UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION
INSTITUTE OF SCIENCES AND TECHNOLOGY

MONITORING OF POWER SYSTEM BY USING WEB-SERVER BASED MICRO CONTROLLER

MASTER THESIS

Nori Shaker AL-LUHAIBI

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

MASTER THESIS PROGRAM

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Nori Shaker AL-LUHAIBI, having student number 1406030032 and enrolled in the Master Program at the Institute of Science and Technology at the University of Turkish Aeronautical Association, after meeting all of the required conditions contained in the related regulations, has successfully accomplished, in front of the jury, the presentation of the thesis prepared with the title of: "Monitoring Of Power System By Using Web-Server Based Micro Controller"

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Thesis Defence Date: 18 January 2018

UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION TO THE INSTITUTE OF SCIENCES AND TECHNOLOGY

I hereby declare that all information in this study I presented as my Master's Thesis, called Monitoring Of Power System By Using Web-Server Based Micro Controller, has been presented in accordance with the academic rules and ethical conduct. I also declare and certify with my honor that I have fully cited and referenced all the sources I made use of in this present study.

18.01.2018

Nori Shaker Al-LUHAIBI

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In the name of Allah, the most merciful god
All the praises and thanks to Allah, and peace and blessing is on the prophet of Allah; on his family member and on all those who proceed on his path.

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January 2018 Nori Shaker AL LUHAIBI

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ABBREVIATIONS

ARP : Address Resolution Protocol
DIP : Dual In-line Packet
DMA : Direct Memory Access
EEPROM : Electrically Erasable Programmable Read-Only Memory
HTML : Hyper Text Mark Language
HTTP : HyperText Transfer Protocol
ICMP : Internet Control Message Protocol
IDE : Integrated Development Environment
IEEE : Institute of Electrical and Electronics Engineers
I/O : Input and Output
IP : Internet Protocol
ISA : Industry Standard Architecture
ISN : Initial Sequence Number LAN: Local Area Network
LCD : Liquid Crystal Display
MAC : Media Access Control
OSI : Open System Interconnection
RAM : Random Access Memory
RFC : Request For Comments
RTT : Round Trip Time
TCP : Transmission Control Protocol
PCB : Printed circuit board
RTU : Remote terminal unit
VRMS : Value root mean square
PF : Power factor

ABSTRACT

MONITORING OF POWER SYSTEM BY USING WEB-SERVER BASED MICRO CONTROLLER

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Thesis Supervisor: Asst. Prof. Dr. Özgür KELEKÇİ

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Advanced monitoring systems in which adopting the integration of the software and hardware are having a great impact on power system protection. Intelligent relays and circuit breakers which can be triggered remotely upon fault occurrence are attributed to the clever control and monitoring schemes using programmable electronic chips like microcontrollers. In this research, the microcontroller is used to monitoring a power transformer of 11000/220 volt by developing a mini web server that takes all electrical readings from the said transformer and views of it on the web page. This server can be accessed remotely by any terminal computer in the network. Advanced microcontroller from Microchip was used to develop the protection system response to overcurrent, temperature increment and gas leakage, hence this monitoring system is turned to relay and circuit breaker functions upon existing of any undesired event i.e. overcurrent. Hardware module is implemented by PIC 18F4620 and similarly, a virtual model is established in Proteus v8 software. The system is designed as automatic protection-monitoring algorithm and along with that, a number of functions are integrated where the user/protection engineer can manually initiate of them, for example, the manual alarm in case of fire of emergency events and total shut down of alternator whenever it seems required. Furthermore, hardware model is including some other properties such as manual switching the cooling system like on-off the fans to cool up the transformer body and increasing the load demand to examine the system response. The system is attributed by low-cost design and independent on networks resources as the case of GSM control system, hence with computer network LAN or even WAN network can be established using developer own capacity with lesser investment.

Keyword: RTU, PIC, Proteus v8, LAN, WAN

ÖZET

MİKRODENETÇİ TEMELLİ AĞ SUNUCUSU KULLANILARAK GÜÇ SİSTEMİNİN İZLENMESİ

AL-LUHAIBI, Nori Shaker

Yüksek lisans, Elektrik ve Elektronik Mühendisliği

Tez Danışmanı: Yrd. Doç. Dr. Özgür KELEKÇİ

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Yazılımın ve donanımın entegrasyonunu benimseyen geliştirilmiş izleme sistemleri, güç sistemi koruması üzerinde büyük bir etkiye sahiptir. Hata oluşması üzerine uzaktan kontrollü olarak tetiklenerek başlatılabilen akıllı röleler ve devre kesiciler, mikro denetleyiciler gibi programlanabilir elektronik çiplerin kullanıldığı akıllı kontrol ve izleme programları olarak belirlenmektedir. Bu araştırmada, mikro denetçi, 11000/220 voltluk bir güç transformatöründe tüm elektriksel okumaları alan ve internet sayfası üzerinde onu inceleyen bir mini internet sunucusunun geliştirilmesiyle güç transformatörünün izlenmesi amacıyla kullanılmaktadır. Bu işlem merkezine, ağdaki herhangi bir terminal bilgisayarından uzaktan erişilebilir. Mikroçiplerden olan geliştirilmiş olan mikro denetçi, aşırı akım, ısı artışı ve gaz kaçağına tepki vermek üzere koruma sistemini geliştirmek üzere kullanılmış ve böylelikle de, izleme sistemi, aşırı akım vb. gibi beklenmedik bir olayın mevcut olması durumunda röle ve devre kesiciyi açmaktadır. Donanım modülü, PIC 18F4620 aracılığıyla uygulanmakta olup ve buna benzer şekilde Proteus v8 yazılımında bir sanal model kurulmuş bulunmaktadır. Sistem, otomatik koruma - izleme algoritması olarak tasarlanmış olup bununla birlikte kimi fonksiyonlar, örneğin: manuel alarmın, yangın gibi acil durumların ve gerekli olması durumunda alternatörün tamamen kapatılması gibi, manuel olarak bunları başlatabilen kullanıcı/ koruma mühendisinin olduğu yerlerde entegre edilmiştir. Donanım modeli,

transformatör gövdesini soğutmak ve sistemin tepkisini incelemek için yük talebini artırmak amacıyla fanları açma - kapama gibi soğutma sistemini manuel olarak değiştirme gibi kimi diğer özellikleri de içermektedir. Sistem, GSM kontrol sistemlerinde olduğu gibi network kaynakları üzerinde düşük maliyetli ve bağımsız biçimde tasarlanmış olup ve bununla birlikte, bilgisayar ağları olan LAN veya WAN ağları ile daha düşük bütçeli geliştiriciler tarafından kendi imkanlarını kullanarak tesis edilebilir.

Anahtar Sözcükler: RTU, PIC, Proteus v8, LAN, WAN

CHAPTER ONE

INTRODUCTION

1.1 Background

Power system is supplying consumers with electricity which becomes one on life important demands as almost all daily applications are tends electronic. Home applications such as cooking, lighting, food refrigeration and all others are demanding electrical power in order to operate. It is important for power providers to supply the electric power in the expected quality. The term quality is associated with the technical considerations such as voltage regulation, frequency stability as well as some technical issues such as electrical fault; however, for enhancing the electric power quality, a deep concern must be paid for such criteria. Basically, power system is consisting of three major entities; the unit of power generation which in turn producing the electrical power as high voltage in mega volt; these units are followed by power distribution systems which considered as most important part of power system where the generated power are planned to transport from generation end to load end within the tolerated amount of losses. Finally power is transferred from high voltage into low voltage to serve the working loads. In this project, power transformer is kept under consideration so that all issues experienced by transformers are studied to design a digital system that control the operation and solve the errors. Transformer is supplied with high voltage at the input (11000 volt) and making an output of (220 volt) has been analysed to predict the error before their occurrence and hence to stop that operation which is causing the error; a microcomputer is the best options that serve this requirement. However, system is expected to monitor of power transformer and control it at the same time; the control is needed in both option manually and automatically so that error part will be shutdown any time before error take place moreover, it can work in manual mode where alarms and cooling system may start. Most of transformers errors are developed from wrong usage such as over loading the transformer, it leads to draw more current from the secondary winding and ultimately increasing the temperature of the winding. Temperature increment will lead to fire if it is not treated quickly/ fault may also happen inside the winding because of unbalanced loading of transformer phases. However, current, voltage, temperature are referred as fundamental participants of this system and hereafter advanced monitoring and control system is implemented using of microcontroller and computer networks.

1.2 Motivation

For keeping smooth process of the power system, it became necessary to monitor the component of interest so that errors can be diagnosis and correcting accordingly. Our project is suggesting an easy access control system involving micro-processor as a backbone. By employing the free coding power of Arduino we can assure good handling for the system control signal. Moreover PIC is performing responsive control so that user (operator) will be dealing with the system through graphical interface (GUI). Our system is allowing the electronic content to be tied with human beings by using the internet or intranet.

1.3 Contribution

Our project is involving two major parts, the first is to develop a virtual micro-processor within computer environments and design the input and output ports for connecting the power network in which need to be managed. This part involves the micro-processor logical instructions and codes; hence a powerful C code is developed for performing the intended functions in our system. The second part is server designing so that the information passing through PIC is handling and viewing. A responsive web page is designed by help of hyper text terminal protocol. This page is used to pass the human signal to logic circuit and to monitories the power system status. In this second part IPs will be assigned for the network members so that wireless local area network can be started. Remotely locating devices can access to the network through Wi-Fi router.

1.4 Problem Statement

Finding out a control system which is capable to monitor remote devices is a challenging task. Many researches were trying to develop such system in efficient way. The problem of cost [1] is raised after using a SMS based monitoring system, this system is based on GSM network and allowing any communication between the terminals required a call fares will be applicable and charged by mobile operators. Since SIM card is always connected to GSM network operator. One more problem is the network coverage, in other word, the geographical area where the remote monitoring system is located could be not covered by the network operator then the use of SMS based system will be impossible since no communication will be presented at such scenario.

1.5 Aims and Objectives

The main goal of this project is to present economical efficient and powerful method for enhancing the control system used to handle the power components such as transformers. Below are the interested contents:

1. To present review of PIC framework and its designing issues.
2. To present the study on background power system monitoring technologies and its different schemes.
3. To present architecture and algorithm for TCP/IP protocol stack.
4. To present a method for detecting the overload occurrence, gas leakage, oil temperature and winding temperature and hence, developing the required tools such as cooling system and alarms to prevent any disorder.

1.6 Thesis Organization

This report is consisting of seven technical chapters that cover our project illustration. The first chapter "Introduction" was about the pre technical definitions and contains the motivations and objective of our project. The second chapter entitled as "Literature survey" is containing the existing methods implemented to serve as control system underlying architecture. Chapter three "Network topology" is discussing the network methods which facilitate the implementation of computer network. Chapter four "Methodology" is discussing the protocols and theoretical concepts of this project. Chapter five “Simulation of monitoring system” the simulations environment, settings, scenario’s and performance metrics used. Chapter six “Hardware implementation” is discussing the project practical hardware setup. Finally conclusion is made base on the simulation results chapter seven “Conclusion”.

CHAPTER TWO

LITERATURE SURVEY

2.1 Background

This section of dissertation report is listing the most popular approaches that found in the field of power system control and monitoring applications. It also detailing the work and experiments which practiced by the researchers in last ten years; power systems are monitored to ensure the reliability of power delivered to consumers as well as for efficient usage of power device. Transformers are one of important and effective units in power system; it steps up or steps down the supplied input so that load tied on its secondary windings will operate.

Basically, any transformer is consisting of primary windings, secondary windings, cooling system and other protection devices. Circuit breakers are always interfaced with both ends of transformers to control of current flow and keep it under the tolerance level of winding so that faults and short circuits may be prevented. Recently, many other alternatives are used for protecting of power transformers such as advanced electronic systems, they used other facilities to transfer the control signaling between the site devices and remote monitoring stations; mobile network and radio frequency antennas and also Bluetooth were used as meditators between the sides of monitoring system.

Communications by power carrier is drawing some disadvantages while they used in monitoring devices, the frequencies operate on communication system is generally radio frequency unlike the same in power system that operates on fifty Hz at most; however, frequency interference may take place with power carrier if it is used in monitoring equipment. In communication systems, signal may suffer from attenuation and other noise associations spatially when the signal travels for long distances. According to these disadvantages, communication system is considered critical for accuracy as noise may destroy the signal information and the exact data may get jittered and hence another information will be received at host node that con not be relied for controlling of power system.

Radio frequencies in communication systems may be used with higher accuracy to send and receive of control information, some developers have deployed of microcontrollers to control and monitor of power devices at home, however most of the listed approaches seems implemented with less possible functions and for limited operations.

The researches of monitoring system implementation by using mobile cellular network are also listed in the literature of this dissertation, global system of communication GSM is mobile network that radiate the information among mobile handsets and control the traffic of data by big infrastructure such as base station where load is distributed between cells with similar size and cover of particular geographical area, the network capability to deliver its service to a known geographical area is called “coverage”; some of authors have used GSM modem to transmit control signals from the objects to control station and vice versa; actually deepening on mobile network is good option to achieve perfect control and monitoring process but some disadvantages are developed also at meanwhile.

Mobile network (if any) is drawing relatively high cost of data renting, furthermore it is limited to the area of coverage. From other hand, cellular network is highly affected by the data traffic at surrounding premises and objects so that service can be cut at any time where power system monitoring and control must be continued 24 by 7 without fail.

2.2 Review of Existing Methods

At [1] Mohamed Ahmed Eltayeb, Ahmed ElmustafaHayati and Sherief F. Babiker mentioned that monitoring the power transformers is essential to control the losses in distribution systems and maintain the efficiency within the permissible constrains. The monitoring of power system according to the writers is simplifying the task of control engineers and maintainer’s staff as well as the designers to estimate the weak points in the grid and rectify the errors in rapid procedure. The research of [1] is involved gathering the data such as voltage, current and temperature from the transformer and sending it across mobile cellular network to the monitoring end user platform. The exact date and time is been attached in such signal (SMS) to simplify of decision making. The data is sent to storage/database to be referred at any time by control engineer. The outcomes of the monitoring system that implemented in this paper is made it possible to present on site PC.

At [2] P.M. Sneha Angeline has implemented a control system using of microcontroller to pickup the signal from power transformer. System used to control gas and oil leakage so that two sensors were in use i.e. gas sensor and level sensor to gage oil level that kept at oil vacuum. System adopted a radio frequency transmitter to send the control signaling to relay so that tripping can be take place. An RF sensor is tied with the receiver to collect signals from the microcontroller in case of malware presence (error occurrence). According the authors, such real time control system is help to prevent any gas leakage and protect the transformer from fire by keeping the oil under observation. However, oil is responsible of maintaining the transformer coils as cool as possible and hence fire can be prevented.

At [3] Amal F. Abd El-Gawad has presented a monitoring system underlying by microcomputer for cooling of distribution transformers by fixing the temperature rate using a temperature sensor and level sensor to check the oil level. Author suggested a method to enhance the cooling system of transformer by adding extra units into the same, such is help to avoid over heat problem for the transformers which kept under tough environments. Furthermore, alarm system is implemented in this research to shut down the transformer in case of over temperature; a temperature sensor is implemented on site for monitoring of temperature. This system was implemented virtually by Protuse software, writer mentioned that, by doing such implementation in the software, the economic worth can be estimated as well as the system robust can be verified.

At [4] Ashok J. Naiknaware, Sagar M. Jadhav and Suhas B. Jadhav stated that internal fault in power transformer can be take place due to over-temperature, non-tolerated voltage input or over current (over loaded transformer). As a result, a protection system is proposed in this research to protect the said transformer. Microcomputer is proposed to implement an effective and reliable monitoring system where data can be enquired from the transformer and sent across to the terminal computer to perform the required action for stopping the mess of irregularity of any parameter and ultimately safeguard the transformer.

At [5] Dharanika T, Sibiraj R, Sathiyaraj E, Vijay Ganesh B and Vijay Bhaskar stated that; a switching circuit implementation by relay and microcontroller combination can be used to prevent the over current and over load occurrence in power transformer. For bringing such system into reality, measuring/sensing circuits for voltage and current are implemented to measure such signals at both sides of transformer i.e. input and output (demand side). The measured parameters are been directed into the concern person by means of cellular network modem. A GSM modem is interfaced with the circuit to transfer the status of this transformer to the faraway computer where the control engineer is sitting.

