there is no limitation as to the number of times to access the condition of the distribution transformer. This makes is easier and convienient to monitor all the transformer parameters which will help to ensure reliable supply of power. Xv

LCD Displaying Received Query | QUERY SMS Received on Phone

Figure 5.4: System Reporting Transformer Status

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this research, distribution transformer key parameters like voltage, current and temperature were monitored employing a microcontroller.

The components necessary to carry out the monitoring were chosen and interfaced with the microcontroller. The wireless communication technology (GSM) was put to work to transfer the monitored parameters from the microcontroller to a designated mobile phone.

The system was constructed and its performance tested. The system operated successfully. Therefore, this system can be practically used for monitoring of distribution transformers.

5.2 Future Recommendations

The following are recommended for future studies in order to improve performance.

- Provision of a switch so that the transformer can be disconnected when the voltage, current or temperature rises to a value that can damage the transformer.
- A server module can be integrated to this system to receive and store transformer parameter information periodically. This database will serve as a useful source of information on utility transformers. Analysis of these stored data will help utility companies to monitor the operational behavior of their distribution transformers and

identify faults before any catastrophic failures occurs thus this will result in significantly saving cost as well as improve on system reliability.

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APPENDICES

APPENDIX A : DESIGN CALCULATIONS

DC VOLTAGE DESIGN CALCULATION.

The secondary voltage of the transformer is 12VAC and connected to a bridge rectifier, therefore the DC output is approximately:

$V_{DC} = (1.414 \times V_{AC}) - (2 \times 0.7)$

$= (1.414 \times 12) - 1.4$

$= 15.57V \approx 16V$

CALCULATING A SUITABLE BURDEN RESISTOR SIZE

Primary peak-current = RMS current × √2

= 100A × 1.414

= 141.4A

Secondary peak-current = Primary peak-current / no. of turns

= 141.4 A / 2000

= 0.0707

VOLTAGE ACROSS THE BURDEN RESISTOR AT PEAK-CURRENT

Thus: AREF / 2 = 2.5 Volts

Ideal burden resistance = (AREF/2) / Secondary peak-current

$= 2.5\ V / 0.0707\ A = \underline{35.4\ \Omega}$

ALTERNATIVE CALCULATION APPROACH

Burden Resistor (ohms) = (AREF * CT TURNS) / (2√2 * max primary current)

CT output = 50mA rms

Peak value = 70.7mA

Peak-to-peak value = 141.4mA

Generates a voltage of $= 141.4mA \times 33\Omega$

$= 4.666V$ *peak-to-peak*

Peak-to-peak input to Arduino $= 4.666 - 0.7$

$= \underline{3.966V}$

APPENDIX B:

SYSTEM DESIGN FEATURES

FEATURES OF ARDUINO UNO R3

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

(https://www.sparkfun.com/products/11021)

FEATURES OF SIM900:

SIM900 is suitable for this project given the under listed features.

- ✓ Quad-Band 850/900/1800/1900 MHz - would work on GSM networks in all countries across the world.
- ✓ Compatible with Arduino
- ✓ Control via AT commands

- ✓ Short Message Service (SMS) - so that you can send small amounts of data over the network (ASCII or raw hexadecimal).
- ✓ Supply voltage range: 3.2 - 4.8V
- ✓ Low power consumption - 1.5mA (sleep mode)
- ✓ Industrial Temperature Range - -40°C to +85 °C

(http://www.sainsmart.com)

FEATURES OF THE TEMPERATURE SENSOR

- Low cost solid state sensor
- Standard resistance tolerances (accuracy) down to ±2%
- High sensitivity to changes in temperature
- Temperature range -40ºC to 225ºC
- Excellent mechanical strength.

APPENDIX C:

