DEVELOPMENT OF SOFTWARETOOLS FOR LOAD ANALYSIS, FEEDER, SUBSTATION DESIGN ANDSCADA MONITORING AND CONTROL SYSTEM: A DESIGN FOR CHIADZWAMINE

ATHESIS PRESENTED TO THE

ELECTRICAL ENGINEERING DEPARTMENT

FACULTY OF

UNIVERSITY OF ZIMBABWE

IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE

MASTER OF SCIENCE DEGREE IN ELECTRICAL ENGINEERING

BY

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JULY 2020

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ABSTRACT

Title: Development of software tools for load forecast, feeder, substation design and SCADA monitoring and control system: 33kv power supply line for two mines and residential electrification in Chiadzwa

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The project focuses on the development of two software tools for designing and monitoring. These include a software for design and the other one for monitoring electrical parameters for safe and adequate supply of power. Load forecasts is the predicting of electrical power required to meet the short term, medium term or long-term demand. Electrical feeder is a voltage power line transferring power from a distribution substation to the distribution transformers. Electrical substation is a subsidiary station of an electricity generation, transmission and distribution system where voltage is transformed from high to low or vice versa

The first software focuses on load forecast, feeder and substation electrical design. The software is used to calculate various parameters which include cable/conductor sizing, transformer rating, receiving voltage, load demand etc. Currently in Zimbabwe there is no local documented software tool that has been developed to focus on these calculations.

The second software tool focuses on the remote monitoring and control of substations within Chiadzwa area using Supervisory Control and Data Acquisition (SCADA) tool which I developed using processing 2.1. The monitored parameters include voltage, current, temperature, oil level, buchholz relay status. Currently in Zimbabwe there is no local documented software tool that has been developed to for SCADA operations and also SCADA remote monitoring has been applied at national level that is national grid. There is no organisation that has monitored its power draw trends and monitored its substations remotely.

ACKNOWLEDGEMENTS

I would like to thank my advisor, Eng. Diwa and my supervisor Dr. Marisa for their wisdom, guidance and extreme patience in working with me over the last 2 years during this project. I would also like to thank all my friends, family and wifeMitchell Ngandu who supported me in completing this thesis and assisting with software tools for programming. I would like to thank the Almighty God who gave me the strength and wisdom to continuously focus on my objectives and yield the desired results.

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LIST OF ABBREVIATIONS

SCADA - Supervisory Control and Data Acquisition

ZESA – Zimbabwe Electricity Supply Authority

PLC – Power Line Carrier

PLC – Programmable Logic Controller

VT – Voltage transformer

CT – Current transformer

ABB – AseaBrown Boveri

CHAPTER 1 INTRODUCTION

With the expansion and the increase in numbers of decentralized power generators, this will call for more substations and feeders. The computer technology has taken over for the past three decades and has been advantageous to users in the electrical field for design and monitoring. One of the generic strategies for any organisation is low cost production and for the small decentralized generators there is need to have a SCADA system to protect the equipment and this can be achieved by a locally designed software which is cheaper and can help with lower service costs if need be. There is also need for proper design in terms of calculations for the required components on the feeder and in the substation by looking at the load analysis for future expansion of the power system. This is made by developing a software tool which focuses on the load analysis.

Various software programs for load analysis and substation monitoring and control have been designed before worldwide and in Zimbabwe we have been importing such services and software from ABB, Siemens, Allen Bradley etc. and this affects gross domestic product as a nation, availability in case of breakdown, also forcing organisations to ignore the use of such tools as they require more effort to acquire them. The state of the art design software also does simulation, making it more expensive but as for my design software it does load analysis, calculation for substation components and provides the monitoring and control software which is the most important part. The SCADA software can be used by small scale industries in monitoring their substation equipment e.g. transformer oil temperature which can guide on transformer fault status. It can also show voltage and current trends which is a sign of disturbance or reaction within the grid system hence they can help the grid power service about some abnormalities in the system.

This paper is divided into 7 main chapters. The following chapter addresses the current setup in substation monitoring, where it is being used and it also explains various software being used for load analysis, substation and feeder design. Chapter 3 discusses the system design, with block diagram for SCADA and flow chart for the design software tool. Chapter 4 describes the hardware and software implementation showing how the software was developed and interfaced, it also shows development of hardware circuit, and PCB for

power supply and control circuit. Chapter 5 shows the results of the developed circuit and results from the calculations done by the design software. Chapter 6 explores different design to make the two software better and finally chapter 7 is the conclusion.

CHAPTER 2 BACKGROUND

2.1 BACKGROUND

Power system planning is the planning done to integrate new elements which include generators, circuits or equipment into the power grid. The traditional way only considered supply side management, but because of new technology and resource management systems there is need to focus on demand side management in power system planning. Power system planning includes load estimations, and forecast. Load estimation requires an estimate of loads to be installed, level of use, type of loads, geographical location. Load analysis includes demand, maximum demand, demand factor, average load, load factor, diversity factor, load diversity, utilisation factor, capacity factor, loss factor, load curve, load duration curve and plant factor. After determining these factors, another section would do component sizing and feeder configuration design and calculation. After the installation the user would now do the monitoring control and maintenance.

Substations are an essential element in the transmission and distribution of electrical energy, with a primary role of transmission and transform electrical energy by stepping-up or down the voltage. To do this, high voltage switching equipment and power transformers are used, in addition to other measurement and control process variables of transformers, which supply the status of the primary system to the secondary equipment. Electrical substation is a subsidiary station of an electricity generation, transmission and distribution system where voltage is transformed from high to low or vice versa.Substations have several components which include supply line, bus bars, surge voltage protection, transformers, switching apparatus, protective equipment, and grounding.A design specification with consideration of load behaviour helps in the choice of components

Substation Automation Systems are then used to control, protect and monitor the substations. Additional equipment in the Grid line cause some disturbances which need to be traced or seen in real time before they damage equipment.

Digital technologies for power system data acquisition, control, and automation have been continuously evolving for the last three decades. We propose a revolutionary utilization and integration of existing technologies for load forecasting, feeder and substation design and substation monitoring and control for safe operation and protection of the future. Background of relevant technology is provided in this section.

2.2 POWER SYSTEM PLANNING

Power system planning includes load estimations, load analysis and load forecast. Load estimation requires an estimate of loads to be installed, level of use, type of loads, geographical location. Load analysis includes demand, maximum demand, demand factor, average load, load factor, diversity factor, load diversity, utilisation factor, capacity factor, loss factor, load curve, load duration curve and plant factor. Load forecast includes system planning, operational planning and operational control.

Load estimate requires some load characteristics and takes into consideration the relationship of demand factor of connected loads and the actual demand imposed on the system and also looking on the level of use like duration for use, the type of loads if they are inductive or capacitive, geographical location that is where it is located.The level of use helps the planner to know the components required and their wear rate, level of service required on the components and durability. Type of load helps plan for power factor correctionand budget on increased power demand in case of low power factor. Geographical location helps to identify conductor size, length, potential voltage drops and power loss.

Load analysis isa survey that is done on an electrical distribution system to make sure that the electrical system is well balanced for the user requirements without interruptions. It includes demand, maximum demand, demand factor, average load, load factor, diversity factor, load diversity, utilisation factor, capacity factor, loss factor, load curve, load duration curve and plant factor.

- **Demand** - load drawn from the source averaged over a suitable and defined interval of time in kW, kVA or Amps.
- **Maximum demand** – The greatest demand that has occurred over a defined period stated with reference to the defined interval i.e. daily, weekly, monthly or annual.
- **Demand factor** - $\frac{maximum\ \ demand}{total\ \ connected\ \ load}$
- **Average load** - $\frac{\text{energy con sumed in a given period}}{\text{time in that period}}$
- **Load factor** - $\frac{\text{average load}}{\text{peak load}}$
- **Diversity factor** - $\frac{\text{sum of individual MDs}}{\text{coincident maximum demand}}$
- **Utilisation factor** - $\frac{\text{maximum demand}}{\text{rated system capacity}}$
- **Capacity factor** - $\frac{\text{peak load x load factor}}{\text{plant capacit y}}$
- **Loss factor** - $\frac{\text{average power loss}}{\text{Power loss at peak load}}$
- **Load curve** - Graphical representation of sequential load against time plotted as either daily, weekly, monthly or annual load curves
- **Load duration curve** - A plot of load against time with greater load at the left and lesser loads towards the right
- **Plant factor** - $\frac{\text{actual energy produced in time T}}{\text{maximum plant rating x T}}$

Load forecasts is the foreseeing of requisite electrical power to meet short, medium term or long-termdemand. Short term planning focuses on the contingencies, medium term planning focuses on the maintenance plan of components in a power network. Long term planning is used for power network expansion. Short-term load forecasting considers time factors, weather data (temperature and humidity), and possible customer classes. The medium- and long-term forecasts look into the historical load, weather data, the number of customers in different categories, the appliances in the area and their characteristics including age, the economic and demographic data and their forecasts, the appliance sales data, and other factors. It will be derived from the distribution utilities and large commercial and industrial customers. These planners use algorithms or formulation which are used to calculate the future load growth in a given region. The team will also include surveyors who

survey the land where the load has the potential to increase to find the resources available to generate power.