At [6] Arpit Rana, Jeet Shah and Anuradha Deshpand have implemented a microcontroller circuit to predict the fault of power transformer that exists due to over voltage. The circuit is designed to monitor the terminal voltages and accordingly sending a signal into the relay where the transformer can be powered off automatically upon over voltage events. Authors used the Protuse software to execute a virtual system.

At [7] authors are explained the effect of transformer protection unites that integrated with the transformer entity such as Silicon gel, humid ity, temperature and status of Buchholz relay. As per [7], the above parameters should be always observed to prevent any unwanted event such as fault and fire. Current demanded from the secondary windings and voltage in windings terminals are also detected and all set of parameter is being sent to control point by means of GSM modem. As information is received in control center, the instruction will initiate for changing the tap charger position, parameters status will be displayed on computers of that remote center and so the tap charger will be updated by the concerned staff at the same time, report of transformer status will be made on there. As per the writer, this procedure will enhance the durability of transformer and other materials that attached to it such as wires and circuit breakers. From the consumer's point of view, better services are provided.

At [8] Mangesh Kawale and Vijay Kumar have stated that distribution transformer is vital for distribution system and considered as major unit on the same, so that care should be taken for dealing with power transformer. In this research a digital to analog converter with microcontroller are used to build of monitoring system, online monitoring system is found to be the best solution of maintaining the transformer as the status of transformer can be available for accessing at anytime so that the risk of unexpected event will be prevented. A monitoring system is designed to check the over current, over voltage and heat level in the transformer, furthermore, oil is checked so that fire will be prevented. According to this article, sensors such as temperature sensor and liquid level sensor are used with wireless transmitter to send the readings into office where the controlling engineer can provide the decision maker system with the proper instructions to act against this error. In general, this project was comprising of two unites, the data collection unit and data monitoring unit. The first (data collector) is installed in the transformer vicinity and the other unit (monitor) is lying on remote monitoring office.

At [9] Kirandesai and Ramchandra are provided an embedded system to monitor of operation parameters in power transformer. Unbalance of voltage, temperature, current and oil level are supposed to be watched while transformer is operational. The project is implemented as microcontroller working with sensors to detect above quantities; a GSM cellular network is used to transfer the data from sensors to the monitoring center through microcontroller ultimately, the integration of those three candidates i.e. (cellular modem, microcontroller and sensor array) will form the protection system that control the transformer and act against any error occurrence. This system was involved a memory elements such as EEPROM in order to store the collected data from the analog to digital convertors (sensors), this monitoring system is began to send short message (SMS) upon any undesired circumstances occurrence. A known mobile number is being coded with microcontroller chip to be used for any communication (sending signals of alarm or error messages) to the authorized person who looks after this transformer. Doing so; can permit a smooth operation and increase the life of the power materials.

2.3 Alternative Techniques

As per the literature of smart monitoring systems, the microcontroller is used to implement the main system as well as sensors to detect the input, many researchers have used cellular network and radio frequency transmitters as means to transfer the control signaling from the microcomputer into remoter terminal computer the articles on above is included many of such examples. From the other hand, other techniques are used such as wireless communication methods; Wi-Fi and Zigbee are used for transmit the collected data into remote control unit. Other approaches were found are used Bluetooth to perform such task in hereafter some examples of registered researchers which implemented with those technologies.

At [10] Sunen Soni, Mayank Thanvi, Shivam Sharma, Sunil Yadav and Mr. Vikas Singh have presented project controls electrical appliances and components at home to be automatically or remotely controlled by the system or by the user respectively. The backbone of this system is the Arduino UNO microcontroller and Wireless Ethernet shield which provides the interface between the user and the appliances. Via internet (webpage) user can access or operate any connected device from anywhere and system also checks for any device left switched on by user to switch it off. With the use of various sensors (Infrared sensors, temperature sensors) and actuators entire connection is established between Ethernet shield and the device. System would also be able to monitor presence of any person inside the room and using this data, user can manage the operability of any connected devices. Modules can be integrated as and when required for easing the task and effort of human.

At [11] Zaidjabbar and Kawitkar have done home control project that enable the user to control of home applications without needing of computer server. More that switch have been used to connect multiple applications and also to provide the accessible terminal from ZigBee system. The access to smart home is made by the writers from mobile phone and as per them it is provided a good and quick services to the users with moderated rate.it made possible by this article to connect the electricity devices from different vendors without any constrains.

At [12] R.V. Patil, Dhiraj Kalantre, Niranjan Hirugade, Arun Moreand Ashwinee Kakade have designed and implemented of a mobile embedded system to monitor and record key parameters of a distribution transformer like load currents, oil level and ambient temperature. The idea of on-line monitoring system integrates a Global Service Mobile (GSM) Modem, with a standalone Arduino and different sensors. It is installed at the distribution transformer site and the above parameters are recorded using the analog to digital converter (ADC) of the embedded system. The obtained parameters are processed and recorded in the system memory. If any abnormality or an emergency situation occurs the system sends SMS (short message service) messages to the mobile phones containing information about the abnormality according to some predefined instructions programmed in the microcontroller. This mobile system will help the transformers to operate smoothly and identify problems before any catastrophic failure.

At [13] smart home is designed by Andi Adriansyah, Akhmad Wahyu Dani have by using of Arduino microcontroller and wireless local area network. House hold applications such as room temperature and lighting systems or fire alarm system is monitored by this approach, the resulted system is possible for interacting with humans by web-browser using of HTML page, system as been stated by the writers is showing proper response for human commands and this attributed to the facilities provided by computer network.

2.4 Summary

In this literature, authors are seen at three groups of implementations, some of them have used the micro-controllers to control of power devices with help of mobile cellular network by integrating of GSM chip with their projects, some others have used the radio waves to connect the controllers and relays which used to implement of control decisions from microcontroller instructions. Other group of writers have developed arduino and microcontroller with integration of wireless sensors using WAN. This project is designed to provide the facilities of most literature articles with respect to their cost; so advanced microcontroller with computer network is used to implement the control strategy.

CHAPTER THREE

NETWORK TOPOLOGY

2.1 Introduction

Local Area network (LAN) is effective topology of computer networking that connect a number of hosts together by means of transmission medium. Medium of transmission is usually made by copper cable RG forty five. Moderated speed of connection is achieved by those applications employing the local area network; LAN can be attributed with the sufficient bandwidth which can be utilized to exchange relatively large packets of data, error rate and time delay are also considered low in such topology. LAN is always good option to communicate a limited geographical area such as buildings, offices and extra; limited computer (hosts) can be joined the network as in [34]; the potential configuration of LAN is depicted in figure 3.1.

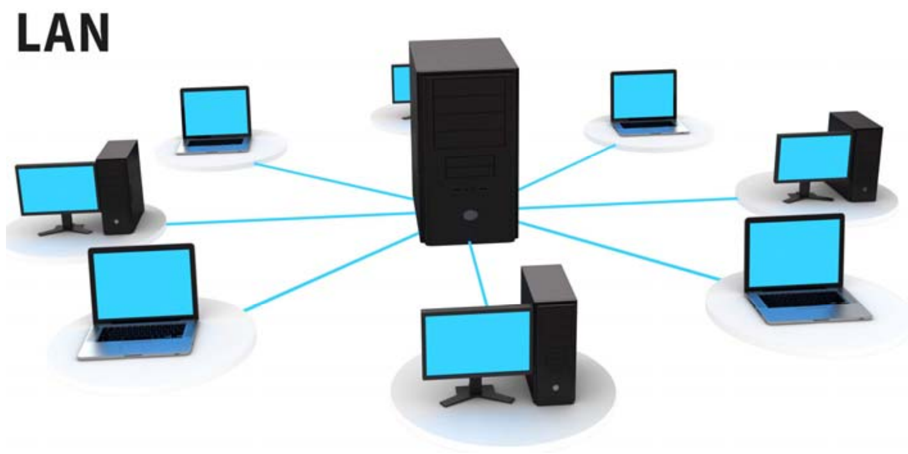

Figure 3.1: LAN structure [34].

2.2 Transmission control protocol/IP

Computer networks are designed under so many considerations to cop with complex environments, networking problems can be divide base on the network task that let a particular number of hosts inline. So that, networks are created by distributing the networking related matters into different categories and each category is studied individually for simplification purposes. Network is about many layers that interfaced with each other and performed a particular task and ultimately making the hosts to be connected.

Ordinary networks are made by couple of networking models that are; TCP/IP model to perform the network tasks using of four layers (application layer which deals with applications such as computer programs in software level, transport layer which is in turn routing the packets in to the next referenced layer, internet layer and finally the layer of interface that performing the interfacing of physical medium with software). OSI model of seven layers is also found to perform the networking and it can be described by its seven reference layers (physical layer, data link layer, transport layer, session layer, presentation layer, application layer), the figure 3.2 is depicting the TCP/IP and OSI protocols.

Each layer is performing a particular task to provide the connection between the two layers that surrounding it from up and down. Every layer is looking after its own process to divert the data packets from upper layer to lower layer of vice versa and not responsible of any process of others.

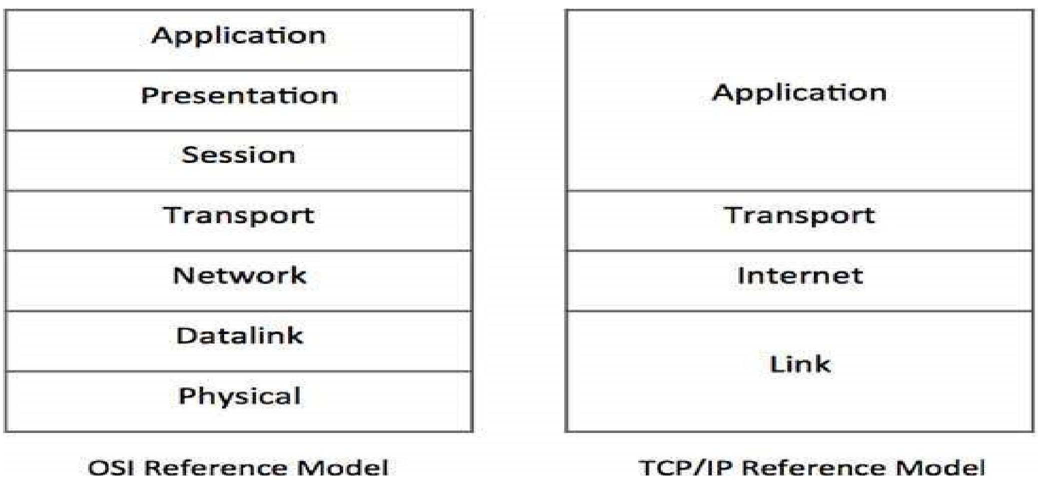

Figure 3.2: OSI and TCP/IP reference models [34].

Internet architecture is usually described by TCP/IP model and figure 3.2 is showing that TCP/IP protocol is a subset part of OSI seven layers model; at interface layer (the lower layer of TCP/IP protocol) data can be exchanged between the network physical medium and internet layer by attaching the required header with data packets and unlashing it to the network. Data is transmitted as packets with header; it can be routed into any node in the network by help of this header.

Transferring the data packets between two nodes within the network is performed by internet layer where data in form of packets is sent from source (mother node) into destination node. Congestion control and other functions such as fragmentation of packets and routing table is conducted by internet layer. This layer is experienced the presence of some other protocols like ICMP (internet control message protocol), such protocol can be reside on internet layer by assigning a number for recognition for example, number (1) is used to recognize the ICMP/1 protocol in case of many ICMPs are existed.

Another layer called transport layer is responsible to ensure a reliable and successful connection between the networks host, basically, two pair of hosts are connected by transport layer. Error flags are residing in this layer to check the disorders in network packets; error can be packet duplicated or packet lost on the low layer. The procedure that done in transport layer is mostly sending of request to the lower layer asking to send a particular packet again in case of packet lost UDP and TCP are residing on transport layer and assigned for seventeen and six respectively for recognition purpose.

As higher layer in both TCP/IP and OSI reference models, application layer is occupied to handle different applications of the users. Web browsing, file transferring and many others are managed by application layer. This layer is experiencing the presence of protocols such as HTTP for web applications and FTP (file transfer protocol) for file transfer as the name indicating.

Figure 3.3 is describing the encapsulation and DE capsulation process, the first is taking place at the time of sending the data from source to destination whereas the de-capsulation is involving the process required to receive the data packets by different layers.

2.3 Internet Protocol

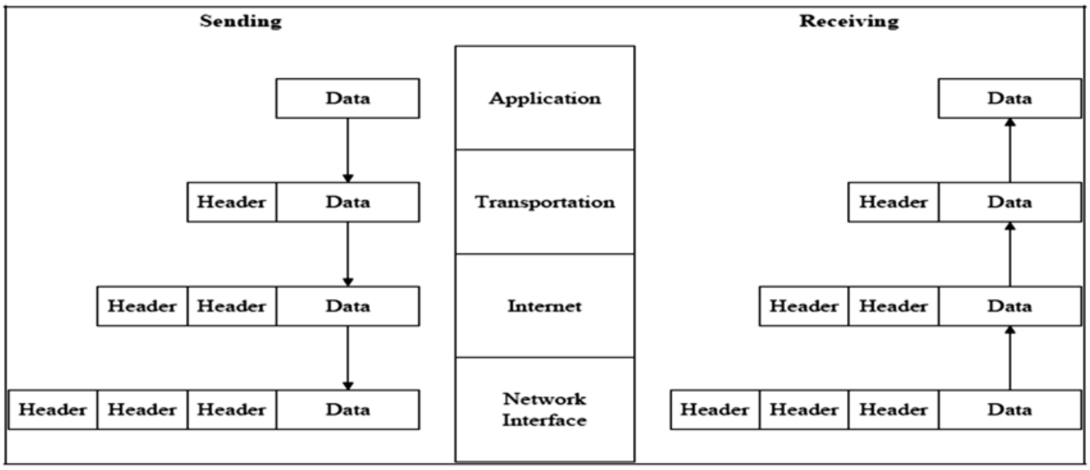

Figure 3.3: Encapsulation process [34].

Protocols are sets of instructions and standards that defined to control the communication between different computers or hosts sharing the same network and it was designed to make any number of those hosts communicate with each other smoothly and errorless. All network standards (protocols) are made public by RFC organization, Request For Comments (RFCs) are made all the standards available for common users who wish to implement any kind of network.

RFC 791 is detailing of internet protocol, IP is most important participant in internet layer on TCP/IP network model, data is formed in packet wised at internet protocol for transmission purpose through TCP/IP reference model. Internet protocol is used by most other protocols that may be required to share data through network; it is involving some foundation to perform data transmission strategies. Datagram is defined in this protocol with internet scheme of addressing; data can be exchanged between transport layer and interface layer by help of internet protocol; datagram can be reassembled and rout to any faraway host by using of internet protocol as in [35].

Figure 3.4 is showing internet protocol datagram, the term of datagram involves the data reformation as packets by breaking of data burst into small segments called packets, these packets are appended with smaller segment called header; each header is involving the routing details and other important information; the combination of data packet and header is termed as datagram..

<table>
<tr><td colspan="2">Bit 31</td><td colspan="3">Bit 0</td></tr>
<tr><td>Version (4)</td><td>IHL (4)</td><td>Type of Service (8)</td><td colspan="2">Total Length (16)</td></tr>
<tr><td colspan="3">Identification (16)</td><td>Flags (3)</td><td>Fragmentation Offset (13)</td></tr>
<tr><td colspan="2">Time to Live (8)</td><td>Protocol (8)</td><td colspan="2">Header Checksum (16)</td></tr>
<tr><td colspan="5">Source Address (32)</td></tr>
<tr><td colspan="5">Destination Address (32)</td></tr>
<tr><td colspan="5">Options and Padding (0 or 32)</td></tr>
<tr><td colspan="5">Data starts … ...</td></tr>
</table>

Figure 3.4: Internet protocol datagram [34].