PROGRAM CODE

SYSTEM OPERATION CODE

```
// include the library code:
#include <LiquidCrystal.h>
#include "SIM900.h"
#include <SoftwareSerial.h>
#include "sms.h"
#include <EmonLib.h>
#include<math.h>
// initialize the library with
the numbers of the interface
pins
LiquidCrystallcd(4, 5, 6, 7,
10, 11);
// initialize the library
instances
SMSGSM sms;
EnergyMonitor emon1;
//Simple sketch to send and
receive SMS.
boolean started = false;
charmsg[160];
char sender[20] =
"+233500094665";
//Threshold parameters
double THRESHOLD_VOLT = 175.00;
double THRESHOLD_CURR = 1.00;
double THRESHOLD_TEMP = 45.00;
booloperatorNotified = false;
voidprintLCD(String r1,
String r2);
doublegetTemp(intanVal);
boolnotifyOperator(String
msg);
voidreadSMS();
doublegetVoltage();
doublegetCurrent();
//Tmp36 analog input pins
constint tmp1 = A2;
constint tmp2 = A3;
constintcurr_sens = A0;
constintvolt_sens = A1;
```

```
//GSM control pins
constint GSMPWR = 9;
constint GSMRST = 8;
String err = "";
String errmsg = "";
int t1, t2;
doublecurr, tmp, volt;
void setup() {
  // set up the LCD's number
of columns and rows:
lcd.begin(16, 2);
for (int i = 0; i <= 100;
i++) {
printLCD("Init...",
String(i) + "% completed!");
delay(50);
  }
  //initializing Serial
printLCD("Init. GSM",
"Please wait...!");
Serial.begin(9600);
if (gsm.begin(2400)) {
printLCD("GSM status",
"Connected!");
started = true;
  } else {
    //retry connection
printLCD("GSM status",
"Not Connected!");
delay(2000);
printLCD("Reseting GSM",
"");
digitalWrite(GSMPWR, HIGH);
delay(500);
digitalWrite(GSMPWR, LOW);
int attempts = 0;
while (!started &&
attempts< 5) {
if (gsm.begin(2400)) {
started = true;
break;
      }
delay(1000);
attempts++;
    }
if (!started) {
```

```
printLCD("GSM status",
"Failed!");
   } else {
printLCD("GSM status",
"Connected!");
delay(2000);
   }
  }
printLCD("Initializing",
"system...");
emon1.voltage(volt_sens,
260, 1.7);
delay(1000);
}
void loop() {
readSMS();
  t1 = analogRead(tmp1);
  t2 = analogRead(tmp2);
curr = getCurrent();
volt = getVoltage();
tmp = (getTemp(t1) +
getTemp(t1)) / 2.0;
delay(500);
if ((curr>= THRESHOLD_CURR
|| volt<= THRESHOLD_VOLT ||
tmp>= THRESHOLD_TEMP) && !
operatorNotified) {
if (curr>=
THRESHOLD_CURR) {
errmsg = "System
overloaded!";
operatorNotified =
(notifyOperator(errmsg) > 0)?
true:false;
   } else if (volt <=
THRESHOLD_VOLT) {
errmsg = "Low voltage!";
operatorNotified =
(notifyOperator(errmsg) > 0)?
true:false;
   } else if (tmp>=
THRESHOLD_TEMP) {
errmsg = "System
overheated!";
operatorNotified =
(notifyOperator(errmsg) > 0)?
```

```
true:false;
    }
printLCD("Status:",
errmsg);
delay(1500);
  } else if (operatorNotified)
{
printLCD(errmsg, "Operator
alerted!");
delay(1500);
  } else {
printLCD("Temp.(" +
String((char)223) + "C)",
String(tmp));
delay(1500);
printLCD("Voltage(V)",
String(volt));
delay(1500);
printLCD("Current(A)",
String(curr));
delay(1500);
  }
}
voidprintLCD(String r1,
String r2 = "") {
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(r1);
lcd.setCursor(0, 1);
lcd.print(r2);
}
doublegetTemp(intanVal) {
delay(500);
return (((anVal / 1024.0) *
5000.0) − 500.0) / 10.0;
}
boolnotifyOperator(String
mss) {
mss.toCharArray(msg, 140);
returnsms.SendSMS(sender,
msg );
}
voidreadSMS() {
bytepos = sms.
IsSMSPresent(SMS_UNREAD);
if (pos> 0) {
```

```
printLCD("New SMS!",
"reading...");
sms.GetSMS(pos, sender,
20, msg, 160);
delay(1000);
printLCD("From: ",
charToStr(sender));
delay(1000);
   String data =
charToStr(msg);
printLCD("Msg: ", data);
if (data == "QUERY") {
int t1 =
analogRead(tmp1);
int t2 =
analogRead(tmp2);
doublecurrAvgTemp =
(getTemp(t1) + getTemp(t2)) /
2.0;
    String query = "Sys
Report: ";
query += ("\nTemp / deg.
C: " + String(currAvgTemp));
query += ("\nVolt / V: "
+ String(getVoltage()));
query += ("\nCurr / A: "
+ String(getCurrent()));
notifyOperator(query);
   } else if (data ==
"RESET") {
operatorNotified = false;
   }
printLCD("Del. sms...",
"");
if (sms.DeleteSMS(pos)) {
printLCD("Status:",
"Message deleted!");
   }
  }
}
doublegetVoltage() {
delay(500);
emon1.calcVI(20, 2000);
return emon1.Vrms;
}
doublegetCurrent() {
```

```
int cur = (513 −
analogRead(curr_sens));
returnfabs(((cur * 27.03) /
1024.0) − 0.03);
}
String charToStr(char data[]) {
  String str = "";
for (int i = 0; data[i] !=
'\0'; i++) {
str += data[i];
  }
returnstr;
}
```

CODE FOR VOLTAGE SENSOR

```
#include <Wire.h>
int val11;
int val2;


void setup()
{
  pinMode(LED1,OUTPUT);
  Serial.begin(9600);
  Serial.println("Emartee.Com");

  Serial.println("Voltage: ");
  Serial.print("V");
}
void loop()
{
      float temp;
      val11=analogRead(1);
      temp=val11/4.092;
      val11=(int)temp;//
      val2=((val11%100)/10);
      Serial.println(val2);


   delay(1000);
}
```