2.3 SUBSTATION DESIGN

Electrical substation is a subsidiary station of an electricity generation, transmission and distribution system where voltage is transformed from high to low or vice versa. Substations have several components which include supply line, bus bars, surge voltage protection, transformers, switching apparatus, protective equipment, grounding. A design specification with consideration of load behavior helps in the choice of components. Substation components are determined by the capacity of the substation hence calculations are done for the bill of quantity. These include transformer size, conductors, cables, switchgears, isolators etc.

2.4 FEEDER DESIGN

Electrical feeder is a voltage power line transferring power from a distribution substation to the distribution transformers. It consists of control and power circuits, which are wired according to design of the load demand and reaction of the line when a fault occurs. Components of a feeder include conductors, disc insulators, isolators, protection relays, bus bars, grounding, surge voltage protection and switchgears. These components specifications are deduced from the design.

2.5 ELECTRICAL POWER LOAD ANALYSIS FLOW

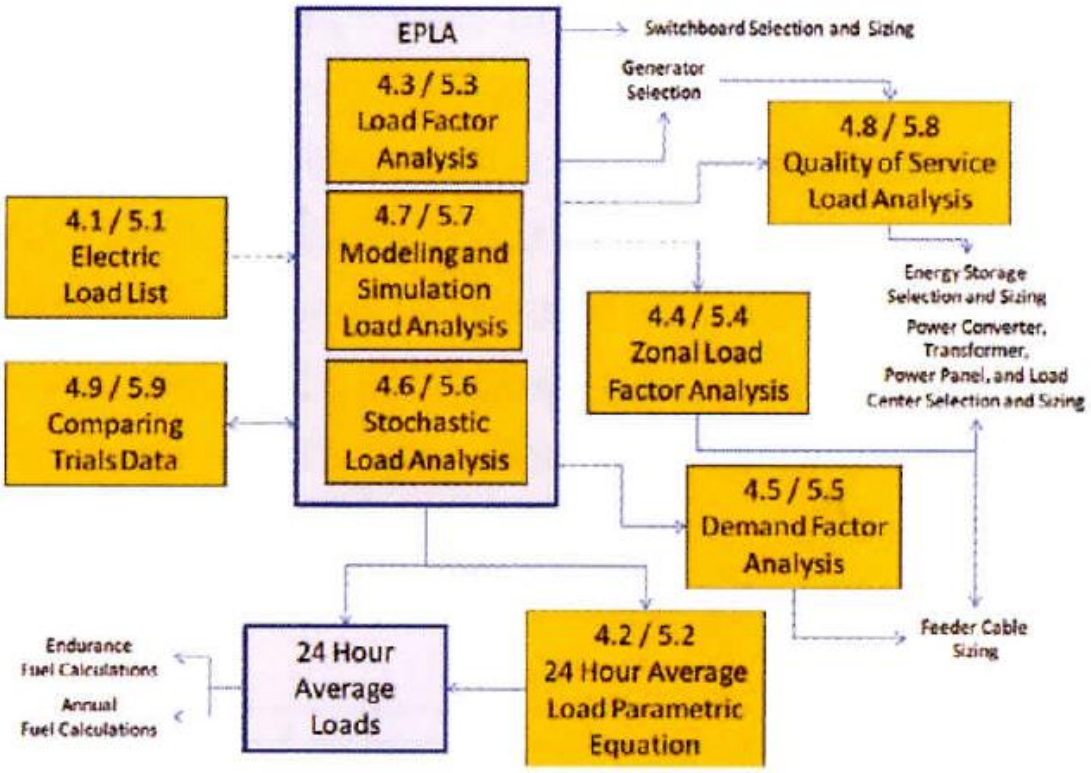


Figure 2.5 Load analysis flow diagram [16]

The above figure shows the flow diagram for load analysis and components determination and calculation for substation and transmission.

2.5.1 LOAD ESTIMATION

An electric load list is first created to determine the maximum load required by the system. It is a database of all electrical loads in the system.

2.5.2 LOAD FACTOR ANALYSIS

This is the ratio of average electricity use against maximum electrical demand for a given time period for example 2MWh in 24 hours, shows and average use of 83.3 kw per hour. It helps in closing the gap between average electricity use and peak electricity demand. It helps to reduce peak demand charges by the utility. A demand request is put by an operation

system and it must stay close to the demand. Load factor is increased to cater for cyclic load variance in the instantaneous power requirement hence there is need to pay attention on equipment sizing. The load estimates are used for the load factor analysis.

2.5.3 MODELLING AND SIMULATION ANALYSIS

When the load size is large that its impact can be felt by the generation there is need to have a rolling reserve which is not reflected in the average or in complex correlation, this might require simulation of the load analysis. In an industry which uses soft starters or variable speed drives it is prone to harmonics and the produce harmonic currents which are induced into the system and hence there is need for simulation.

2.5.4 STOCHASTIC LOAD ANALYSIS

This model uses probability density function, with aggregation of load typically done through Monte Carlo simulation method. An average mean value of the aggregated load for a certain period is used. This information is used for determining an acceptable probability for the load exceeding the generation plant capacity.

2.5.5 ZONAL LOAD ANALYSIS

This is for determining the required power rating for transformers and other power conversion equipment in a zone. Itmodifies the traditional load factor analysis method to accommodate the reduced numberof loads within a zone and the resulting increase in varying loads. This can help by providing a methodfor increasing the load factor of individual equipmentbased on the demand load of the zonalpower system element as calculated by traditional load factor analysis, and on the peak load of the individual load. The modified load factor is known as the zonal load factor of the individual load for the particular zonal power system.

2.5.6 DEMAND FACTOR ANALYSIS

This is used to determine the current rating of bus feeder conductors, cables, circuit breakers. This is important as it protects the equipment from overheating, tripping of breakers because of overloads.

2.5.7 QUALITY OF SERVICE LOAD ANALYSIS

This is a key factor for determining the power required for reserve or standby power in case there is an expansion in load demand so that there is continuity of power supply to the operations. It can be a generating system supplying extra power or a storage system available for reserve power supply. Thestandby power is the power rating of the designatedoffline standby generator for each operationalcondition in case of a grid power fault and this can reduce the downtime due to power unavailability.QOS load analysis does not directly calculate the Mean Time Between Service Interruption but it presents a summaryof loadbreakdowns into the QOS categories that can help in designs which meets the quality service goals.

2.5.8 LOAD ANALYSIS

It includes demand, maximum demand, demand factor, average load, load factor, diversity factor, load diversity, utilisation factor, capacity factor, loss factor, load curve, load duration curve and plant factor for an average of 24 hours.

2.6 POWER SYSTEM DATA ACQUISITION POWER SYSTEM

Power system data acquisition is the basic process where data is collected for all power system monitoring, control and operations. Since the 1920s when power systems started developing, various developments have emerged over the years to establish perfect and accurate systems for substation monitoring and control function. It involved a unique

discrete component (electromechanical relay) within the substation control house. Add to this the requirement of redundant equipment (primary and back up) for critical functionality and the number of wires and handmade connectors can be imagined. In the 1970's the first multifunction relays were introduced to simplify wiring requirements of data acquisition.

The most recent attempt to simplify the wiring requirements of data acquisition is to use standardized connectors and interface equipment. Efforts have been made to simplify the circuit and wiring. The basic infrastructure of power system data acquisition is the instrumentation channel which is installed in almost every substation and these substations rely on instrumentation channels for data acquisition. Instrumentation channels include instrumentation transformers, control cables, burdens, attenuators, and digital processors

2.7 POWER SYSTEM PROTECTION ELECTRIC POWER SYSTEMS

The instability of generation and loaded units will always cause faults and equipment failures in the system and that results in unsafe conditions and recurring of such faults can damage electrical and electronic equipment. The rate at which these faults occur and unnoticeably makes it imperative to disconnect the faulty equipment before further damage of other units. Also efforts have been to improve on the technology developed to achieve the protection goal. The key components of the protection technology include fuses, relays, and breakers. The technology has evolved into very classy protection components with extraordinary capabilities by introducing protective relaying. The key component in power system protection is the protective relay that performs system protection by monitoring the system, identifying of faulty or intolerable conditions, and making decisions as to when to interrupt circuits or initiate shut down procedures. The objective of protective relaying is to selectively isolate a faulty power system component in the minimum possible time so that:

i. Exposure of the system to fault conditions will be minimized
ii. Damage avoidance will be maximized
iii. Safety hazard to persons in and around the faulty power systems will be minimized.

2.8 ELECTIRCAL POWER SYSTEM AUTOMATION

The integration of data in substations and throughout the power system enterprise has been the topic of intense research and development for many years. The foundation of system automation is based on the use of Intelligent Electronic Devices to collect data, digitize it, and interface the data via common communication protocols. The main objective of system automation is to integrate all substation sub-systems utilizing the existing structure of wiring and equipment. Substation sub-systems include protection, fault recording, SE, SCADA, etc. system automation attempts to maximize the use of available substation data and minimize the capital costs for equipment purchasing, wiring, and commissioning. Substation equipment includes relays, meters etc.