In computer networks, two fundamental terminologies that commonly used to represent of network. “NODE” is the point of interest at any kind of application so coming to the main points, the term source node is representing the source of data packets and the destination node is representing the place where packets should be sent. As mentioned in last sections, the header is involved routing information and main part of this called IP address, two types of IP address are invented till date: IP virgin IV and IP virgin VI. In IP virgin four, a four octet are used to describe the address of any node in the network domain; IP address is divided into network section and host section and both are work side by side to identify any host at any network.

<table>
<tr><td colspan="5">IP Address: 192.168.0.22</td></tr>
<tr><td rowspan="2">Decimal Expression</td><td colspan="3">Network</td><td>Host</td></tr>
<tr><td>192</td><td>168</td><td>0</td><td>22</td></tr>
<tr><td rowspan="2">Binary Expression</td><td colspan="3">Network</td><td>Host</td></tr>
<tr><td>1 1 0 0 0 0 0 0</td><td>1 0 1 0 1 0 0 0</td><td>0 0 0 0 0 0 0 0</td><td>0 0 0 1 0 1 1 0</td></tr>
</table>

Figure 3.5: IP address format [34].

At early stage, IP address is designed with only eight digits of binary number and capable to form 256 networks of computers; such possibility of networking was acceptable at that time as field of application was yet developed. After the revolution of computer science, this number of networks has become non-sufficient for today uses.

Therefor IP address is classified into six categories; the main advantage of this classification is utilize the said “IP address” with different applications; for example, some areas are not demanding high deployment of computers and ten computers are probably satisfy its demand so that particular category of IP address can be assigned for those computers.

A to E alphabets are used to identify the IP address classes so that every class is used for particular service as in figure 3.6.Class A is made with 24 bits of binary from network part and right bits of binary for host part whereas sixteen bits are used for network and same bits also for hosts in class B. Eight host bits and twenty-four network bits is in class C.

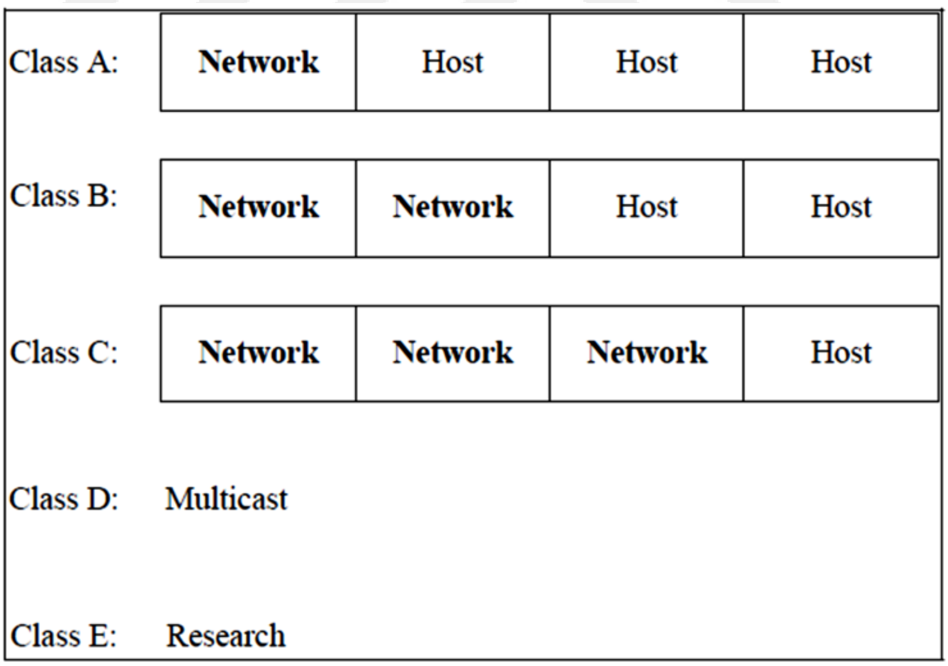

Figure 3.6: Classifications of IP address [34].

It is possible now to recognize the IP address at any network by checking the first octet digits on IP address so if that octet started with 110 it implies that class C is used; if it is starting with 10, that means class B is used, otherwise class A is recognized if first octet started with zero. The figure above is depicting of IP address classification flowchart.

2.4 Transmission Control Protocol (TCP)

Data can be exchanged between the network nodes by performing a signalling scheme between the concerned nodes; signalling implies sending the control information between source node and destination node; it is usually involved a TCP control information at packets headers. As mentioned before, data willing to reach any host in the network is divided into number of segments at node of production. Upon the reception of those segments at the destination node; original form of data is reforming again by joining the small segment together.

Bit 31			Bit 0
Source Port (16)			Destination Port (16)
Sequence Number (32)			
Acknowledgment Number (32)			
Offset (4)	Reserved (6)	Control Bits (6)	Window (16)
Checksum (16)			Urgent (16)
Options and Padding (0 or 32)			
Data starts … ...			

Figure 3.7: TCP segment format [34].

In order to allow the destination node to verify if the received segment has been undergone error and got damaged due to this error; so that checksum bit is applied into the segment. The destination node will start error correction procedure upon receiving of faulty data segment, firstly, destination will discover that segment is experiencing of error by checksum monitoring and hereafter, it sends an acknowledgment to the source node indicating that segment is damaged so it may ask the source node to resend of same segment and it may discard the old one. Source will be waiting for specific time to receive the acknowledgment from destination stating that segment is successfully; in case of non-acknowledged segment, receiver will consider that node is not received successfully and will send it again; this process is enhanced by the header lying on each segment which has the required information as segment sequence number; such will help the error correction mechanism between source node and destination node. Transmission control protocol is starting of packets transmission between any pair of nodes by establishment of link before exchanging of any segment that's why it termed as connection oriented protocol.

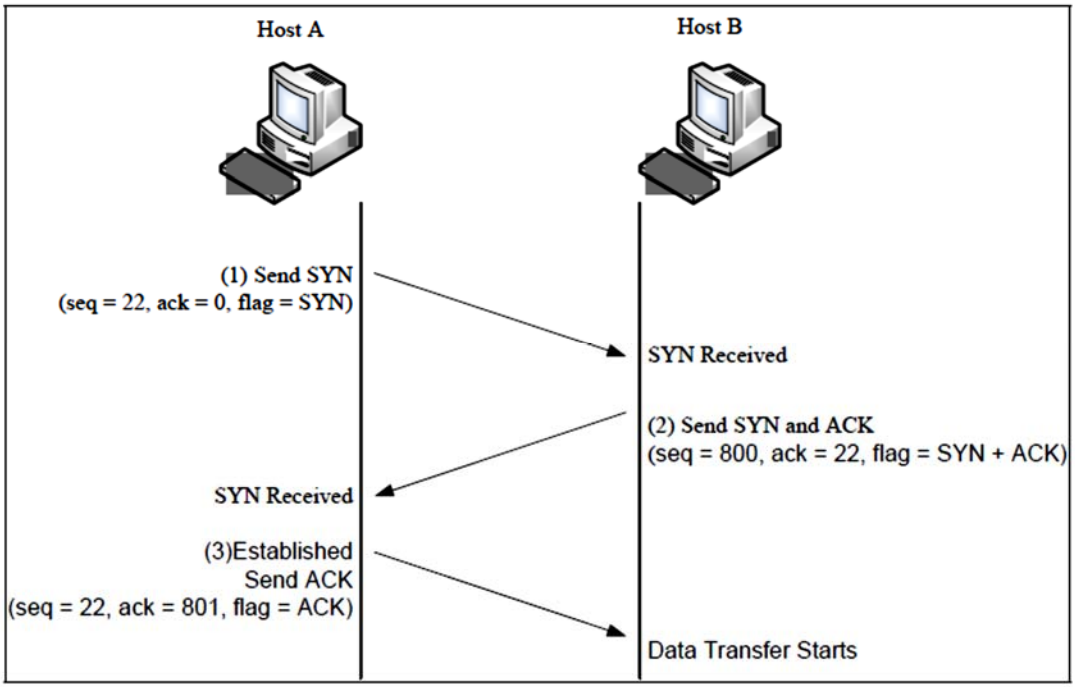

Figure 3.8: Three way hand shaking [34].

Since the TCP is establishing of connections prior to any data transmission so it is important to study of the way connections are initiated. Three Way Hand Shaking is used to establish of linkers between the transmitter node and receiver node as in figure 3.8. Communication between node A and node B as in above figure is started by synchronization segment to be sent from A to B, this segment is holding the synchronization information like initial sequence number and acknowledgment number. In figure 3.8 node A may send ACK. NUM. of zero and ISN number of 25 to node B; zero acknowledgment number is usually assigned to the first segment of data. The first transmitted segment is like any other segment is headed with control bits on its header; the ACK bit will be zero in the first segment and the SYN (synchronize bit) will be one. After node B received the segment of "1" SYN and "0"

ACK, it will reply the node A with control segment that including “1” in ACK and 1 in SYN with ISN of 26; it means that node B is informing the node A that last segment is received and next segment is needed after that is holding the sequence number of “26”.

The node A will receive of this signal and check the acknowledgment of last sent data o, if ACK bit is indicating “1”, node A will check the ISN number of wanted node and accordingly will revert with the same. If in case that no acknowledgment is received by node A from node B, the sent segment will considered as lost segment and will be resend after a known waiting time.

2.5 Internet Control Message Protocol

RFC 792 is detailed the internet control message protocol (ICMP), this protocol is part of internet protocol and it used to diagnosis of any disorder in IP datagram and hence correcting that disorder by exchanging of error notes between the network layers. This small protocol is providing the TCP entity with flow control mechanism such as reporting the errors when the destination node in not reachable of connecting between the nodes is no longer valid. Echo request and echo reply function is achieved by ICMP protocol through using of command window operation system to ping the destination node or source node; the pinged node may reply with reflection of sent request. Usually, the ping function is used to determine the status of remote terminal node so that it can be said node is working correctly if and only if the echo message will be reverted back from the destination node with the same length and no error is found. Rout trip time is provided by ping function and used to measure the connection reliability as well as it used for error debugging roll; ICMP is part of IP as mentioned earlier so encapsulation of ICMP message is given in below figures. The echo signal and echo reply signal is depicted in figure below.

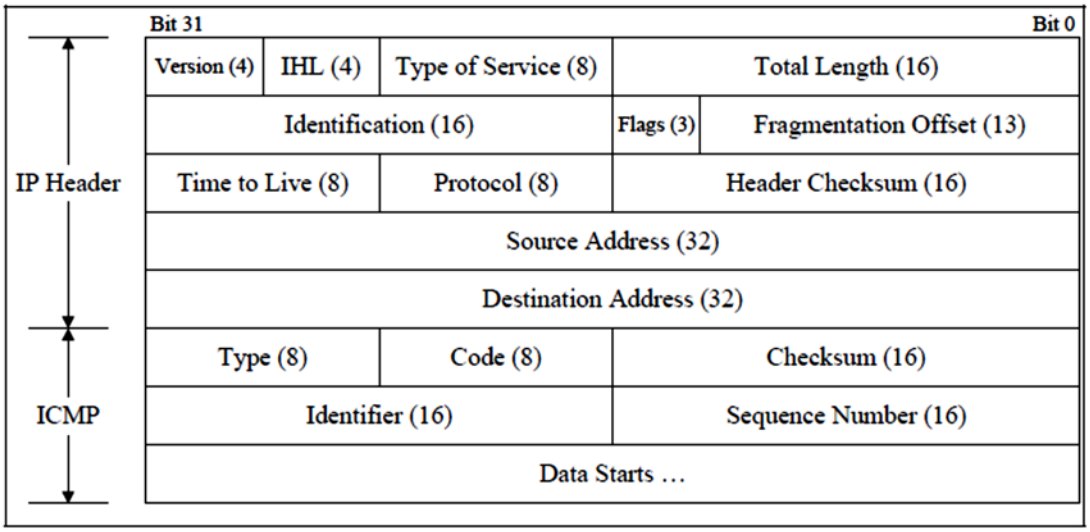

Figure 3.9: ICPM format [34].

2.6 Address Resolution Protocol

The RFC 826 is defined the address resolution protocol (ARP), this protocol is perfectly used to form of physical address and logical address such as MAC address and IP address. ARP is integrated with Ethernet and not associated by any means with IP protocol, IP address can be mapped into MAC address if the source requested the data from ant node, that node will form the needful and send it to that node which carry a unique MAC address that is assigned to Ethernet board. Figure 3.10 is depicting of the mapping process. The both logical and physical address are associated with Ethernet network. The MAC address is attached also with any data segment at the time of transmission from the source to destination; MAC address of source node with MAC address of destination node are assigned in the segment as network physical layer understands the physical address only. The cache table of ARP is checked by the network at first before sending any datagram from source node to destination node so if MAC address (which is mapping the IP address) is not presented, the source node will broadcast of this datagram to all over network so it can be received by all nodes. Figure 3.10 depicts the packet format of address resolution protocol.

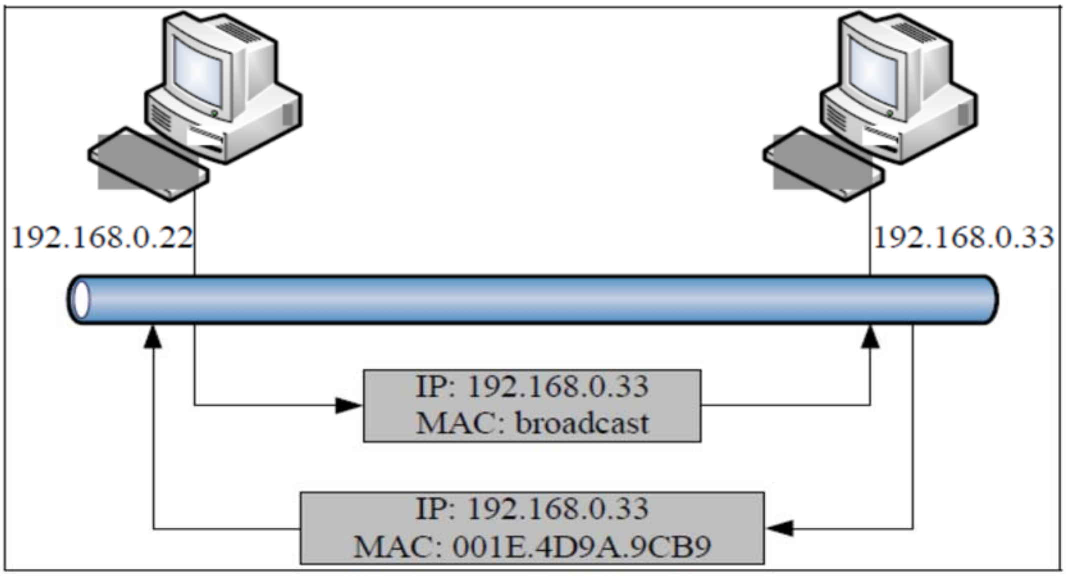

Figure 3.10: Address resolution protocol mapping [34].

2.7 Hypertext Transfer Protocol

RFC 1945 is defined the (HTTP) hyper-text control protocol, this protocol is residing on application layer as object oriented protocol. It is stateless and may be adopted by many applications such as web servers and name servers or file system management. HTTP using internet to provide the connectivity between the clients and servers and it is supported by TCP protocol, in that any user or host under the server network can quire the web page through its IP address by using of web browser; as a result to that, server may reply with this page and user can view the same from his computer. Server will terminate the connection with this user after sending the required information.

CHAPTER THREE

METHODOLOGY

3.1 Overview

Power systems that basically including of generators, transformers and transmission lines are subjected to unexpected incidents such as faults or equipment damages due to external forces (high wind, floods, heavy rain, and lighting) or even the change in working conditions like load increments. All of those can participate to degrade the performance of such systems. It is obvious that power system materials are quite costly and any disorder may lead to undesired circumstances for both consumers and operators. Traditionally, multiple means are introduces to protect power system such as relays and breakers, fuses and extra. Many protection scenarios may be implementing with different parts of power system to maintain a smooth operation and avoid the errors. The technology of monitoring the system is playing important role to avoid the problems existence due to power system faults. Microcontroller based monitoring and protection is used in this project to maintain the performance of transformer. This monitoring system is using a web to update the statues of transformer and reveal the information to the protection authorities; meanwhile, some protection strategies are implemented in microcontroller to take the immediate actions and efforts to avoid the unwanted incidents such as over current and temperature hike. The following sections are describing the operation mechanism of monitoring system like the interface of different sensors with microcontroller and bursting of the output information to the web. All the interfaces such as Ethernet and network and methods to connect the miniature web server with the network will be discussed as well.