CODE FOR TEMPERATURE SENSOR

(www.hacktronics.com/tutorials/arduino-thermistor-tutorial.html)

```
/*
   Arduino thermistor example software
   Tutorial:  http://www.hacktronics.com/Tutorials/arduino-thermistor-tutorial
   Copyright (c) 2010 Mark McComb, hacktronics LLC
   License: http://www.opensource.org/licenses/mit-license.php (Go crazy)
*/

#include <LiquidCrystal.h>
#include <math.h>

/*

LCD Connections:
rs (LCD pin 4) to Arduino pin 12
rw (LCD pin 5) to Arduino pin 11
enable (LCD pin 6) to Arduino pin 10
LCD pin 15 to Arduino pin 13
LCD pins d4, d5, d6, d7 to Arduino pins 5, 4, 3, 2
*/

LiquidCrystallcd(12, 11, 10, 5, 4, 3, 2);
intbackLight = 13;    // pin 13 will control the backlight



void setup(void) {
  pinMode(backLight, OUTPUT);
  digitalWrite(backLight, HIGH); // turn backlight on. Replace 'HIGH' with 'LOW' to turn it off.
  lcd.begin(20, 4);              // rows, columns.  use 16,2 for a 16x2 LCD, etc.
  lcd.clear();                   // start with a blank screen
  lcd.setCursor(0,0);            // set cursor to column 0, row 0
}

double Thermister(intRawADC) {
  double Temp;
  // See http://en.wikipedia.org/wiki/Thermistor for explanation of formula
  Temp = log(((10240000/RawADC) - 10000));
  Temp = 1 / (0.001129148 + (0.000234125 * Temp) + (0.0000000876741 * Temp * Temp *
Temp));
  Temp = Temp - 273.15;           // Convert Kelvin to Celcius
  return Temp;
}
```

```
void printTemp(void) {
  double fTemp;
  double temp = Thermister(analogRead(0));  // Read sensor
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print("Temperature is:");
  lcd.setCursor(0,1);
  lcd.print(temp);
  lcd.print(" C / ");
  fTemp = (temp * 1.8) + 32.0;    // Convert to USA
  lcd.print(fTemp);
  lcd.print(" F");
  if (fTemp> 68 &&fTemp< 78) {
    lcd.setCursor(0,3);
    lcd.print("Very comfortable");
  }
}

void loop(void) {
  printTemp();
  delay(1000);
}
```

APPENDIX D:

AT COMMANDS

Overview of SMS commands

Number	command	description
1	AT+CSMS	Select message service
2	AT+CSAS	Store settings of +CSAS and +CSMP to EEPROM or SIM card
3	AT+CRES	Restore the settings specified by AT+CSCA and AT+CSMP commands to EEPROM
4	AT+CSDH	Show SMS text mode parameters
5	AT+CPMS	Preferred SMS message storage
6	AT+CSCA	SMS service center address
7	AT+CMGF	Select SMS message format
8	AT+CMGL	List SMS message from preferred store
9	AT+CMGR	Read SMS message
10	AT+CMGS	Send short message
11	AT+CSMP	Set SMS text mode parameters
12	AT+CMGW	Write short message to memory
13	AT+CMSS	Send short message from storage
14	AT+CMGD	Delete short message
15	AT+CSCB	Select Cell Broadcast Message Indication
16	AT+CNMI	New short message indication
17	+CMTI	Indicate the MEM index location of received message (Enabled by AT+CNMI)
18	+CMT	Indicate the short message was sent to DTE directly after received
19	+CBM	Indicate that the cell broadcast message was sent to DTE device after received
20	AT+SMSC	Change the status of message stored in SIM card
21	AT+SUSS	Set REC UNREAD status of these messages which remain Unchanged

SMS Text Mode

A: Sending a message in the TEXT mode

(1) Default alphabet

AT+CMGF=1
AT+CMGS="15921272576"
>HELLO9527<ctrl-z >
+CMGS: 36
OK

(2) UCS2 format

AT+CMGF=1
AT+CSMP=19，143，0，2 （<DCS> value is UCS2）
AT+CMGS="15921272576"
>4F60597D<ctrl-z >
+CMGS: 36
OK

(3) 8bit format

AT+CMGF=1
AT+CSMP=19，143，0，1 （<DCS> value is 8bit）
AT+CMGS="15921272576"
>3031<ctrl-z>
+CMGS: 36
OK

B: Receiving a message in the TEXT mode

AT+CMGF=1
AT+CMGL="ALL"
+CMGL: 1,2,"REC READ","+8615921272576","08/07/16,12:16:33+32"
0031003200334F60597D

C: Status report

AT+CSMP=39, 143, 0, 0 (enable SMS status report)
AT+CMGF=1
AT+CNMI=3，0，1，1
AT+CMGS="15921272576"
>00680065<ctrl-z >
>+CMGS: 45
OK

(Following is the status report)
+CDS: 2, 45,"+8615921272576, 145,"08/07/16,13:41:15+32""08/07/16,13:41:15+32",0