2.8.1 EXISTING POWER SYSTEMAUTOMATION

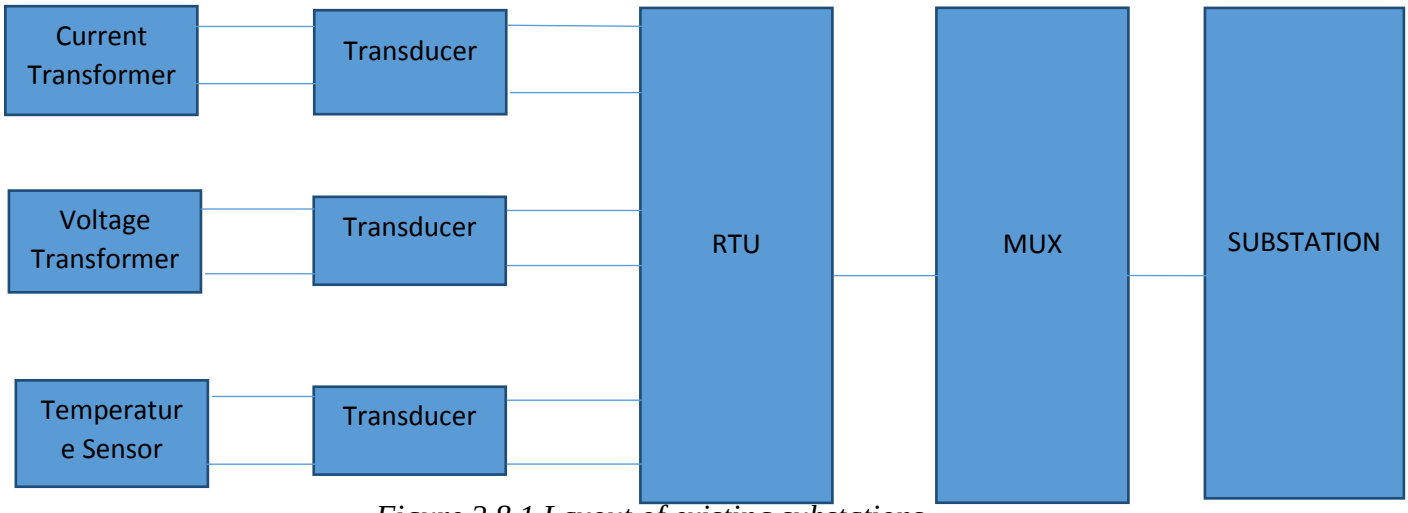


Figure 2.8.1 Layout of existing substations

2.9 PROBLEM STATEMENT

- Load analysis, substation and feederdesign software tools have been developed independently yet they work hand in hand and this has proven to be time consuming and costly
- Unavailability of small/medium and large scale industries substation SCADA monitoring and control system has resulted in lack of real time monitoring, loss of substation equipment, unnoticed effects of grid power, unsafe condition monitoring/switching of personnel at times resulting in damage to property or injury to personnel.

2.10 PROBLEM SOLUTION

- This project aims to:
    i. Reduce organisational costs by designing a software tool for power system planning, substation and feeder design calculations
    ii. Provide real time monitoring and remote control by designing a SCADA System.

2.11 AIM

- To develop a software tool for power system planning load analysis, substation and feeder design calculations for correct sizing of equipment and installation.
- To design a SCADA based system measuring and controlling substation process variables which gives real time values for control and protection.

2.12 OBJECTIVES

- To acquire remote parameters (Voltage, Current, Temperature, buchholz condition) and send real time values via serial communication to a SCADA System.
- To design an efficient SCADA system software with trending facility.
- To interface Arduino controller to SCADA system
- To network 3 substations to one control room
- To develop a software tool for power system planning load analysis, substation and feeder design calculations for correct sizing of equipment and installation

2.13 SCOPE OF STUDY

- The research and design will major on the following technologies

    i. Data Acquisition - Real time system consists of thousands of components and sensors. It is very important to know the status of particular components and sensors. Sensors like current transformer to measure current, voltage transformers to measure voltage, temperature sensors. These parameters will also be used to show power consumption over a period and guide the user on control of power usage.

    ii. Data Communication - The SCADA system uses wired network to communicate between user and devices. From the process variables instruments the signal is sent to the Atmega controller on the Arduino board then via the Ethernet cable to the Ethernet switch and then central computerwhich is the central control room. The real time applications use lot of sensors and components which should be controlled remotely. All information is transmitted using specific protocols. Sensor and relays are not able to communicate with the network protocols so RTUs used to communicate sensors and network interface.

iii. Information/Data presentation–The process variables from the field sensors are then displayed or presented on the developed SCADA system. This is the human machine interface (HMI) which provides all of the information gathered from the various sensors. The SCADA system is used to monitor and control the equipment in the industrial processes which include water distribution, oil distribution and power distribution. As described from the objectives in this document, the main aim of this project is to process the real time data and control the large scale remote industrial environment in the real time scenario.

iv. Monitoring/Control - The SCADA system uses different switches to operate each device and displays the status at the control area. Any part of the process can be turned ON/OFF from the control station using these switches. SCADA system is implemented to work automatically without human intervention.

- Interfacing micro controller to:
  - **i.** Current transformers - They can be defined as the type of instrumental transformers which are used to convert very high currents which can burn or cause damage to measuring instruments like ammeters or other small devices like relays, into lower current values, which are in direct proportion to their higher, primary current values. In this way, current can be easily measured through the device, and as it is directly proportional to the original high current, the true and precise values of current can also be found without damaging the instrument. The secondary current differs in the phase angle from the primary current in a very small value which can almost be approximated to zero if the direction of the connections is appropriate. On the basis of the output supply, the current transformers can be classified into two categories: 1. Measuring Type Current Transformers 2. Protection Type Current Transformers Measuring Type Current Transformers If the output of the current transformer is used to provide protection to measuring devices, electric meters and other such instruments, then the transformer is known as the measuring type current transformer.

2.13.1 PRINCIPLE OF OPERATION

As the conventional transformers, a current transformer also consists of three basic parts that are the Primary winding, a magnetic core and the secondary winding. The basics of the working principle are also the same, i.e. when current is supplies to the primary winding, it produces an alternating flux in the core, due to which an alternating current is also induced in the secondary coil. The thing that is different from conventional transformers is that in case of a current transformer, the primary winding consists of only one or very few turns of the coil, which can be wrapped around the core or just a wire passing through its center. But the secondary winding consists of several turns and is wrapped around the core in this way: The core is chosen of a low loss magnetic material on which the secondary winding is wound, so that the flux density is low and the current can easily be stepped down to the required level. The secondary winding is then connected to the output measuring device or any other device to which we had to supply the output. This connection is made as shown in the figure below:

Applications of a Current transformer

1. Current transformers are used for measuring and monitoring currents, usually of very high values.

2. On buildings whose meters have to measure currents higher than 200 amperes, these current transformers are used there to drive their electrical watt meters.

3. These are also used to keep track of the current readings on power grid stations.

4. These are used in relays for their driving and proper operation of the circuit.

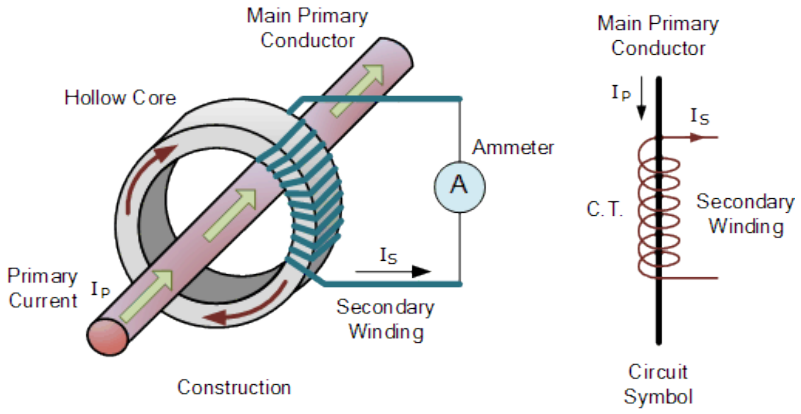


Figure2.12.1 Current Transformer operation[2]

Voltage transformer - A transformer can be defined as a static device which helps in the transformation of electric power in one circuit to electric power of the same frequency in another circuit. The voltage can be raised or lowered in a circuit, but with a proportional increase or decrease in the current ratings.

The main principle of operation of a transformer is mutual inductance between two circuits which is linked by a common magnetic flux. A basic transformer consists of two coils that are electrically separate and inductive, but are magnetically linked through a path of reluctance. The working principle of the transformer can be understood from the figure below.