3.2 Monitoring System

Design a monitoring system to observe the operation of power transformer and detect real-time ratings as well as initiate the protection scenarios base on the existing error is going to be practiced under different conditions. This logic is going to be implemented by microcontroller; it is supporting web facilities to allow remote monitoring regardless the venue of monitoring unit/department. In other word, this monitoring system is tracking an active transformer, recording its inputs and output and processing that information and finally posting the result on remote terminal unit. RTU can be installed anywhere far/near from the microcontroller and the last is providing a mobility monitoring in such way the user can access from any computer in the network by web browser.

3.2.1 Design Considerations

Automated monitoring system is going to be implemented jointly with power transformer that producing a 220 volt at secondary windings and variable current depending on load amount. Firstly currents from the primary winding and secondary winding are detected by using current sensor, the voltage of the output is also detected by voltage transformer which produces a five DC voltage. Moreover, winding temperature, oil temperature, gas leakage of this transformer are detecting by specific thermal sensors and gas sensor. As a result microcontroller is taking all of those inputs and pre-processing it in order to take the proper action hereinafter, microcontroller is going to post all the detections to the webserver and keep it ready for user access. User can manually initiate some functions remotely such as stating alarm; furthermore, dynamic protection can be started by microcontroller itself such as breaking down the supply source in case of overcurrent or even starting a cooling system in case of extra temperature detection.

3.2.2 Hardware Adaptation

Granting the result as expected from this design is required a network of hardware and software implementation. Same like miniature webserver that embedded with microcontroller that having capabilities to work in such requirements and fulfil the criteria, more hardware are also needed. The following points are illustrating the detailed requirements for setting up the monitoring system:

1) PIC that provide analogue input ports and embedded webserver with satisfied clock speed and enough storage (ROM) capacity to store the web information (HTTP) pages. However, this device must provide a computer interface facility to merge the monitoring system in computer network.

2) Current sensor: in here a couple of sensor is required to get the current rating from both primary winding of transformer end and the rating of current from the load end. However, this sensor is expected to produce a normalized DC voltage of five voltages as a input to microcontroller.

3) Voltage sensor: using of power electronic devices such as diodes as a rectifier, the transformer output voltage (220 v AC) can be scaled into five volte DC and headed to the microcontroller.

4) Thermo sensor: in order to pickup temperature of transformer windings and oil temperature, a specific temperature sensor is required. Indeed two temperature sensors are needed in our case.

5) Gas sensor: oil is being used to keep the winding of transformer as cooler as possible. At some points this oil can be steamed however, the gas emissions from transformer are explicate sign of high temperature and that reveals the oil is burning and it's no longer enough to maintain cooling function so as to avoiding of this occurrences, dynamic control is must. In our project microcontroller is designed to cop with this situation by producing alarm message on RTU page.

6) Over current: this project is adopted an automated load in which can be increased from RTU for testing overcurrent function. Detection of current over 30 A will trigger the microcontroller to shutdown the circuit breaker n the load side. Overcurrent is probably resulting due to fault or some similar occurrences, regardless the reason, hike of current is sign of error and hence shutting down the load is the best action may be made by microcontroller, furthermore, alarm message will be passed into RTU so that the concern department can rectify the error and recover the operation.

7) Active power: it is necessary to implement a code to make the microcontroller to determine the load power. With help of pre-defined power factor active power can be resulted from the following formula:

$$P\ (watt) = Vout * I\ out\ldots\ldots \quad (1)$$

3.2.3 Control Mechanism

Getting all the analogue inputs together and programming the microcontroller to process the same is ending with question that what actions will be taken?. Connecting the proper designed tools with microcontroller output is another challenging task. The aim of this existence is to maintain smooth operation of power system for that, breaking devices, switches, and alarms are importantly required to be interfaced with microcontroller output. The following circuit are being derived to fulfil design objectives of monitoring system.

1) Four functions are being intended to incorporate with RTU, four different task are expected form the same:

a) Function A: ON button is animated in HTML page and upon the click on that button, a buzzer turns on and that terms to voice alarm indicate expected fire and revealing the same to the people close to transform (they may run-out and taking the fire precautions).
b) Function B: on clicking of this button, the current of the load will be raised from zero to 10 A.
c) Function C: on clicking of this button, the current of the load will be raised from 10 A to 20 A.
d) Function D: on clicking of this button, the current of the load will be raised from 20 A to 30 A.
e) Post to that, 30 A is the maximum capacity of current sensor and hence microcontroller that per designed to break the supply upon the detection of 30 A.

2) External cooling system: two fans are used to work according to the oil temperature. For 55 degree FAN1 will be ON and for more hike in temperature FAN2 will be start as well. Microcontroller may OFF the both fans and start risk indicator if more and more hike of temperature is occurred. The figure (4.1) is describing the entire procedure of monitoring and protection system.

3.3 Rectifier Circuit

In order to scale the transformer voltage into 5 volts DC, power electronic needs to be incorporated within monitoring system. The following diagram is demonstration the rectifier circuit components:

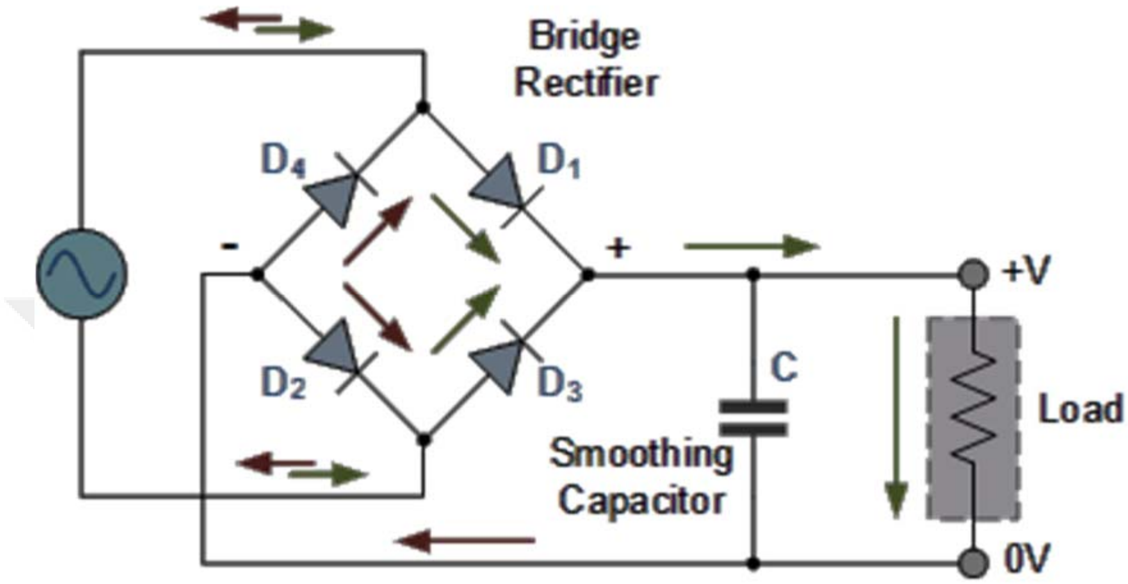

Figure 4.1: Full bridge AC rectifier [36].

Rectification is a means to convert the alternating current waveform into direct current waveform, first stage shown in figure (4.1) is a compensation of four diodes connected in specific directions the all they do is unified the sine wave of AC input to be in positive sequence, the role of capacitor lies of its charge and discharge mechanism so that waveform at the output will look relatively flat. Another device may also connect “voltage regulator” to fix the output and stabilize the resultant waveform to pure DC shape. Figure (4.2) is describing the waveforms producing by each stage of rectifier circuit.

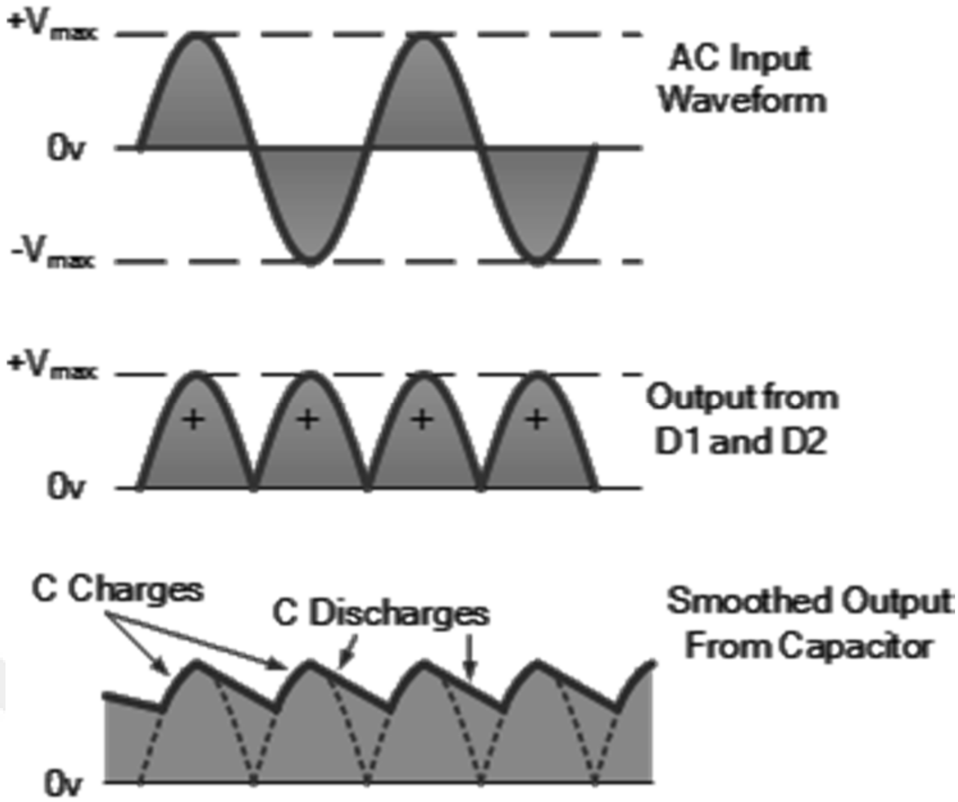

Figure 4.2: Resulted waveforms [36].

Form mathematics point of view, the DC output voltage can be derived as following:

$$Vdc = \frac{1}{\pi}\int_0^{\pi} Vm\sin(wt)\,.dt \quad (2)$$

$$Vdc = \frac{Vm}{\pi}[-\cos(wt)] \quad |0:\pi| \quad (3)$$

$$Vdc = \frac{2Vm}{\pi} \quad (4)$$

$$Idc = \frac{Vdc}{R} = \frac{2Vm}{\pi R} = \frac{2\,Im}{\pi} \quad (5)$$

The Root mean square value can be derived from the following equations:

$$Vrms = [\frac{1}{\pi}\int_0^{\pi} Vm^2\sin^2(wt\,)\ .dwt\,]\text{^}0.5 \quad (6)$$

$$Vrms = \frac{Vm}{\sqrt{2}} \quad (8)$$

$$effeciency = \frac{Po}{Pi} = \frac{Vo*Io}{Vi*Ii} = 81.2 \quad (7)$$

3.4 Over Current Condition

The secondary AC current exiting from transformer is scaled depending on the sensor of current which bear 30 A as maximum rating. However the current must be simulated to change periodically during the simulation time, this can be accomplished by connecting more loads in parallel with secondary winding of transformer. Current is ranging from 10 A through 30 A by 20 A. in order to sense the current variation in our system, a 30 A current sensor was used. This sensor is producing a DC voltage in output up to 5 volts, this voltage is representing the maximum current can flow through the said sensor (5 volt is termed to 30 A of current) this sensor is designed to start sensing at 2.5 v through 5 v where 2.5 is representing no current state.

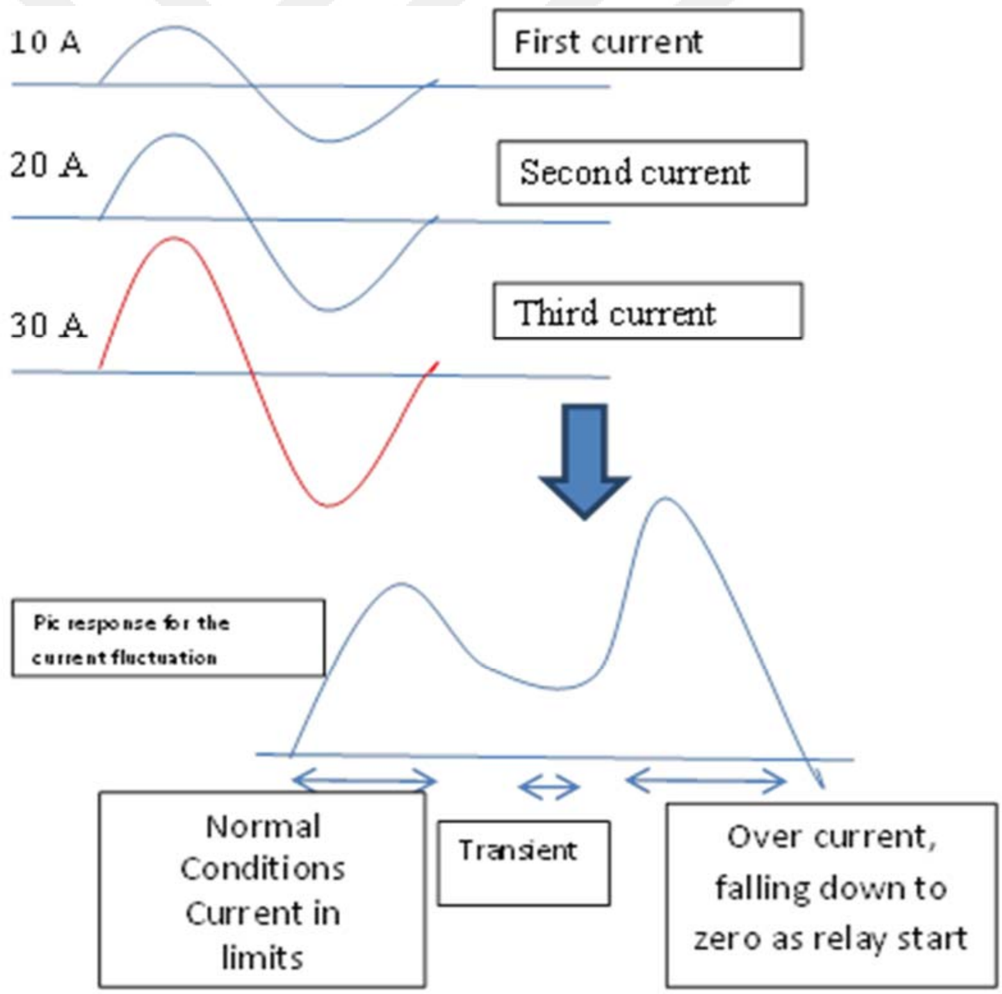

Figure 4.3: Microcontroller response for current fluctuation.

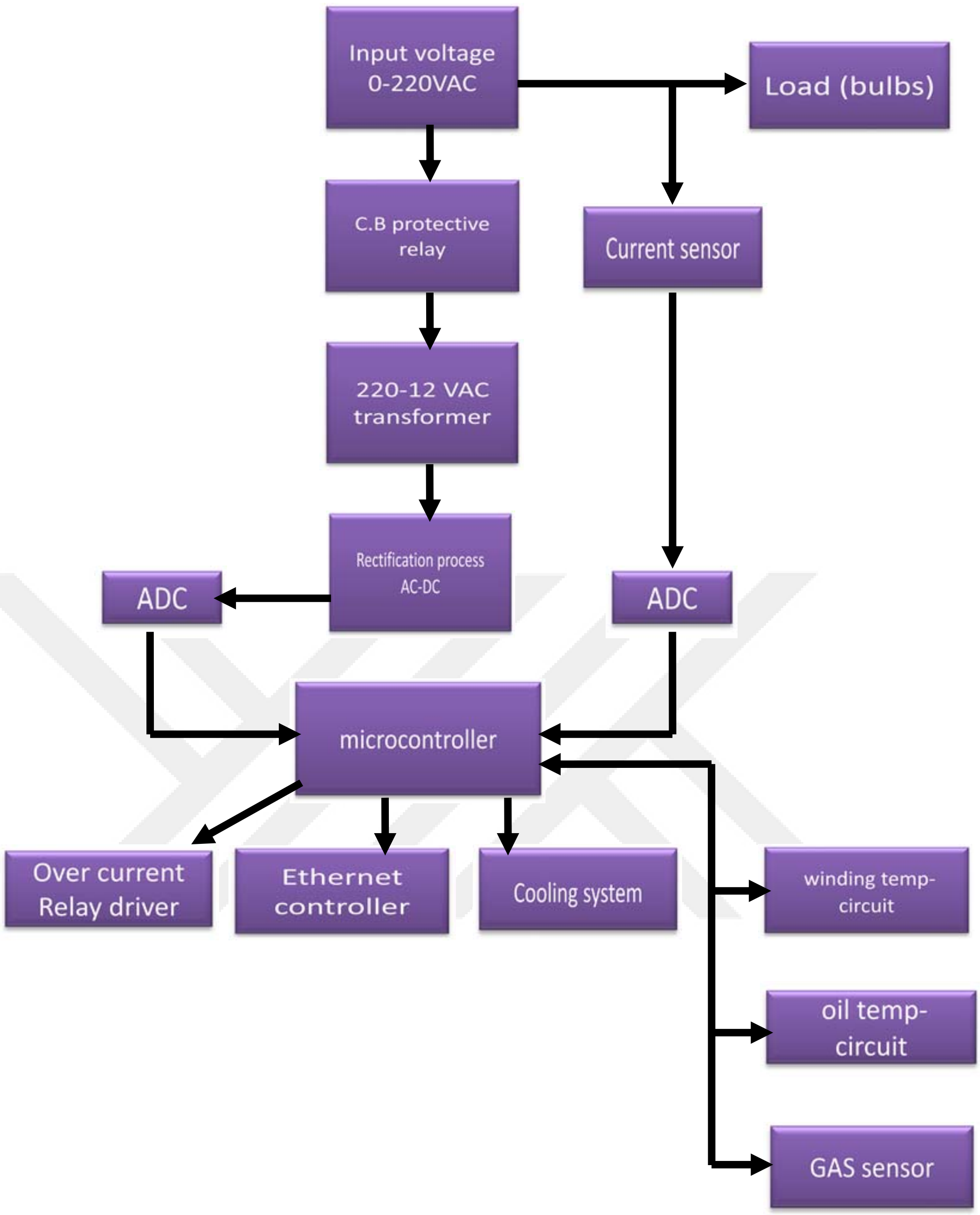

Figure 4.4: Monitoring system diagram.

Figure (4.4) shows the proposed monitoring system, step-down transformer feeds the rectifier circuit which connected to the microcontroller via analog-digital converter, current sensor ACS is connected to the microcontroller by ADC pin to measure the current of the load. The winding temperature, oil temperature and gas sensor are the input signals that measured by microcontroller. The first output signal is sent to the cooling system to operate additional cooling fans in case of transformer overheating. The second signal is sent to the Ethernet controller for communication.

The third one is sent to the over current protection relay in order to disconnect the load in case of overloading.

3.5 Microchip

As per the functions prescribed in the preceding sections microcontroller 18f4620 is being selected to meet the design requirements. The 40 pins chip is illustrated in figure (4.5), this device is manufactured by Microchip and designed to work with embedded webserver hence it can perform the web functions and networking protocols initiation. Nano-Watt technology is facilitating many service introduced by this model of microcontroller such as Alternate Run Modes, Multiple Idle Modes, On-the-Fly Mode Switching and Low Consumption in Key Modules. The following points are stating the features and significance of this device.

1) Master Synchronous Serial Port (MSSP) module Supporting 3-Wire SPI (all 4 modes) and I2C™ Master and Slave mode.
2) Enhanced Addressable USART module:
a) Supports RS-485, RS-232 and LIN/J2602
b) RS-232 operation using internal oscillator block (no external crystal required)
c) Auto-wake-up on Start bit
d) Auto-Baud Detect
3) 10-Bit, up to 13-Channel Analog-to-Digital (A/D) Converter module:
a) Auto-acquisition capability
b) Conversion available during Sleep
4) Dual Analog Comparators with Input Multiplexing
5) Programmable 16-Level High/Low-Voltage Detection (HLVD) module:
a) Supports interrupt on High/Low-Voltage Detection
6) Operating Frequency: DC – 40 MHz.
7) Program Memory (Bytes): 65536
8) Program Memory (Instructions): 32768
9) Data Memory (Bytes): 3968

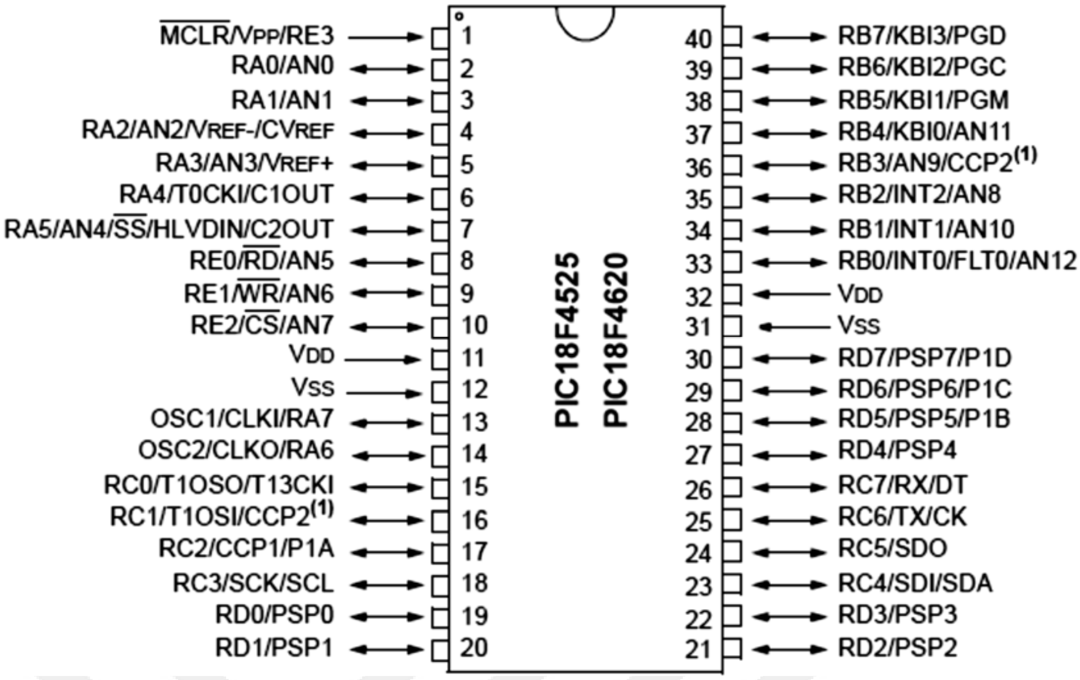

Figure 4.5: Microcontroller pin diagram [36].

3.6 Network Interfacing

ENC28J60 is development board with UEXT connector and 10 Mbit ENC28J60 Ethernet controller from Microchip Technology Inc. it is providing the interface between the microcontroller entity and computers however, the ENC24J60 is incorporated with RJ 45 port to intake the network cable. The features of this device can be stated as following:

1) MOD-ENC28J60 is the easiest way to add 10 Mbit Ethernet connectivity to any of our boards with UEXT connector
2) ENC28J60 Ethernet controller with UEXT connector for easy connection to our other development boards with UEXT connector
3) LAN connector with build in transformer
4) two status LEDs on LAN connector
5) SPI interface takes only few pins to add Ethernet interface to your microcontroller project
6) UEXT 10 pin interface on 0.1" row pins header
7) backward compatibility with ENC28J60-H with 2×5 pin header
8) PCB: FR-4, 1.5 mm (0,062"), solder mask, white silkscreen component print

9) Dimensions: 40×24 mm (1.55×0.95")
10) space between the pin rows: 20 mm (0.8"). Figure (4.6) showing the chip pin diagram.

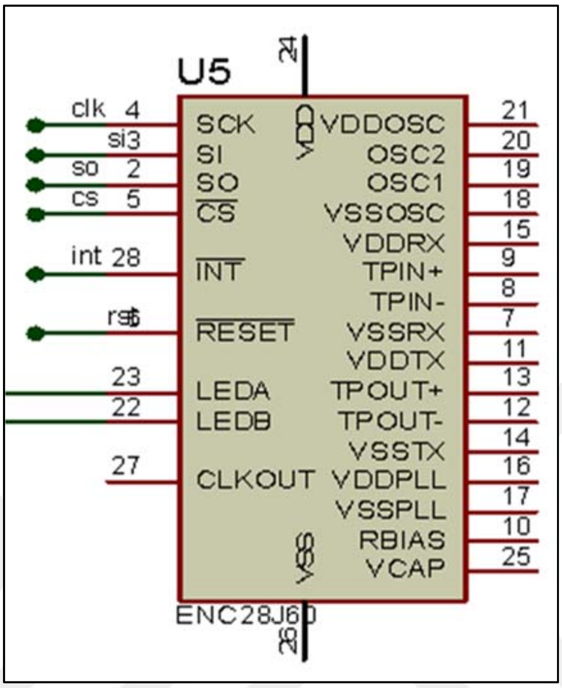

Figure 4.6: Encoder pin diagram [36].

3.7 Thermal Sensor

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ˚ Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4˚C at room temperature and ±3⁄4˚C over a full −55 to +150˚C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy.

It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 μA from its supply, it has very low self-heating, less than 0.1˚C in still air. The LM35 is rated to operate over a −55˚ to +150˚C temperature range, while the LM35C is rated for a −40˚ to +110˚C range (−10˚ with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package. The main features of this integrate circuit can be stated as following:

1) Calibrated directly in ˚ Celsius (Centigrade)
2) Linear + 10.0 mV/˚C scale factor n 0.5˚C
3) Accuracy guaranteeable (at +25˚C)
4) Rated for full −55˚ to +150˚C range
5) Suitable for remote applications n Low cost due to wafer-level trimming
6) Operates from 4 to 30 volts n Less than 60 µA current drain
7) Low self-heating, 0.08˚C in still air
8) Nonlinearity only ±1⁄4˚C typical n Low impedance output, 0.1 Ω for 1 mA load

3.8 Current sensor

The Allegro™ ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems. The device package allows for easy implementation by the customer. Typical applications include motor control, load detection and management, switch mode power supplies, and overcurrent fault protection.

The device is not intended for automotive applications. The device consists of a precise, low-offset, linear Hall circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which the Hall IC converts into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer.

A precise, proportional voltage is provided by the low-offset, chopper-stabilized BiCMOS Hall IC, which is programmed for accuracy after packaging. The output of the device has a positive slope (>VIOUT(Q)) when an increasing current flows through the primary copper conduction path (from pins 1 and 2, to pins 3 and 4), which is the path used for current sampling. The internal resistance of this conductive path is 1.2 mΩ typical, providing low power loss. The thickness of the copper conductor allows survival of Application 1.

The ACS712 outputs an analog signal, VOUT. That varies linearly with the uni- or bi-directional AC or DC primary sampled current, IP, within the range specified. CF is recommended for noise management, with values that depend on the application.

Figure (4.7) describe the pin out of ACS712. Features and Benefits of this device can be tabulated as follow:

1) Low-noise analog signal path
2) Device bandwidth is set via the new FILTER pin
3) 5 μs output rise time in response to step input current
4) 80 kHz bandwidth
5) Total output error 1.5% at TA= 25°C
6) Small footprint, low-profile SOIC8 package
7) 1.2 mΩ internal conductor resistance
8) 2.1 kVRMS minimum isolation voltage from pins 1-4 to pins 5-8
9) 5.0 V, single supply operation
10) 66 to 185 mV/A output sensitivity
11) Output voltage proportional to AC or DC currents
12) Factory-trimmed for accuracy
13) Extremely stable output offset voltage
14) Nearly zero magnetic hysteresis and ratio metric output from supply voltage

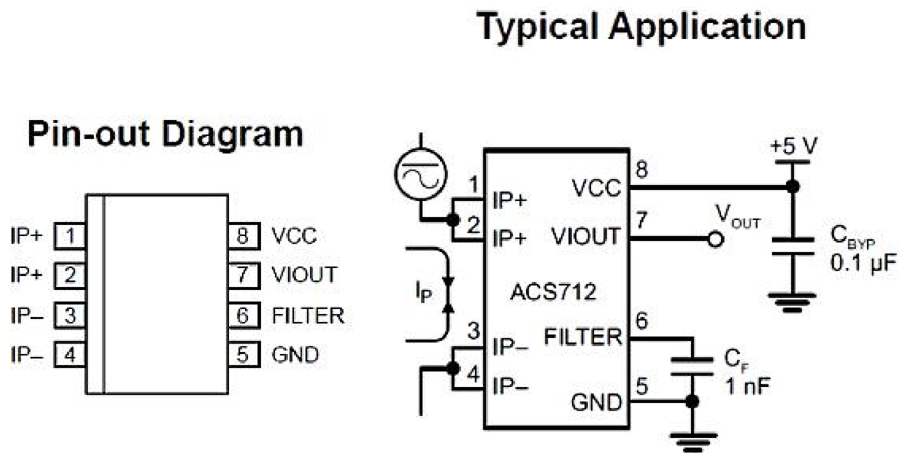

Figure 4.7: Diagram showing out pins in current sensor [35].

CHAPTER FOUR

SIMULATION OF MONITORING SYSTEM

4.1 Outline

Monitoring system is implemented virtually with all the inputs that simulated under different circumstances. Proteus software is found to be best tool for demonstrate the simulation since it provides flexibility to interact with electronic devices electrical sources. In other hand, Proteus is supporting external network interfacing hence data packets can be exchanged between computer network and Proteus network; this chapter is looking after setting up and interfacing each participant in monitoring system. It will simulate the system and so far provides the description of network integration with this system to re rout the data packets from and to microcontroller.

4.2 Tools establishment

Monitoring system to investigate a working mechanism of particular power transformer and to divert reading to remote terminal unit (RTU) is a main demanded from the simulation. As was declared, virtual system will be simulated by Proteus ISIS. The following section will provide a complete understanding of the tools used in simulation.

1) PIC 18F4620: programmable integrated circuit developed by Microchip and can be used to implement the system logically. All sensors are supposed to report to microcontroller are programmed base on their manufacturers data sheet. The program code in microcontroller is making it feasible to understand the coming analogue inputs from particular port and hence, microcontroller is taking the action as per the define conditions in its code. Moreover, this model of PICs can integrate a

miniature webserver and also miniature communication networks such as GSM and USB; that paved the way for remote monitoring and controlling concept. The following IC figure (4.1) is built on Proteus and used in the simulation.