As shown below the transformer has primary and secondary windings. The core laminations are joined in the form of strips in between the strips you can see that there are some narrow gaps right through the cross-section of the core. These staggered joints are said to be 'imbricate'. Both the coils have high mutual inductance. A mutual electro-motive force is induced in the transformer from the alternating flux that is set up in the laminated core, due to the coil that is connected to a source of alternating voltage. Most of the alternating flux developed by this coil is linked with the other coil and thus produces the mutual induced electro-motive force. The so produced electro-motive force can be explained with the help of Faraday's laws of Electromagnetic Induction as

$$\mathbf{E} = \mathbf{M} \times \frac{\boldsymbol{\delta}\mathbf{I}}{\boldsymbol{\delta}\mathbf{t}}$$

If the second coil circuit is closed, a current flow in it and thus electrical energy is transferred magnetically from the first to the second coil. The alternating current supply is given to the first coil and hence it can be called as the primary winding. The energy is drawn out from the second coil and thus can be called as the secondary winding.

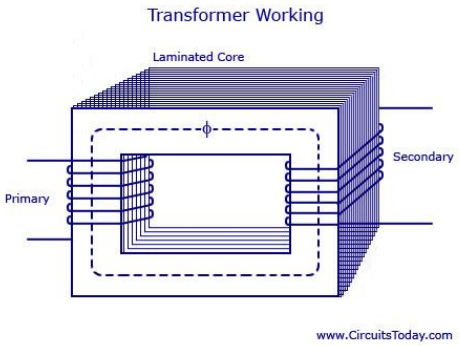


Figure 2.12.2 Voltage Transformer [3]

In short, a transformer carries the operations shown below:

- Transfer of electric power from one circuit to another.
- Transfer of electric power without any change in frequency.
- Transfer with the principle of electromagnetic induction.
- The two electrical circuits are linked by mutual induction

Relays - A relay is an electromechanical device that is actuated by an electrical current. Relays are like remote control switches and are used in many applications because of their relative simplicity, long life, and proven high reliability. All relays contain a sensing unit which is the electric coil, powered by AC or DC current. When the applied current exceeds a threshold value, the coil activates the armature, which operates either to close the open contacts or to open the closed contacts. When a power is supplied to the coil, it generates a magnetic force that actuates the switch mechanism. The magnetic force is, in effect, relaying

the action from one circuit to another. The first circuit is called the control circuit the second is called the load circuit.

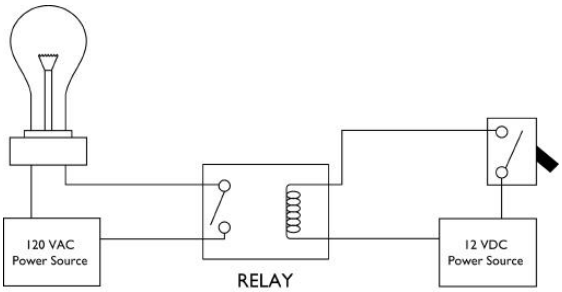


Figure 2.12.3 Relay operation circuit [4]

There are three basic functions of a relay: On/Off Control, Limit Control and Logic Operation.

- On/Off Contro*l*: Example: Air conditioning control, used to limit and control a "high power" load, such as a compressor
- Limit Control: Example: Motor Speed Control, used to disconnect a motor if it runs slower or faster than the desired speed
- Logic Operation: Example: Test Equipment, used to connect the instrument to a number of testing points on the device under test

Types of Relays

There are two basic classifications of relays: Electromechanical and Solid State. Electromechanical relays have moving parts, whereas solid state relays have no moving parts

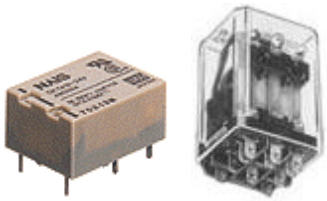


Figure 2.12.4Electromechanical Relays [4]

These active semiconductor devices use light instead of magnetism to actuate a switch. The light comes from an LED, or light emitting diode.

- Arduino programming as well as interfacing hardware and software - The ATmega32 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega32 achieves throughputs approaching 1 MIPS per MHz allowing the system designed to optimize power consumption versus processing speed. With Atmega328P I will have to study new programming language to be able to program it.
- MikroC as a programming language to interface hardware and software.

CHAPTER 3 SYSTEM DESIGN

3.1 OVERVIEW OF THE SYSTEM

The project system is designed into 2 parts, the design part and the monitoring and control part.

i. The design part focuses on the load analysis calculation, substation components sizing and feeder deign components sizing. It helps to calculate and list the components required for a substation and their specifications according to the load analysis calculated. Data is collected for the load required, rated system capacity, peak load, hours of demand etc. they are then entered into the application calculator and results obtained. After obtaining the results, the system guides on the required components/equipment for the substation hence helps to calculate the recommended size for a particular size e.g. 5MVA, 400V system required switch gear. All components/equipment for substation are calculated and then the feeder design is also done. This part helps to determine the sending voltage, conductor size, conductor separation. After this has been done the software lists down all the data and the specifications.

ii. This system was designed to help user to interface the machine with electric substation. As it monitors electric parameters like voltage, current, temperature, buchholz status and protection system remotely and displaying it on a personal computer. The system adds safety in the transmission and distribution of electricity industry as operators and electricians have to deal with low voltage and low currents. Breaker control and phase changing is done in the control room with low voltage of 5V D.C driving coiled breakers

of high voltage up to 33KV. It is software based reducing the wide use of physical components like overload unit which might fail to save its purpose due to wearing out. The efficiency of the system is high because it is not affected by physical conditions. Current transformer, voltage transformers, temperature sensors, limit switches, buchholz relay are connected to the microcontroller which is interfaced to a computer via serial communication. The computer then displays current, voltage, temperature, buchholz relay status, breaker status. From the computer commands are sent via micro controller to the breakers for control.