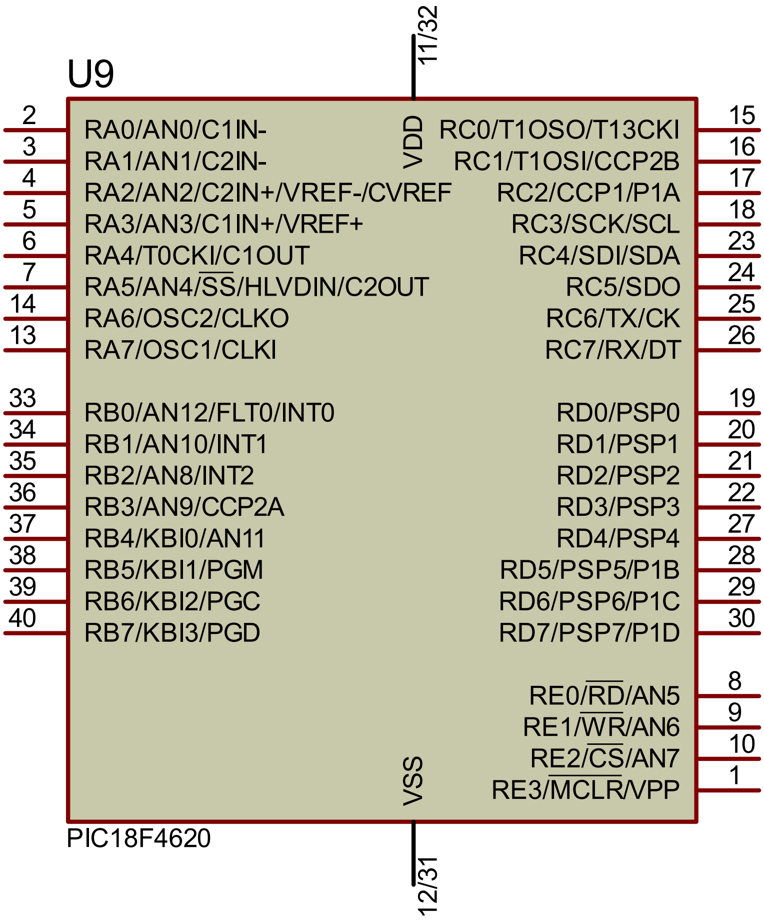

Figure 4.1: Microcontroller pic 18f4620.

In order to use this device with our network the following setups are required:

2) Defining of ports: identify which ports are dedicated for inputs and outputs, analogue inputs and external PC interfacing ports, table (4.1) reveals all the entitled ports as per simulation requirements.

3) Defining of clock: in this case crystal oscillator with 20 MHz is used to meet the design criteria, speed of the process id found satisfactory at 20 MHz crystal oscillator.

4) The powers in ports are empowered with 5 V to let chip in operational mode. As Proteus is not demanding any power inputs but pin RE3 so 5 V DC supply is connected with the same.

Table 4.1: PIC 18f4620 pins task.

AN0	Analogue pin to connect the current sensor of primary winding
AN1	Analogue pin to connect the voltage sensor from secondary winding
AN2	Analogue pin to connect the current sensor of secondary winding
AN3	Analogue pin to connect temperature sensor of winding
AN5	Analogue pin to connect temperature sensor of oil
AN6	Analogue pin to connect gas sensor
AN7	Analogue pin to connect secondary winding overcurrent sensor
RB0	Producing output signal to start loud for oil over temperature
RB1	Producing output signal to start fan1 for oil over temperature
RB2	Producing output signal to start fan2 for oil over temperature
RB3	Producing output signal to start manual buzzer
RB4	Producing output signal to trip main breaker in case of over current
RB5	Producing output signal to close breaker 1 (manually from RTU)
RB6	Producing output signal to close breaker 2 (manually from RTU)
RB7	Producing output signal to close breaker 3 (manually from RTU)
RC0	Produce in/output signal for reset pin of EN28J60
RC1	Produce in/output signal for chip-selector pin of EN28J60
RC3	Produce in/output signal for clock pin of EN28J60
RC4	Produce in/output signal for serial out pin of EN28J60
RC5	Produce in/output signal for serial in pin of EN28J60
RC6	Serial connection (transmitting port)
RC7	Serial connection (receiving port)
RD0	Produce in/output signal for interrupt pin of EN28J60

5) Transformer: in simulation, AC step down transformer to produce 220 V at 50 Hz is used figure (4.2). The primary winding is breaked by switch transistor and relay to virtualize the circuit breaker.

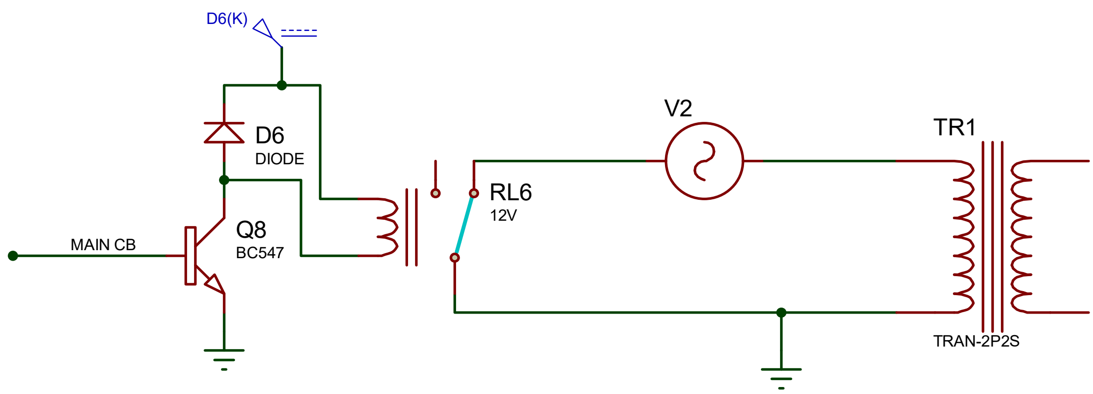

Figure 4.2: AC transformer and circuit breaker simulation.

6) Secondary winding current sensor: figure (4.3) depicts the simulation of this sensor by connecting 220 V supply with three branches of load. Each branch is designated to consume 10 A of current and upon the detection of 30 A, microcontroller may report over current and send control signal to pin RB4 in order to trip the supply.

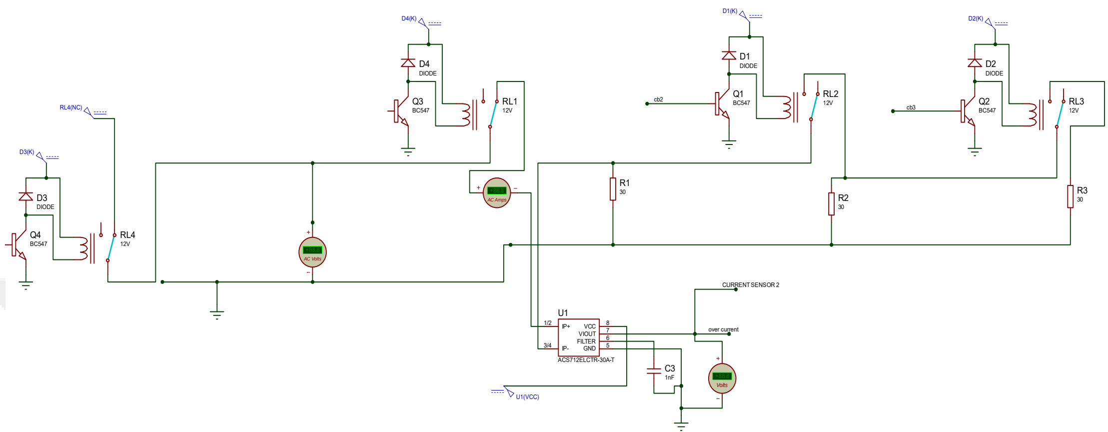

Figure 4.3: Secondary winding current sensor.

As shown in the figure, the voltage supply of 220 V is breaked by driver circuit (switch transistor and relay). Three resistors representing the load and the current of reach resistor is calculated as below.

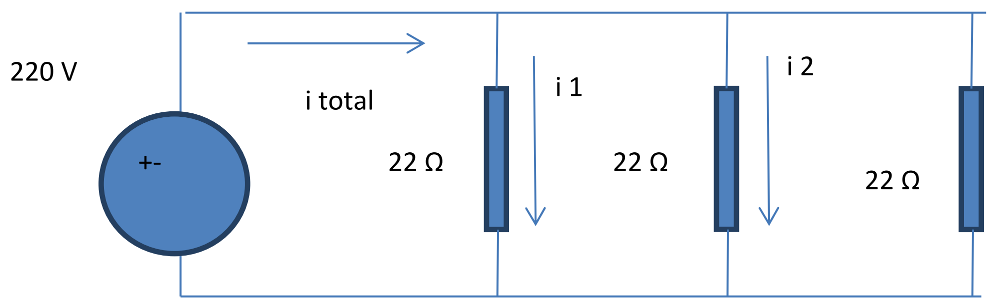

Figure 4.4: Current calculation for load increment.

Resistors are connected in parellel so the voltage is identical in each load

$$i1 = \frac{220\ v}{22\ ohm} = 10\ A = i2 = i3$$

By applying nodal analysis, Kirshhoof current law can predict the total current consumed from the supply as below.

$$in\ KCL:$$

$$i\ total = i1 + i2 + i3$$

$$i\ total = 10 + 10 + 10$$

$$i\ total = 30\ A$$

a) Temperature sensor: two sensors are used to record the temperature of both winding of transformer and the oil of transformer. LM 35 sensors from winding and oil are connected with ports AN3 and AN5 respectively, figure (4.6) is depicted the sensors interfacing.

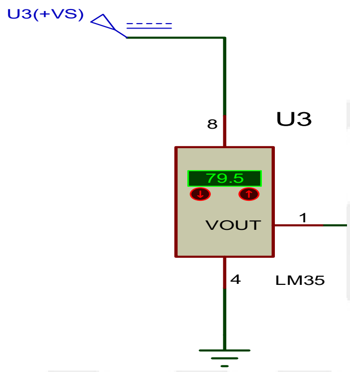

Figure 4.5: LM35 temperature sensor.

Temperature sensor (LM35) is empowered with 5 V DC and directly connected with the pre-defined pin of micro controller. Proteus library is including this animated sensor as in figure (4.6) and temperature can be changed manually from the sensor itself.

a) Gas sensor: for testing the microcontroller detection of gas, a circuit of variable output DC 0 to 5 volts is used as in figure below. Rheostat can be easily varying the voltage output to reach to validate the controller code requirements.

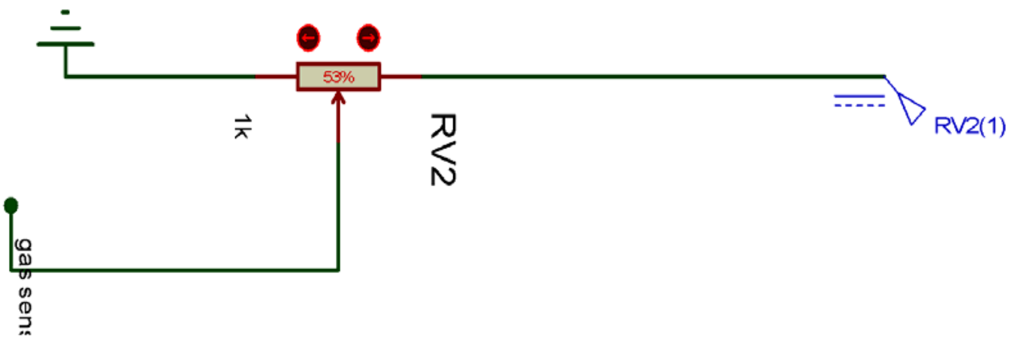

Figure 4.6: Gas sensor.

4.3 Remote Terminal Unit

Miniature web server is embedded with this microcontroller to allow remote access and monitoring of the simulated circuit. Web page is serving as monitor and can be accessed from computers connected with microcontroller circuit. Four functions are designed with this page and acting as remote control of the simulated circuit table (4.2) describes the functions. The functions are embedded with page as buttons to be clicked at the time when remote control is required.

Table 4.2: RTU remote functions.

Title	Description
Function A	To trigger the buzzer in the circuit and it may stand for expected fire occurrence
Function B	To trigger the first circuit breaker to increase the load consumption up to 10 A
Function C	To trigger the second circuit breaker to increase the load consumption up to 20 A
Function D	To trigger the third circuit breaker to increase the load consumption up to 30 A

Upon 30 A detection, microcontroller will treat this occurrence as over load (over load case is programmed to trip the main circuit breaker and hence disconnect the voltage and current reading if the load connected at the secondary winding consumes more than 25 A). The main circuit breaker is controlled by microcontroller pin RB4 which enables the switch transistor and hence changing the relay status. In conjunction with tripping, the micro controller is passing a text to remote monitoring unit stating that over current is occurred. The current sensor is working based on the current values passing through the current sensor as per the following formulas: $I_{resultant} = (V_{o/p} - 2.5)/$ sensitivity $\rightarrow$ in case of 10 A detection the yielded voltage from the sensor will be $V_{o/p} = (10 * 0.066) + 2.5 = 3.16$ v, in case of 20 A the sensor will be yielded $V_{o/p} = (20*0.066)+2.5= 3.82$ v; finally, at 30 A detection $V_{o/p}=(30*0.066)+2.5=4.48$ v.

The temperature sensors are also connected with remote terminal unit so that any fluctuation in the winding and oil temperature will be detected by microcontroller and pass to the RTU. External cooling system is connecting to enhance the oil for keeping the transformer temperature within safe limits. This enhancement system is consisting of two fans and alarm unit as in figure (4.7).

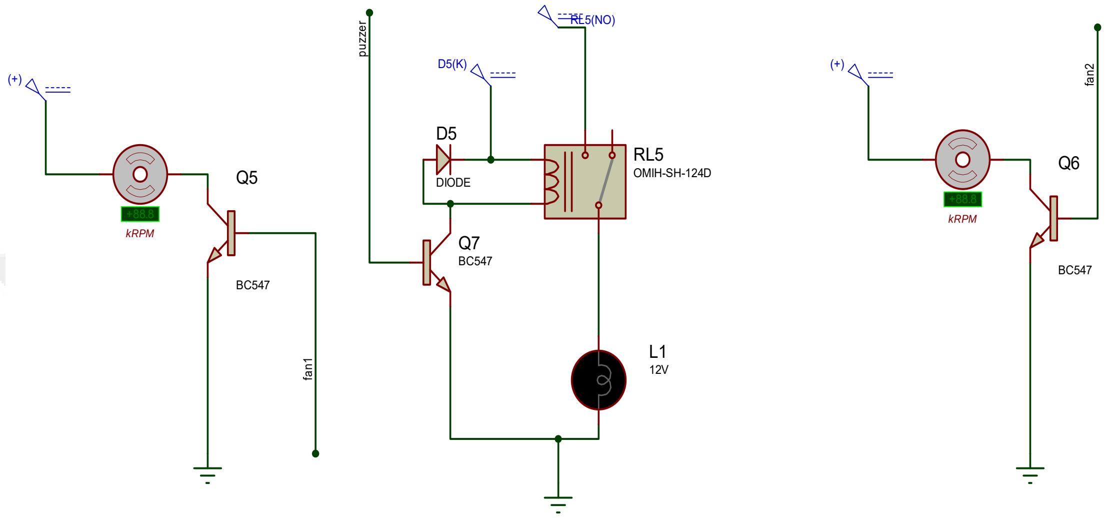

Figure 4.7: Cooling system enhancement.

a) Fan 1 is connected with pin RB 1 and works if temperature of oil reached to 55 degree.
b) Fan 2 is connected with pin RB 2 and works if oil temperature kept increasing to 66 degree.
c) Upon occurrence of higher than 100 degree of oil temperature, microcontroller may shut both fans down and start the alarm function that connected with pin RB0.

Remote Terminal Unit (RTU) comprises of HTML web page which can grab all of the readings and perform the remote control as previously mentioned, the time and date of monitoring is also showed in the monitoring page. Figure (4.8) demonstrate the RTU monitoring page.