3.2 FLOW CHART

3.2.1 LOAD ANALYSIS, SUBSTATION AND FEEDER DESIGN FLOW CHART

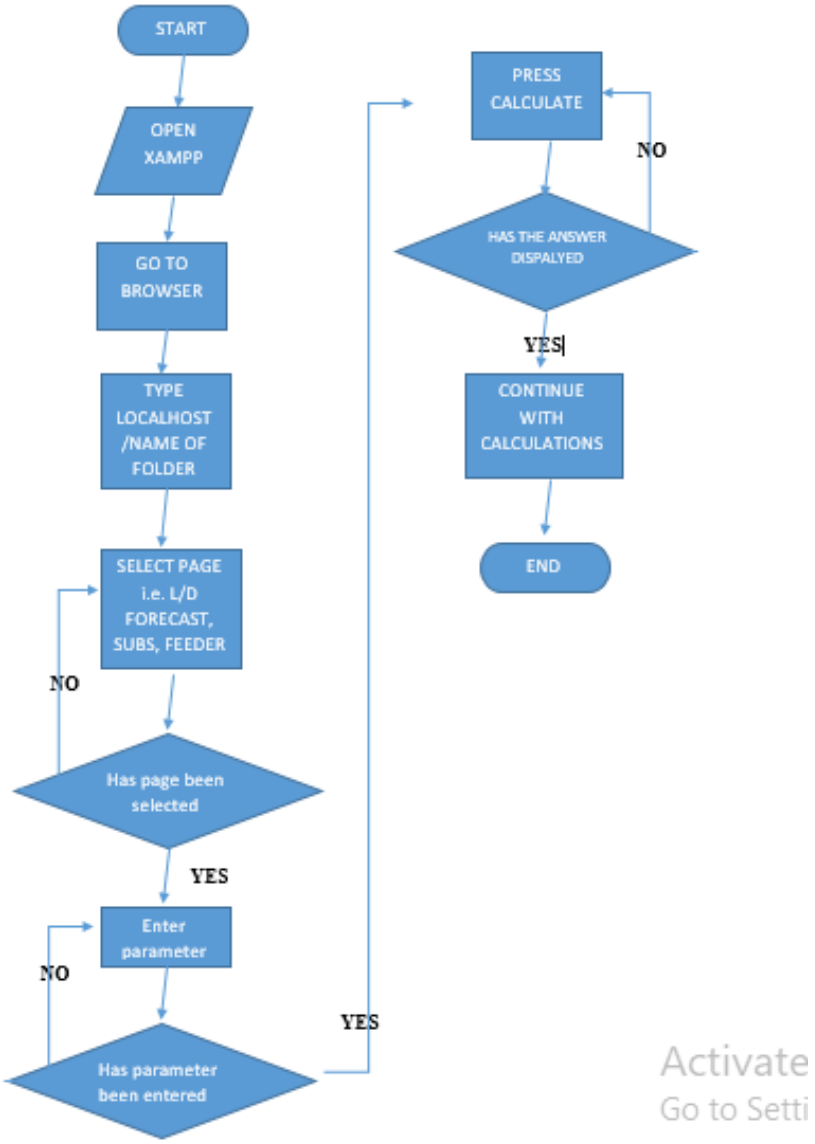


Figure 3.2. 1 Design software tool flow chart

3.2.2 Electrical Power Load Analysis

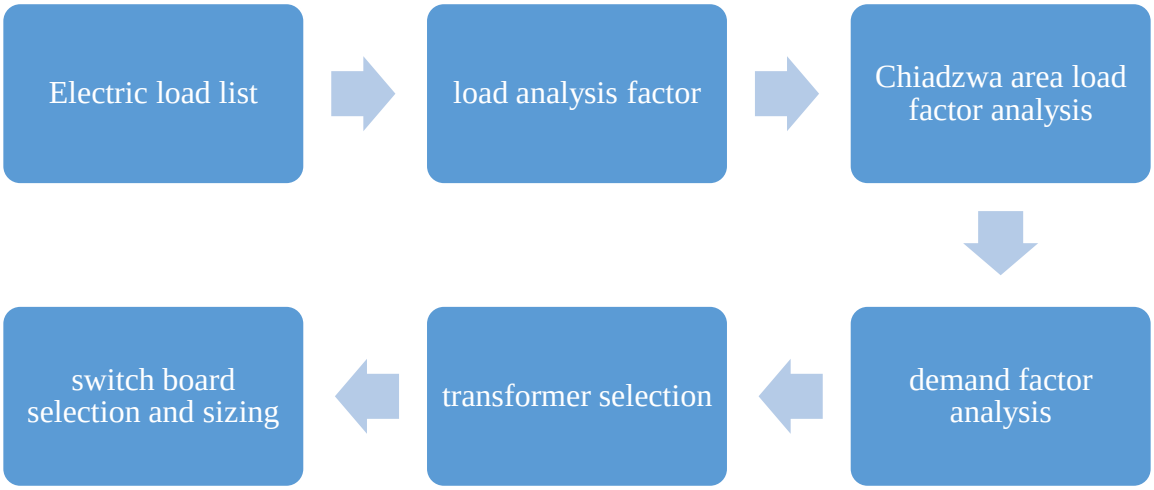


Figure 3.2.1 Load analysis, substation and feeder design software tool

Figure 3.2.1 is a summary of the flow for load analysis, and design for substation and feeder equipment.

3.2.3 DESCRIPTION OF DESIGN SOFTWARE TOOL

The software tool was designed using xampp which is a web system and php programming. From the flow chart above, after programming the code for calculation, the document is saved in folder under xampp application into the htdocs folder. Open xampp and start all modules for checking prerequisites. A user browser is opened to access the xampp application and access the folder with file to run the application. A display of 3 pages is shown and these include the load forecast, substation and feeders design pages. There is an option of choosing the required page and on each page there is a guide on what parameters can be calculated and what to enter to get a required result. A list of all calculated results will be displayed on a separate page, then take a screen shot and do a printout on the bill of quantity with specifications.

3.3 BLOCK DIAGRAM FOR 3 SUBSTATIONS (A, B AND Q)

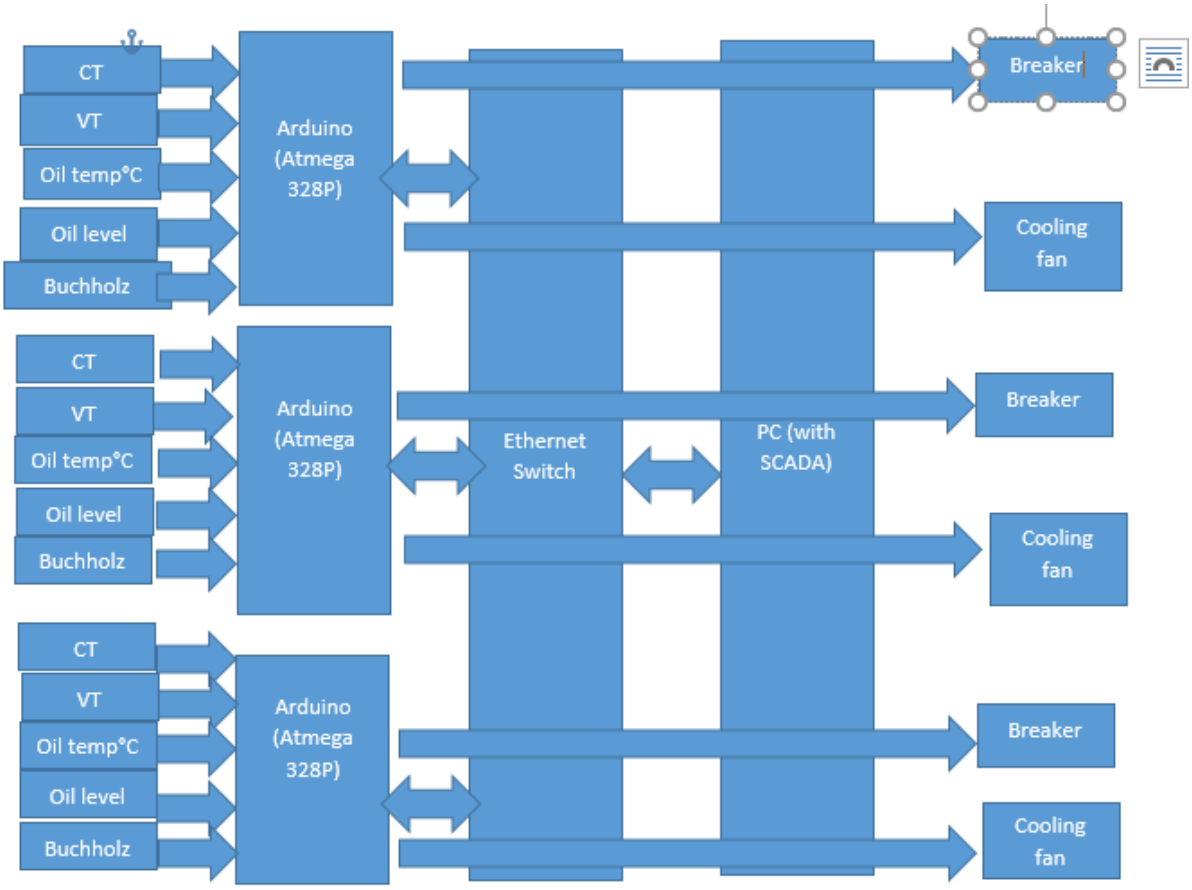


Figure 3.3 SCADA system block diagram

From Figure 3.3 the block diagram shows the interfacing of inputs, processor and outputs. Voltage transformer, current transformer,oil temperature sensor, oil level sensor and buchholz relay status are the input sensors interfaced to the Arduino micro controller. Voltage transformer, current transformer, oil temperature sensor are analogue sensors meaning they measure continuous variables of voltage, current and temperature which are converted to digital values by the microcontroller for processing. These values are then transferred to an Ethernet switch which then transfers to a computer via serial communication to a SCADA system display. Phase monitoring, buchholz status and oil level are digital inputs, meaning they have a discrete value it's either it's a 1 or a 0, which is a high or low. These phase inputs are connected to 220V relay normally open contacts which

change state when there is 220V supply on the coil of the relay. This means when there is no phase voltage on relay the contacts are open and there in no voltage returning to the microcontroller, but when there is phase voltage the contacts close hence the digital input is high indicating phase voltage is present. The buchholz relay is a 2 state relay which is normally open, and when a fault occurs bubbles are produced hence activating the contacts and giving feed back to the SCADA which then response. Oil level sensor is a normally contact condition when the oil level drops it then closes sending a signal to the SCADA to respond by switching of the breaker to protect the transformer.

Via serial communication the microcontroller sends analogue values to the personal computer for display and accepts commands from the personal computer to switch on the breakers. Current limits are set to avoid overloading, when current goes above 5Amps breaker trips and there is no supply current to load. Temperature is also monitored and when it goes above 30 degrees Celsius, fan starts up to cool the substation room.

3.4 SYSTEM DESCRIPTION

Automatic substation monitoring and control involves measuring of parameters like current, voltage, temperature and phase monitoring. These parameter readings are then sent to the operator desk and displayed without need of an electrician to go and physically measure the high currents and voltages. It is also used to switch 'ON' and 'OFF' breakers and also phase line change. It also protects equipment from overload currents and voltages and regulates voltage using the following:

- Current transformer (CT) measures the high current and outputs it with a low current according to CT ratio.
- Voltage transformer (VT) measures the high voltages and outputs it with a low voltage according to VT ratio.

3.4.1 WORKING OF STEP DOWN TRANSFORMER UNIT

Three 240 V to 6 V center tapped step down transformer has been used for the measurement of the phase voltage. Step down transformer is used because the microcontroller can only read voltages up to 5 V. The step down voltage is further rectified through center tapped rectifier. The center tapped rectifier has ripples. Two by 1000 micro Farad capacitor to reduce the ripples are used. One half watt resistor is also used across the terminal output of the rectifier to discharge the capacitor quickly. The output is connected across the potentiometer because the microcontroller can only receive the input below 5V.

The output taken from the potentiometer is nearly 3V and multiplying factor taken as 80 to make it readable as 240V. This value is programmed into the microcontroller. When the input voltage of the step down transformer varies from 240 V, the input of the microcontroller will also vary proportionally. There may be some normal fluctuation in the power system which can exist for few cycles, and tripping of motor for these fluctuations is not required. By taking this into account, the value of resistor across the capacitor is taken as half watt. Higher value of the resistor will discharge the capacitor fast and response of the input value for the microcontroller will fast accordingly to the change of voltages in the input of transformer.

Output of the potentiometer is given to the ADC of the microcontroller.

3.4.2 WORKING OF I-V CONVERTER:

Three current transformers are used for the protection of loads from over current. These current transformers are placed around the three phase windings of the load cable supply. When the load is in running condition, the magnetic flux is produced around the phase cables. This flux induces the voltage in the current transformer. This voltage is sensed by the microcontroller using ADC port. These voltages are compared with rated current value and programmed into the microcontroller when the load is running in the healthy condition. The time delay is given 3 seconds in the programming because the starting current of the load is normally 6-8 times higher than the running condition. The output of the current

transformer is in mV and it increases as the current through the motor increases. The output of the current transformer is directly coupled with the microcontroller ADC port.

3.4.3 MICRO CONTROLLER

These analogue parameters are inputs to Atmega328P which processes the analogue value and displays it. The lower and upper limits are set in the program. If the current and voltages are too high the breaker and contactor automatically switches off. If the temperature exceeds the set a fan starts running hence cooling the system. The microcontroller is also coded in a way to protect equipment to operate within voltage ranges and also confirms if the correct stepping down or stepping up is happening.The system also eliminates manual breaker operation by use of a SCADA system which the operator uses to switch on and off the breakers and monitor data from a central control room. The SCADA system also displays measured parameters.

3.4.4 RELAY

This is the output being controlled by all parameters being measured and it is remote controlled. They are used for isolation of electrical energy and it will create a locking mechanism which will require three different passwords before the breaker is switched on. The purpose of the contactor to the input is to avoid switching on breaker on load, this helps to reduce currents when switching breakers hence no arc flashes resulting from high currents as its contacts give the status in the field.

3.4.5 PERSONAL COMPUTER

The computer is the heart of the system as all operations of the SCADA are done from the operator desk using a computer. It will display measured parameters and also allow operation of what is in the field.

3.4.6 BUCHHOLZ RELAY

It is a safety device mounted on the oil tank conservator and is used for the protection of transformers from the faults occurring inside the transformer. Short circuits faults such as inter turn, core faults which may occur due to the insulation breakdown of the transformer oil. When such faults occur gases are produced which move into the conservator, depending with the quantities they actuate 2 contacts at different levels. The 1st actuation is a warning alarm but as the bubble gases increase they trigger the second contact hence forcing a trip signal to the breaker.

3.4.7 OIL LEVEL SENSOR

This is a float sensor which has a discrete signal from the contacts which are actuated by movement of the float. There are normally open and normally closed contacts on to the switch. For monitoring the level low status, the system uses a normally closed contact which when actuated it opens hence cutting the 5 volts supply to the Arduino board and forcing the breaker to close. This will protect the transformer from operating without oil, though to avoid power interruption it also has a medium level status which acts a warning for the maintenance technician to take action before it critically drops. This can be done on a planned maintenance because the transformer rarely leaks oil.

3.4.8 FAN

Large transformers bigger than 2MVA use the ONAF cooling system, which is Oil Natural Air Forced, this means oil cools by natural means as it expands due to heats and fall when it cools bus as for the air cooling it is forced using fans. This system has the provision of protecting the transformer by bringing in the 3 phase motor fans when the temperature goes above set point. If the fans fail to provide effective cooling and the temperature rises beyond a set point, then a signal to trip the breaker is triggered.

3.4.9 TEMPERATURE SENSOR (LM35)

It gives an analogue range of oil temperature, winding temperature etc. these temperatures have set values which guide and protect the transformer from further damage. For the temperature setting it is guided by the insulation class. Temperature beyond the set activates a warning and trip function to protect the transformer.

3.4.10 BREAKER

This is the switch gear used to isolate the load and the feed side. In case of a fault or unfavorable condition a signal is sent to switch off the breaker automatically, or even in the case of maintenance this breaker is operated from a central control room to reduce or avoid human interference with high voltage circuit.

3.5 CIRCUIT DESIGN

3.5.1 POWER SUPPLY

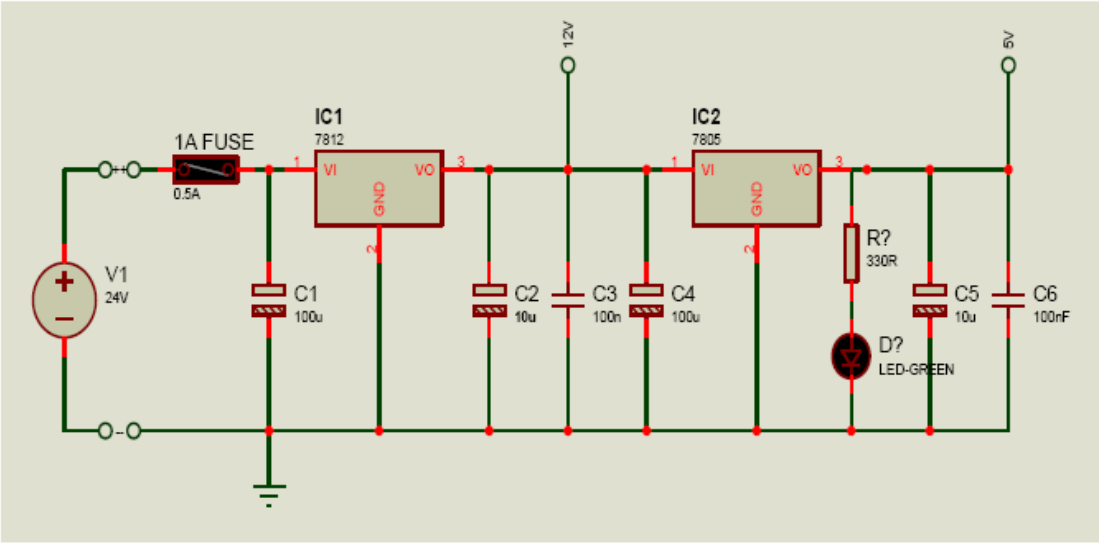


Figure 3.5.1: Proteus depiction of the Power Supply circuit

Figure 3.5.1 shows a 12VDC and 5VDC power supply circuit. The circuit uses two linear voltage regulator ICs 7812 and 7805 for obtaining the required voltages. The unregulated DC voltage from an external DC is filtered by capacitors C1 to obtain a steady DC voltage level. The IC1 regulates this voltage to obtain a steady 12V DC. The output of the IC1 will be regulated by the IC2 to obtain a steady 5V DC at its output. In this way both 12V and 5V DC are obtained. This circuit was so designed because there is need for two DC voltages for the operation of the entire circuit.

The capacitors C1, C2, C4 and C5 filter the ripple from the external battery voltage. A relatively large value of capacitance was used so as to provide a low reactance path to reduce the ripple voltage in the circuit. The 12V and 5V output from the LM7812 and LM7805 respectively are further filtered by the 10µF polar and 100nF monolithic capacitors. The monolithic capacitors are placed as decoupling capacitors to reduce the effects of noise in the supply lines. From the datasheets of both the voltage regulators, it is stated that they can supply a current of up to 1 Ampere.

To indicate that the power supply unit is working, a green LED is placed in parallel with the 5V regulator. The bias resistor for this LED is calculated using the equation $R{=}Vcc{-}VLEDIf$. For the green LED, 10mA is sufficient to turn it on, and the voltage drop across it ($VLED$) is 1.8 volts as specified by the datasheet. So using this data in equation.

$$R = \frac{(5 - 1.8)}{0.01}$$

R = 320 Ω

Therefore, a 330 Ω resistor was used. Re-arranging equation this means that the current flowing through the LED is given by:

$$If = \frac{5 - 1.8}{330}$$

If=9.697mA

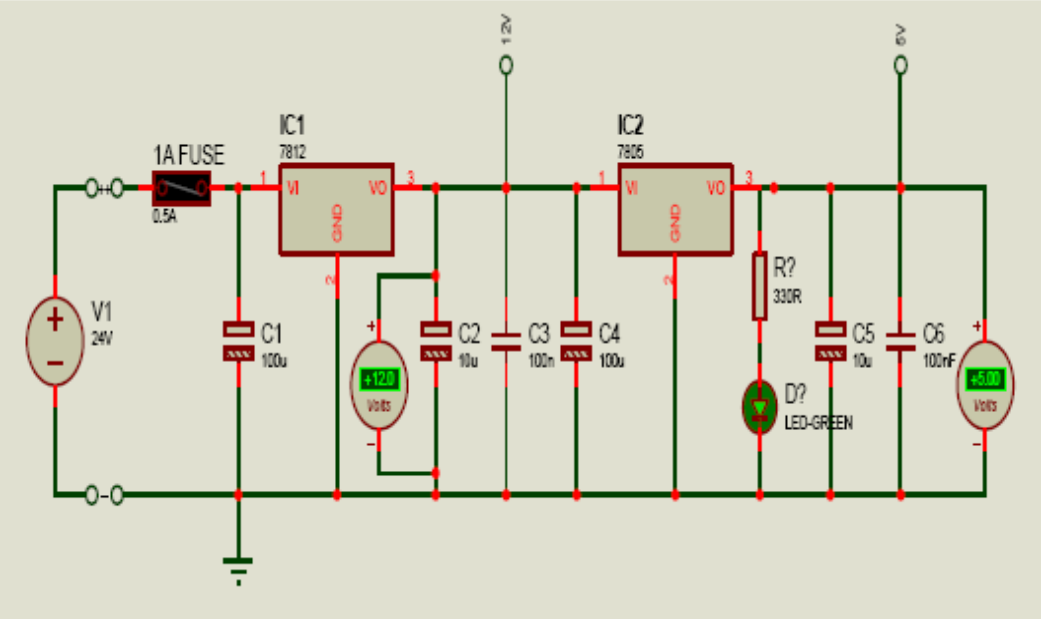


Figure 3.5 1Power Supply Simulation

As seen from the schematic, the output voltage across IC1 is 12V and that across IC2 is 5V. Also, the LED is illuminated, showing that the current passing through the LED is sufficient to turn it on.