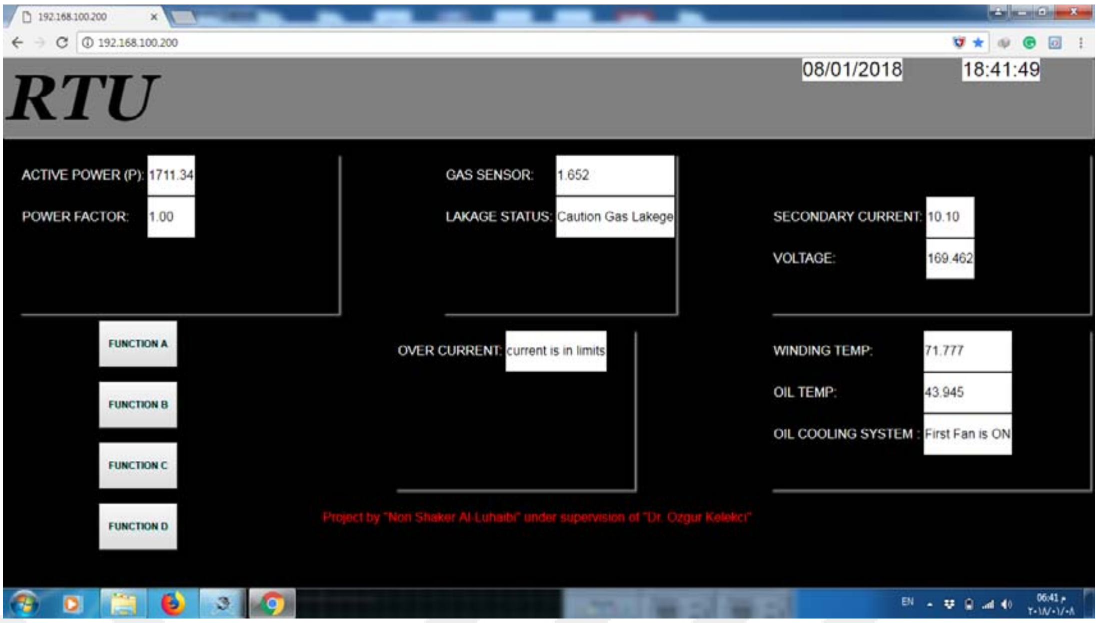

Figure 4.8: Remote web monitoring terminal.

Function A can be used to intimate the people around transformer of fire possibility and they may take the precautions to avoid the risk of fire.

4.4 Switch Transistor Analysis

As in the figure (5.10) this device is passing Vcc through the collector-bias junction (CE). However, both the NPN & PNP type bipolar transistors can be made to operate as "ON/OFF" type solid state switch by biasing the transistors Base terminal differently to that for a signal amplifier. Solid state switches are one of the main applications for the use of transistor to switch a DC output "ON" or "OFF". Some output devices, such as LED's only require a few milliamps at logic level DC voltages and can therefore be driven directly by the output of a logic gate. However, high power devices such as motors, solenoids or lamps, often require more power than that supplied by an ordinary logic gate so transistor switches are used. If the circuit uses the Bipolar Transistor as a Switch, then the biasing of the transistor, either NPN or PNP is arranged to operate the transistor at both sides of the " I-V " characteristics curves we have seen previously. The areas of operation for a transistor switch are known as the Saturation Region and the Cut-off Region. This means then that we can ignore the operating Q-point biasing and voltage divider circuitry required for amplification, and use the transistor as a switch by driving it back and forth between its "fully-OFF" (cut-off) and "fully-ON" (saturation) regions as shown below.

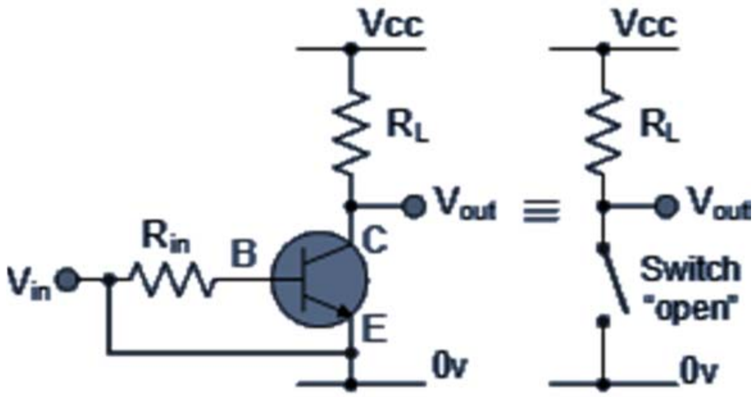

Figure 4.9: Transistor as in switching mode [36].

DC load line of the transistor can describe the cut-off and saturation region respectively figure (3.10).

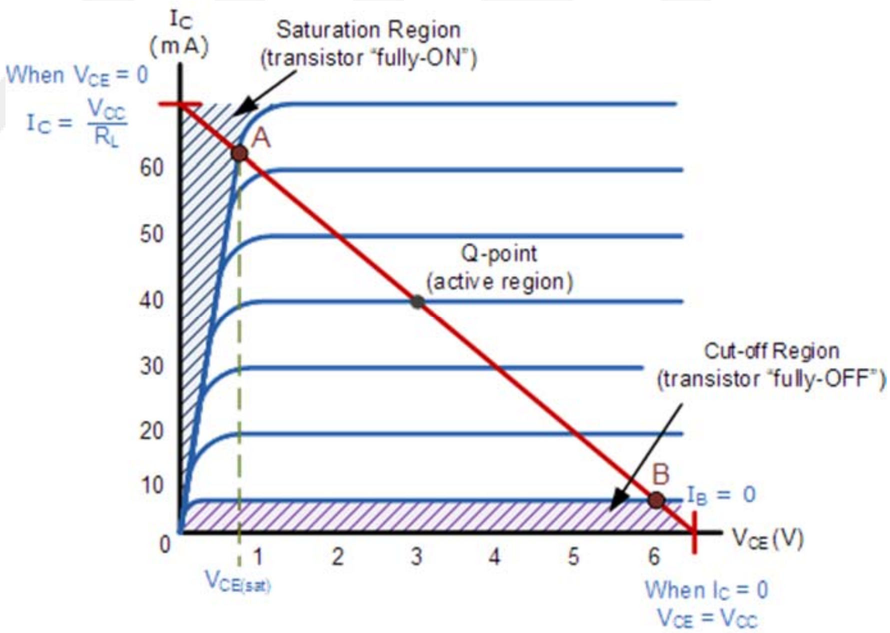

Figure 3.10: Switch transistor DC load line [25].

4.5 Ethernet Interfacing

ENC 28J60 is providing the facilities to connect the microcontroller network with computer network by means of RG 45 interface.

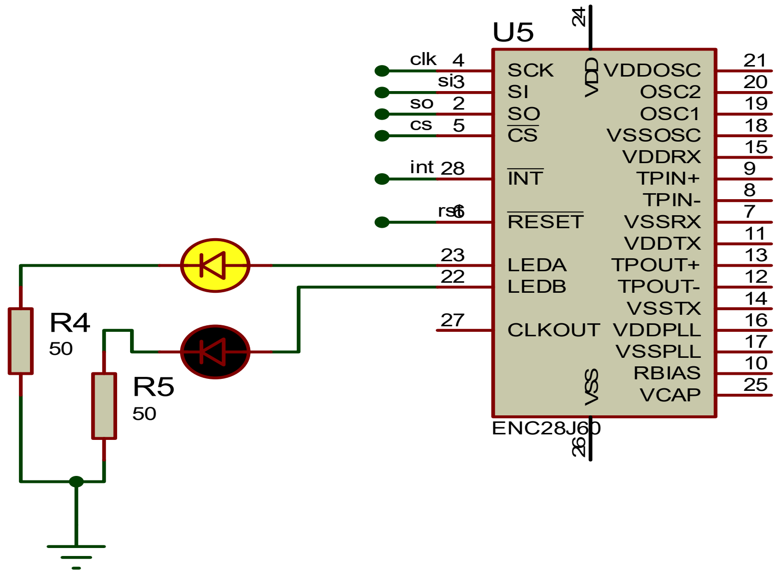

Figure 4.11: ENC 28J60 integrate circuit.

For establishing of this device in Proteus, the Internet Protocol address (IP) must be defined in the encoder setup hence the code was made to connect the network by IP: 192.168.100.200 and the same will hold by this device.

4.6 Computer network setup

Microcontroller was supplied with miniature web server to it passes all the information to that webserver, all network setup and protocols is defined within microcontroller environments and eventually pic network is establishes and allotted the IP of 192.168.100.200; simultaneously the ENC 28J60 is interfaced with microcontroller and it make the last ready to join bigger network such as LAN, WAN etc. For sake of simulation the network done in Proteus is diverted all the data packets to virtual network, VMware is found the best tool to be chosen for this purpose. As depicted in figure (5.13) VMware network is holding same network of PIC and hence all the data will be considered routed to VMware ultimately, changing the setup of computer’s real network card is making it possible to the computer to access the microcontroller and hence monitoring setup. In order to verify the connectivity of all parts and assuring a communication of them, windows CMD tool can be used by pinging the IP of interest and hence connections can be examined to avoid the simulation errors.

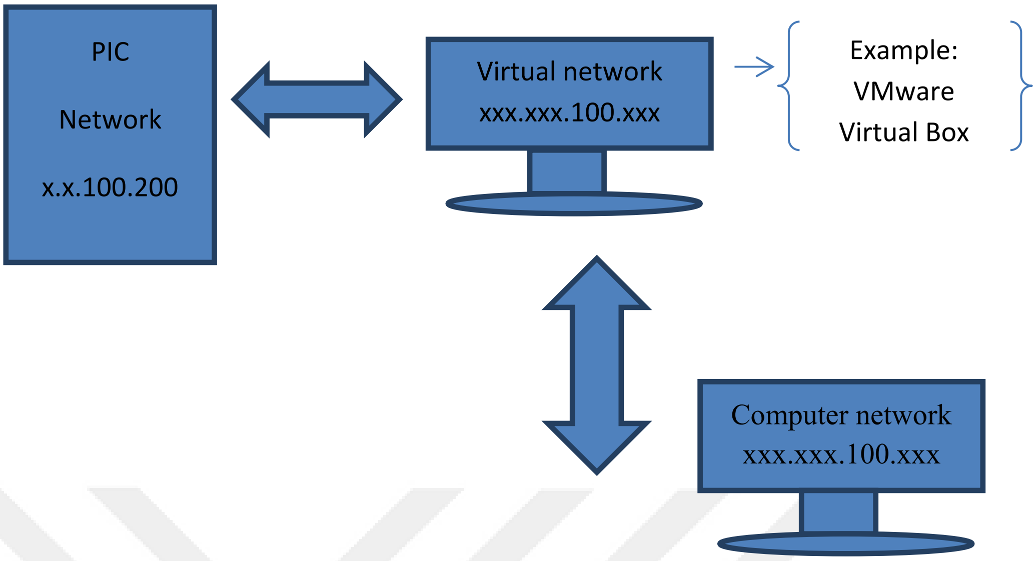

Figure 4.12: Network members to run the virtual monitoring.

The overall simulated system is shown in figure (4.13).

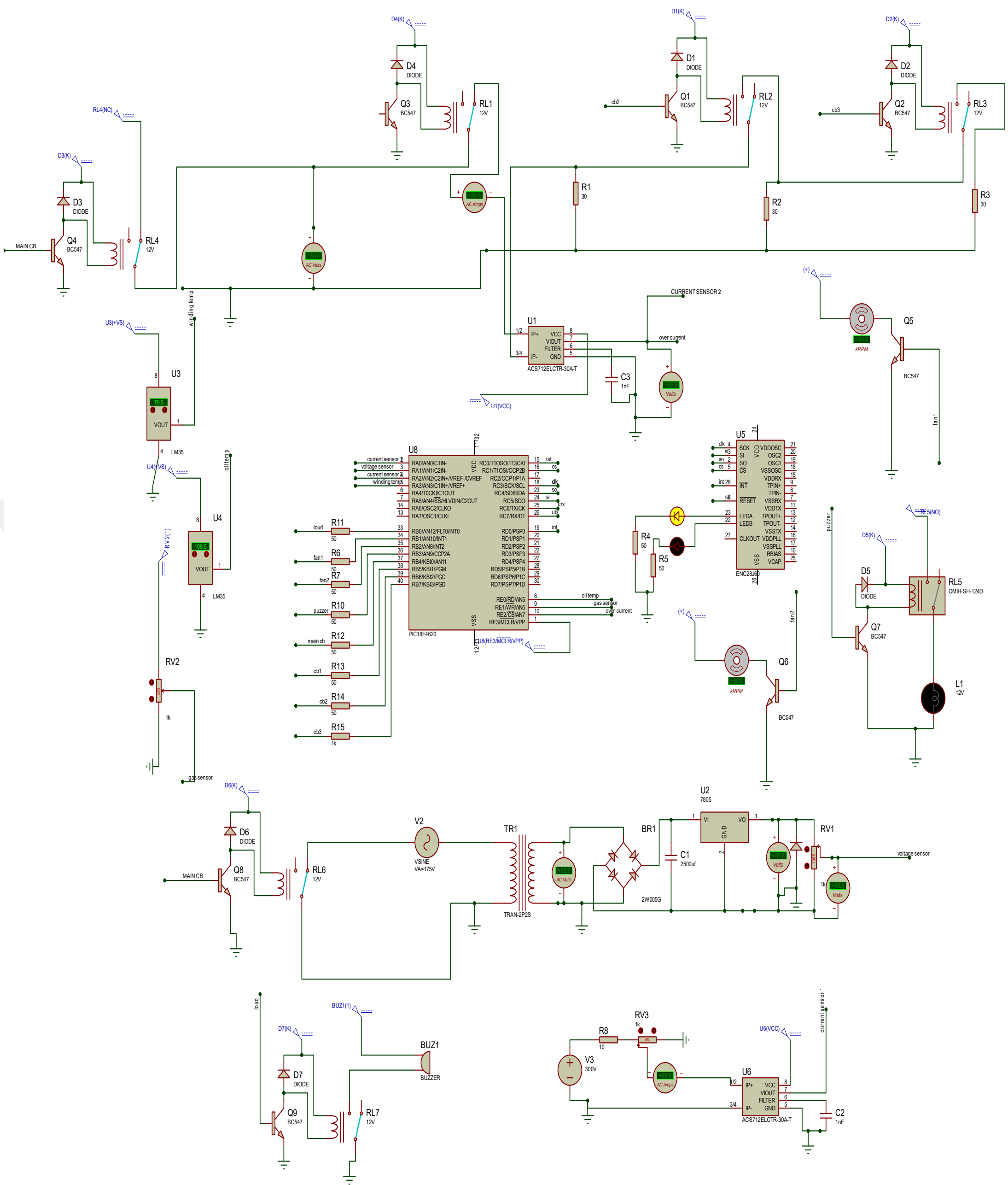

Figure 4.13: Virtual system as per PROTUSE simulator.

CHAPTER FIVE

HARDWARE IMPLEMENTATION

5.1 Overview

Monitoring system of the same properties are being implemented using the available resources of hardware, PIC 18F4260 is used in hardware circuit due to the flexible coding and performance that can be achieved by adopting such kind of microcontrollers. According to the hardware/ implemented circuits, the system can be divided to the following sections as per the performed functions. The hardware case is composed from the hereafter candidates.

5.2 Over Temperature Circuit

Two fans are used in hardware model the first fan is specified to control the temperature of oil and the second fan is used to control the temperature of windings, these fans are working in accordance with temperature reading on of the windings and oil, the both are set to start cooling when the temperature of oil or windings is about 50 degree/C0. Furthermore, if the automotive system goes down for any reason the first and second fan can be controlled manually from web page. One more function is integrated which is manual alarm can be start also from web page

5.2.1 Over Current Circuit

In order to examine the system response in case of over current, a variable resistor rheostat of 30 A (alternating current load), similarly the first load is expected to consume 10 ampere and it can be attached to the circuit by using FACTION A from web page. Similarly, the second load which expected to consume 20 A amperes and it can be attached to the circuit by using check box FACTION B, 20 A are expected to flow in the load circuit so that microcontroller in hardware is designed to go into over current mode upon 30 amperes load existence. Hereafter automatic alarm will be started once this load is took place, the same scenario can be happened manually by tuning the resistor from the circuit board furthermore, both loads can be stopped by using cut power bottom in web page.

5.2.2 Gas Leakage Circuit

A (type device model) is used to detect any CO2 existence in the surrounding environment, upon gas detection an automatic buzzer/alarm is starting and message indicating the same is displayed on the web page. The same is depicted in figure 5.1. The entire circuit output is shown in the figure 5.2 and the web page is also designed to monitor the quantities which stated in the previous chapters i.e. current, voltage, real power, reactive power and extra as in chapter five. Figure 6.2 is depicting the hardware model as per the simulator.