3.5.2 CURRENT SENSING CONDITIONING CIRCUIT

The current to the load is sensed using a hall effect LA 55-P current transducer. The bipolar output voltage of the current sensor is in the range of mill volts and need to be amplified and level shifted to interface with the microcontroller's ADC because it can handle only voltages between 0 V and +5 V. So, the signal from the sensor is first amplified and

then level shifted to fit between 0 and +5 V. The 741 is an operational amplifier configured as a closed loop inverting amplifier with adjustable gains.

Variable resistors are provided for manual gain adjustment as the signal amplitude varies according to the current being measured depending on the load. Figure 6 shows the circuit used for the purpose. A level shifting circuit (Yang et al, 2006) is used to scale and shift the bipolar output (-10 V to +10 V) of the amplifier to unipolar levels (0 V to +5 V) to make it compatible with the microcontroller's ADC.

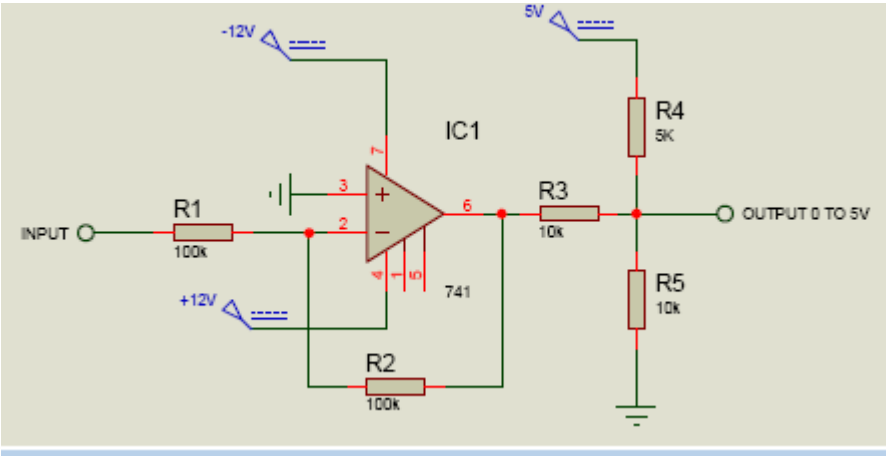


Figure 3.5 2Current Sensing Conditioning Circuit

3.5.3 *AC VOLTAGE SENSING AND SIGNAL CONDITIONING CIRCUIT*

AC voltage sensing and signal conditioning circuit is essentially similar to the power supply circuit except for the additional transformer and rectifier circuit. The voltage sensor senses the presence or absence of electricity from the mains and generator supplies, hence a digital signal was considered sufficient to provide this information. For this reason, the circuit provides a clean 5V at its output in the presence of electricity and 0V in its absence, thus the 240AC from the supply is conditioned to a 5VDC logic level to the microcontroller. The 240Vrms AC signal is stepped down to 12Vrms AC by the transformer. This signal is then passed through the diodes D1, D2, D3 and D4 which achieve full wave rectification of

the signal. The general purpose diodes D1 to D4 were chosen because they have a breakdown voltage more negative than 240V.

This selection criterion is based on the fact that during one half cycle of the AC signal, one diode is reverse biased and therefore experiences a bias potential of 240 volts. If the diode has a breakdown voltage of lower that this, permanent damage can occur to the diode. General purpose 1N4004 diodes have a maximum reverse voltage of 400 volts and so are suitable for this system.

The voltage seen after the bridge is the input voltage less two diode drops. The capacitor C1 filters the ripple from the rectified voltage. A relatively large value of capacitance was used so as to provide a low reactance path to the ripple content of the rectified voltage, as well as to reduce the ripple voltage in the circuit. The 5V output from the LM7805 regulator is then filtered by the 47µF polar and 0.1µF monolithic capacitors and hence ensures that the output to the microcontroller is pure DC voltage. The LED is only turned ON in the presence of AC voltage. Component selection criteria and calculations are the same as those for the power supply.

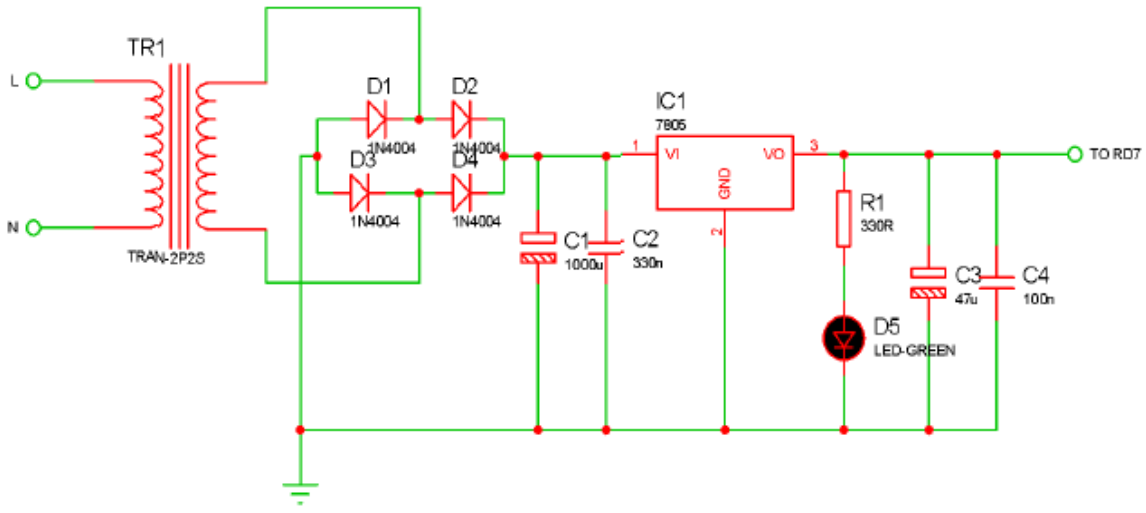


Figure 3.5 3 AC Voltage sensing and Signal conditioning circuit

3.5.4 VOLTAGE SENSOR SIMULATION

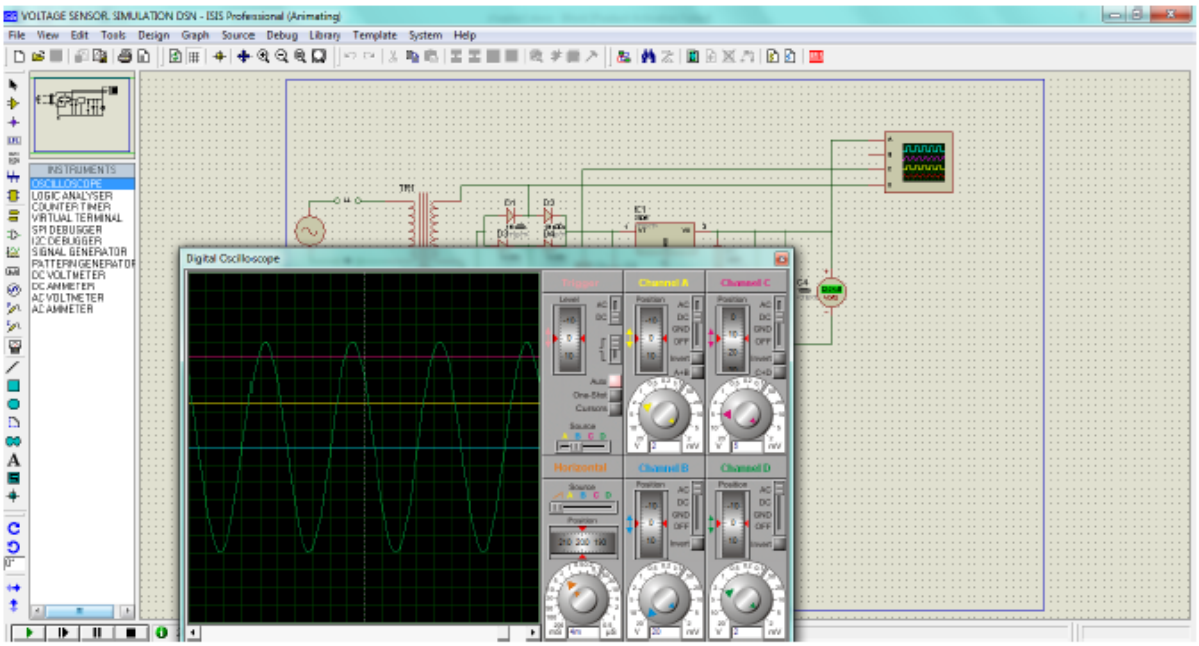


Figure 3.5 4Voltage sensor simulation

The waveforms for the VCC output of the power supply simulated in Proteus 7. The green waveform shows an alternating voltage of 12Vrms from the secondary coil of the transformer. The violet waveform with some visible ripple contents shows the filtered output of the rectifier. The yellow waveform is the final 5V output of the circuit and shows to be pure DC voltage. The blue line is the reference line.