5.3 PCB Design

Bread board was used earlier for testing the designed electronic circuits; it was difficult to rectify the error and troubleshooting of the circuits that implemented with such boards. After the bread-board, a new technology is introduced for testing here that called Printed Circuited Board (PCB). Dip trace software is used for pin out the physical and electrical connections. This software was used due to its neat layout and accurate PCB layout is always the main priority section of the design. Figure 5.1 is depicting the circuit of interest with this software.

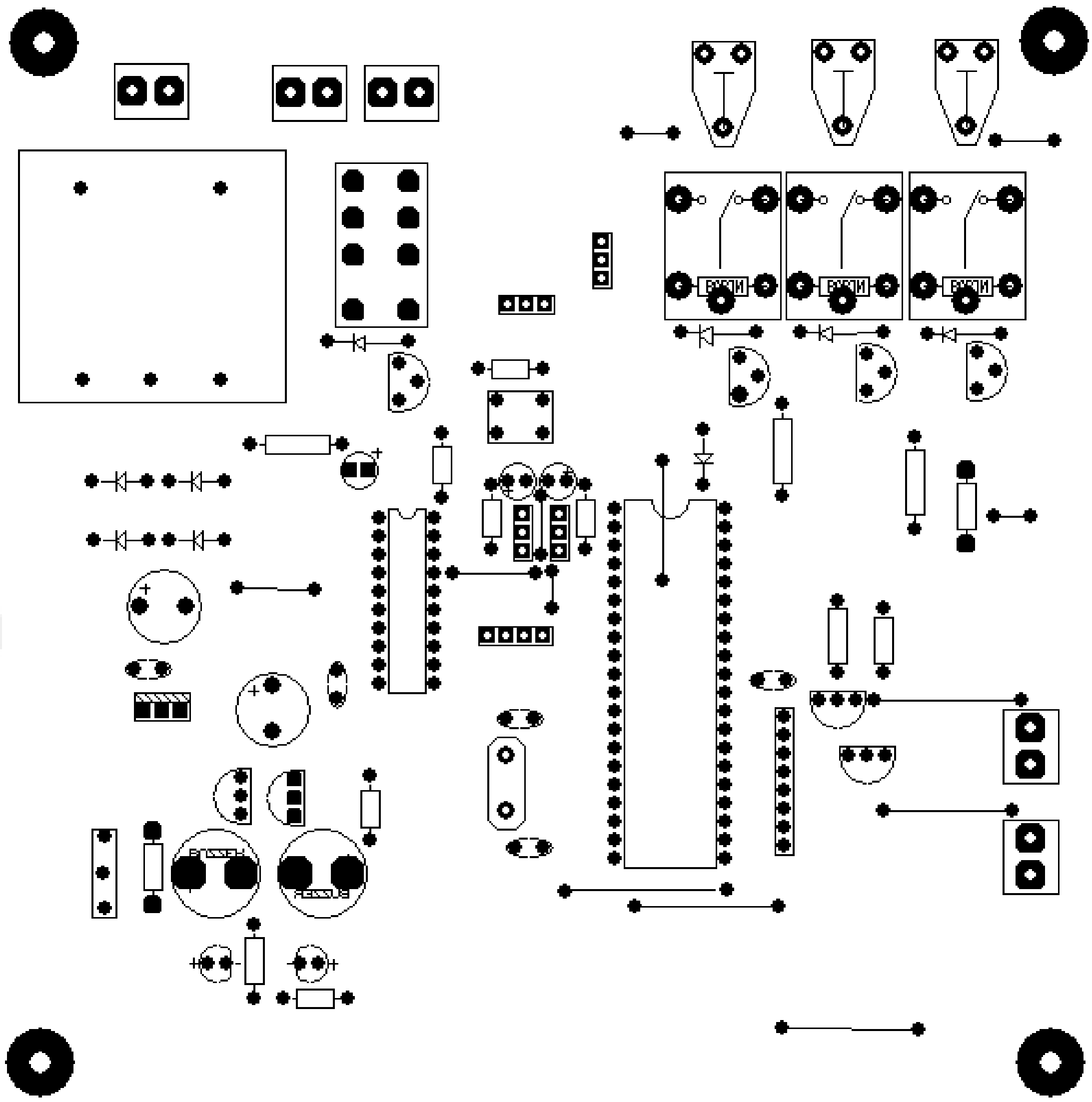

Figure 5.1: Complete circuit PCB design.

The PCB layout schematics were printed on a transparent paper where the layouts were printed with a laser printer. Pressing iron was used to iron the transparent paper on the PCB board systematically for about 10 minutes. The copper clads were allowed to cool off and the transparent paper was removed from the PCB board to expose the transferred image. A permanent marker was used to replace the missing tracks before etching. Etching chemical (HCL acid) was poured into a squared shaped container and the PCB board was placed inside. After that the board was cleaned with Tina chemical in order to remove the unwanted copper and makes the board ready for drilling where the electronic components are being placed on the particular holes drilled on the board. This procedure is taking place after providing the accurate and final design of the circuit from simulation software, in our case Protuse was used to implement of virtual circuit.

5.4 Soldering

After the drilling process, there comes the soldering process. Soldering attentions need to be taken into consideration when laying out the board. Hand soldering is the traditional method basically used for prototypes and small production stuffs. Major impacts when laying out the board include suitable access for the iron, and thermal relief for pads.

5.5 Testing and Troubleshooting

After soldering, finished PCB has to go through comprehensive checks for electrical continuity test and shorts that might occur at time of soldering. This is achieved by using the multi-meter continuity check mode/ short circuit indicator. It checks that the continuity of the tracks if matches each other; if not a troubleshooting session has to take place in order to trace and rectify the problem.

5.6 Project Prototype

As depicted in figure 5.2, the system prototype has been developed with all the features of a monitoring the power system using web server. The loads are connected to the transformer secondary windings (direct alternator input), which means 220 v of terminal voltage to run the loads and this acts as 11000/220 v step down transformer output, current sensor is connected in series with a load for real-time current monitoring. Base on the values of real-time current that consumed by the load, the microcontroller takes a decision over the relay whether to cut off or not. Base on the monitored voltage values; the microcontroller takes decision over the relay. The microcontroller board contains all the sub-circuits onboard including the high voltage sensing circuit, gas sensor, and temperature sensor, relays for protection purposes and finally the ENC28J60 and RJ45 for transmitting the control signals into terminal computer.

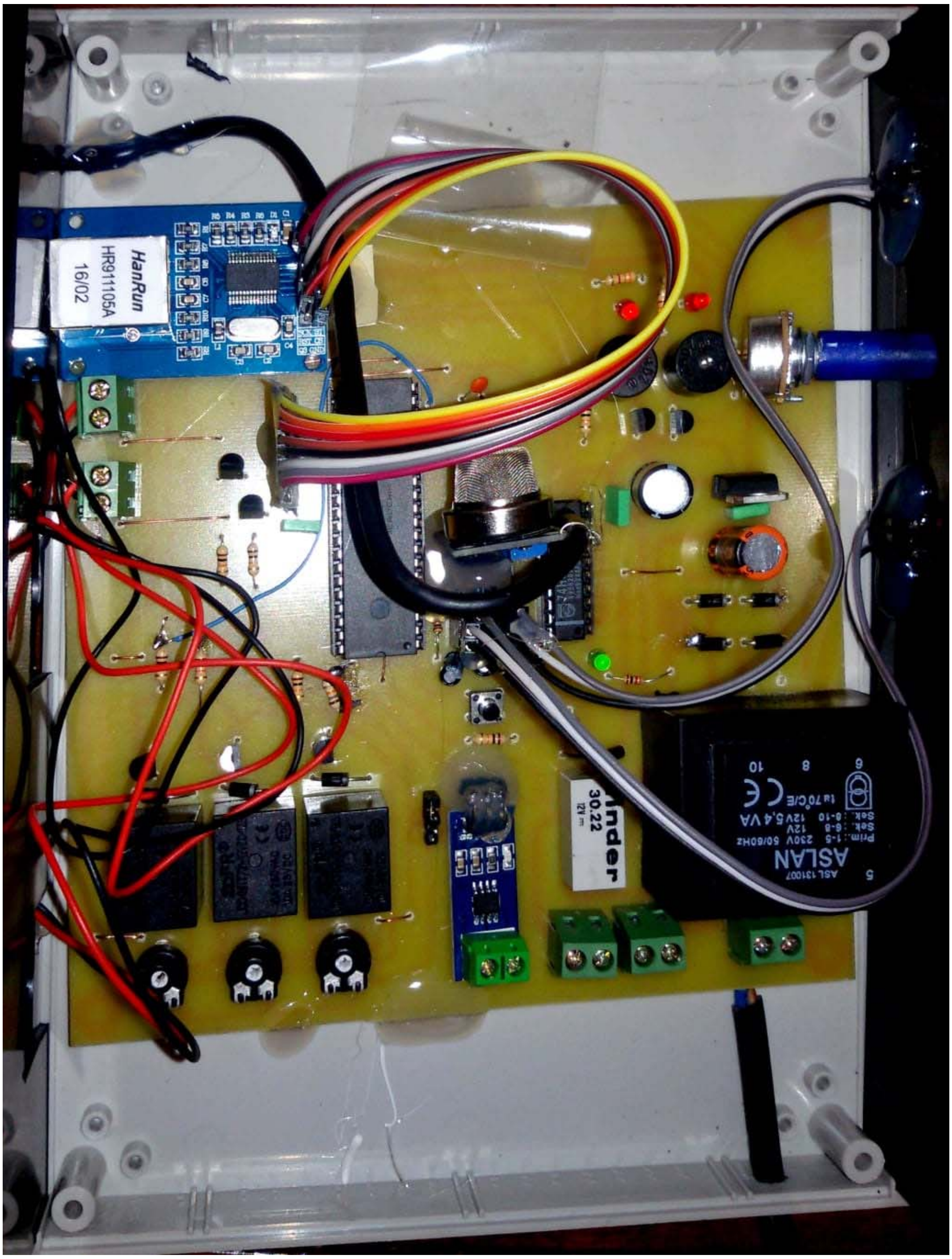

Figure 5.2: Project prototype after implementing the hardware.

Figure above is showing the monitoring system components that implemented inside a white case. The input AC voltage was given through the step-down transformer; the loads were connected at the 220 V side of the transformer to be. Hardware system is implemented to enable the microcontroller for monitoring the current consumed by the loads as well as the voltage on the transformer secondary windings. Furthermore, temperature of windings and oil are controlled throughout temperature sensors that keep observing the transformer warmness. All the readings from every sensing circuit are sent to the microcontroller specific pin and the last is in turn process the said input signals and diverts the result into web server. The web mechanism is integrated on the microcontroller so that used or control engineer can access into that by pinging the particular web page using terminal computer which interfaced in this network.

5.6.1 Sensing Devices

Figure 5.3: Current sensor.

Figure 5.4: Gas sensor.

ACS712 current sensor with 30 A capacity is used to detect any over current may be occur in the system while running the loads, this sensor is described in previous section and set to produce an output between 2.5 through 5 volts DC to be directed into microcontroller. From the other hand, QM_2 gas sensor is used to detect any gas leakage (CO_2), this gas is expected to be produced when fire is there, fire may exist within the transformer or even in the surrounding objects and it has to be cleared upon existence, so that microcontroller will generate alarm message indicating the fire existence by help of this sensor.

5.6.2 Cooling System

In this section we used two small funs that terms as cooling material in our prototype, funs are running with 12 v DC and it can be triggered by microcontroller upon high temperature existence. First fun can be start as temperature reaches to 55 C0 and other fun starts with 65 C0, with super high temperature (above tolerance) microcontroller will order the two funs to stop working and it will start alarm system as fire will be on door, figure 5.3 depicts the funs which installed on the case.

5.7 Network Establishment

Ethernet controller is integrated with microcontroller to provide physical layer connection with remote terminal computer; this computer can access the system by using IP address i.e. 192.168.100.200 from any PC within the network. Figure 5.5 depicts the ENC28j60 Ethernet board.

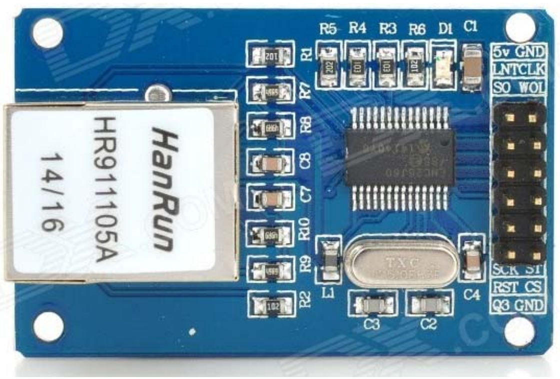

Figure 5.5: ENC28j60 Ethernet board.

System under working condition is depicted in figure 5.6:

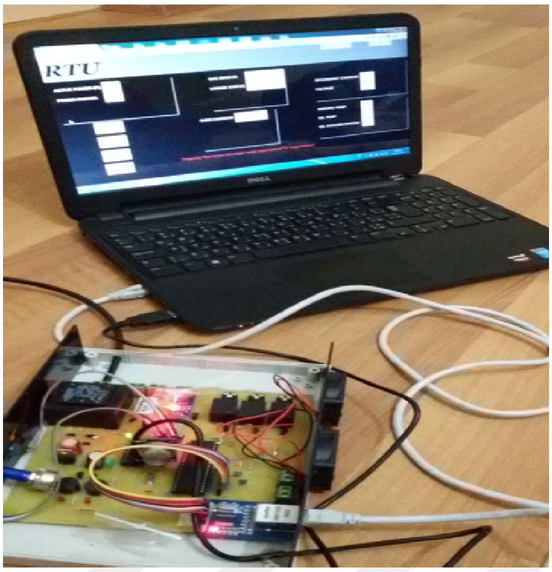

Figure 5.6: Network interfacing between PIC and RTU.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

Protection devices such as relays and breakers are used to protect the power system against error occurrence such as fault or fire. Monitoring system are quite useful for that purpose, many types of protection and monitoring systems are used for different parts of power system i.e. generators, distribution lines and transformers. Well-designed protection is expected to predict the errors prior to their existence and take the required steps for error clearance. Dynamic protection strategies are mostly demanded to avoid any undesired incident which may cause a huge losses and damages in power system. In this project we dealt with the methods of protecting power transformers and hence design the required system to execute these methods. Firstly, discussion of the phenomena that lead to errors was done such as load expansion and consume huge amount of current beyond the capacity of transformer, temperature hike on winding of transformer, the existing cooling system of transformer and the issues lead to disorder the cooling process such as oil evaporation due to over temperature, transformer internal error such as winding fault. However, all those incidents had studied in details and hence advanced monitoring system was designed using a microcontroller. This monitoring system is involving of dynamic decision making and automatic control whenever errors are raised, furthermore, it can detect all the readings such as current rating at both transformer ends, voltage values at different conditions, temperature of winding and oil, gas leakage if any and active and reactive power of the load. All of this information can be sent to remote monitoring unit by means of web. Some functions are integrated to the remote monitoring unit such as manual alarm and load current control. This monitoring system is providing free and time independence access by web; network can be established with any number of hosts and any location. Accurate readings and quick response is ensured while designing this system. PIC 18F4620 was chosen because its performance to work over this complex task, the internal memory is motivate designing of responsive web page including more information and data to display, the random access memory is also one of key points of this device to ensure fast response. From the simulations many issues were reported and solved like clock frequency of the microcontroller, clock has to be chosen accurately and properly. The current sensors were found not perfectly operating with AC source and hence the AC supply is dispensed and compensated by DC voltage source. Moreover, the microcontroller analogue to digital ports were set to intake all the sensors data and process it's recommended to use a proper delay prior to any conversion in our case it was 10 microseconds. Remote monitoring unit is designed to bring all the data from simulation to user along with the data and time of prediction however; user can easily monitor the system remote and apply the required control also by RTU.

One of the important issues is to reroute the data from Proteus environment to the physical card of network (real-talk) in windows, this was done by using multiple software aiming to virtualize the Proteus network and making it ready to ping the physical network card.

The important advantage of this project over other remote monitoring systems such as GSM USB monitoring is completely free of cost usage of network resource since it can be established over intranet and independent of third party network as it is there in mobile network however, mobile network may not cover all the locations and the call may be dropped in some seigniors like network congestion.

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