3.6 DEVELOPING THE MICROCONTROLLER PROGRAM

According to the system block diagram, the implementation of this system was achieved by using the Atmega328P as the host controller. The microcontroller does the control through the software program embedded in it. The Current sensor, voltage sensor and

the Temperature Sensor were interfaced to the microcontroller in order to achieve the needed results by use of a program. The microcontroller program should achieve the operations summarised below:

- The microcontroller monitors the Current, voltage and the Temperature via the internal ADC Module.

- In the case that the current value is above 5Amps, the microcontroller sends a command to start the Buzzer

- In the case that the temperature value is above 30 degrees Celsius, the microcontroller sends a command to start the Fan

- The microcontroller also displays these values and several messages on the Personal computer.

The first program development consideration was to determine the nature and number of inputs and outputs the systemsuses the nature of input signals being classified as analogue or digital. With the need for analogue to digital conversion, the Microcontroller inbuilt ADC module was implemented by the system. The Atmega328P analog-to-Digital (A/D) Converter module has eight pins for the 40 pin chip. Analog input charges a sample and hold capacitor. The output of the sample and hold capacitor is the input into the converter. The converter then generates a digital result of this analog level via successive approximation. The A/D conversion of the analog input signal results in a corresponding 10-bit digital number. The A/D module has high and low voltage reference input that was software selected to a combination of VDD and VSS in this case. The A/D module has four registers and these are:

- A/D Result High Register (ADRESH)
- A/D Result Low Register (ADRESL)
- A/D Control Register0 (ADCON0)
- A/D Control Register1 (ADCON1)

The ADCON0 register, shown in Register 11-1 controls the operation of the A/D module. The ADCON1 register, shown in Register 11-2, configures the functions of the port pins. The port pins can be configured as analog inputs and reference voltage pins or as digital I/O. Since the system implements three analogue inputs, the microcontroller was configured to accept three analogue inputs for its ADC module and use internal voltage references. Table 3.5.1 (Atmega328P Datasheet) shows the bits belonging to the ADCON1 register and their descriptions. This register is used to configure the functions of the port pins of the microcontroller.

3.7 SYSTEM SOFTWARE

BIT	NAME	FUNCTION
7	ADFM	A/D Result Format Select bit
6	ADCS2	Define the TAD
5	-------	Unimplemented, read as '0'
4	-------	Unimplemented, read as '0'
3-0	PCFG3<3:0>	A/D Port Configuration Control bits:

Table 3.7. 1ADCON1 register bits

NAME	CONFIG.	JUSTIFICATION
ADFM	0	Left Justified
ADSC2	0	Combine with other bits to define TAD
PCFG<3:0>	0100	AN0, AN1 and AN3 are analogue pins. The rest are digital pins. VREF+ = VDD and VREF- = VSS

Table 3.7. 2The ADCON1 configurations

The analogue to digital conversion time per bit defined as TAD is another ADC module parameter which is configured for correct module conversion. The analogue to digital conversion requires a minimum 12 TAD per 10-bit conversion. The source of the analogue to digital conversion clock is software selected as follows:

$$TOSC = 1/FOSC$$

Where FOSC is the frequency of the oscillator, off which the PIC is running. For the PIC16F877 running off a 20MHz crystal, FOSC = 20MHz. For correct analogue to digital conversions, the analogue to digital conversion clock (TAD) must be selected to ensure a minimum TAD of 1.6μs.

Therefore,

$TAD = 1.6\mu s/TOSC.$

Using a 20MHz crystal to run the microcontroller, a TAD of 32 is required by the system

3.7.1 PSEUDO-CODE FOR THE MICROCONTROLLER PROGRAM

Based on the information discussed in the sections above, an algorithm was developed for use in writing the microcontroller program. The algorithm, in form of a pseudo-code is presented below.

BEGIN:

- Define the connection between the computer and the microcontroller
- Declare the variables used in the program
- Configure PORT A as analog input
- Configure PORT C and PORT D as digital output
- Initialize the system delays to transfer and retransfer

  REPEAT:
- Check voltage constant supply value
- Read the voltage value from the sensor
- Calculate the actual voltage value
- Check current constant supply value
- Read the current value from the sensor

- Calculate the actual current value
- Check substation room temperature
- Read the temperature value from the sensor
- Calculate the actual temperature value
- Display the actual voltage, current and temperature values
- IF current is High
    - Measure and display current value
        - If current is 3.75Amps flash warning light
        - If current is above 5Amps trip breaker
- IF temperature is high
    - Measure and display temperature value
        - If temperature if 60°C flash warning light and start fan
        - If temperature is above 65°C trip breaker
- IF breaker button is clicked
    - Output relays must switch ON
- IF buchholz relay 1st contact opens
    - Flash warning
- If buchholz relay 2nd contact opens
    - Trip breaker
- IF oil level sensor 1st contact opens
    - Flash warning
- If oil level sensor 2nd contact opens
    - Trip breaker

END

CHAPTER 4 HARDWARE AND SOFTWARE IMPLEMENTATION

4.1 LOAD FORECAST, SUBSTATION AND FEEDER DESIGN SOFTWARE IMPLEMENTATION

The software tool was programmed using php and the application is called xampp. This is a web based application meaning it can be accessed over a network using HTTP (Hyper Text Transfer Protocol). Figure 4.1.1 below shows a code for creating a wok space for calculations

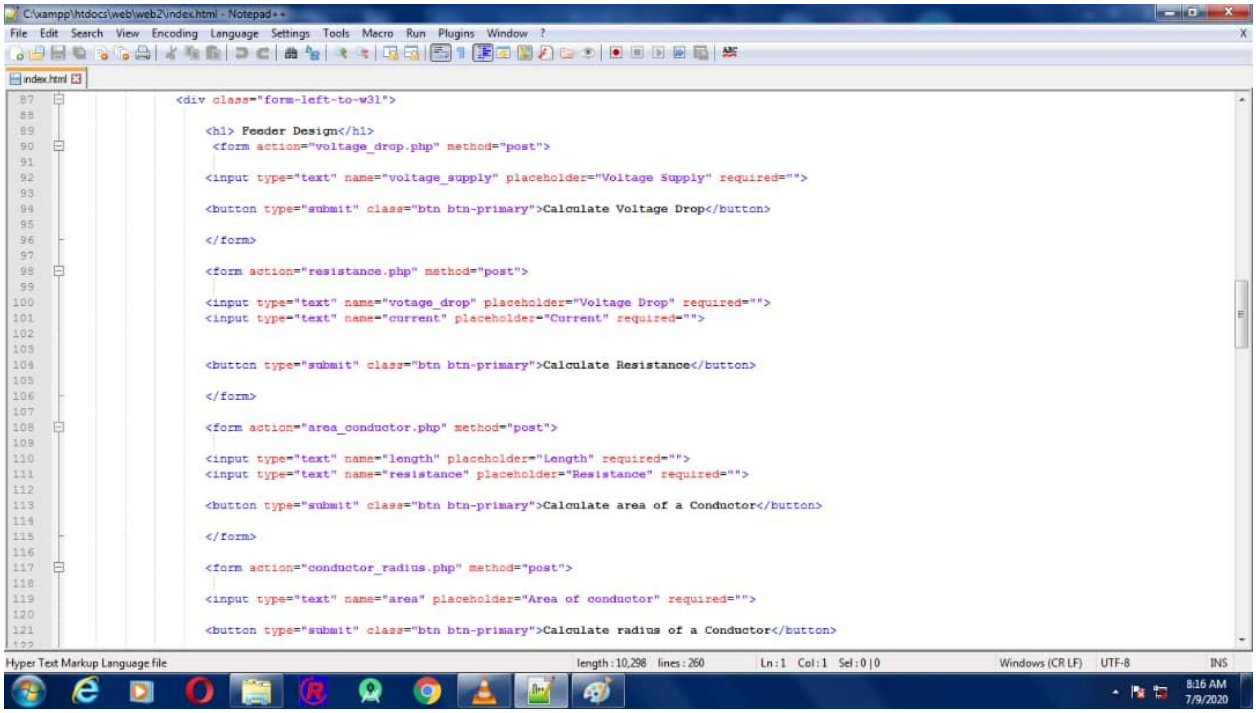


Figure 4.1.1 Creating work space

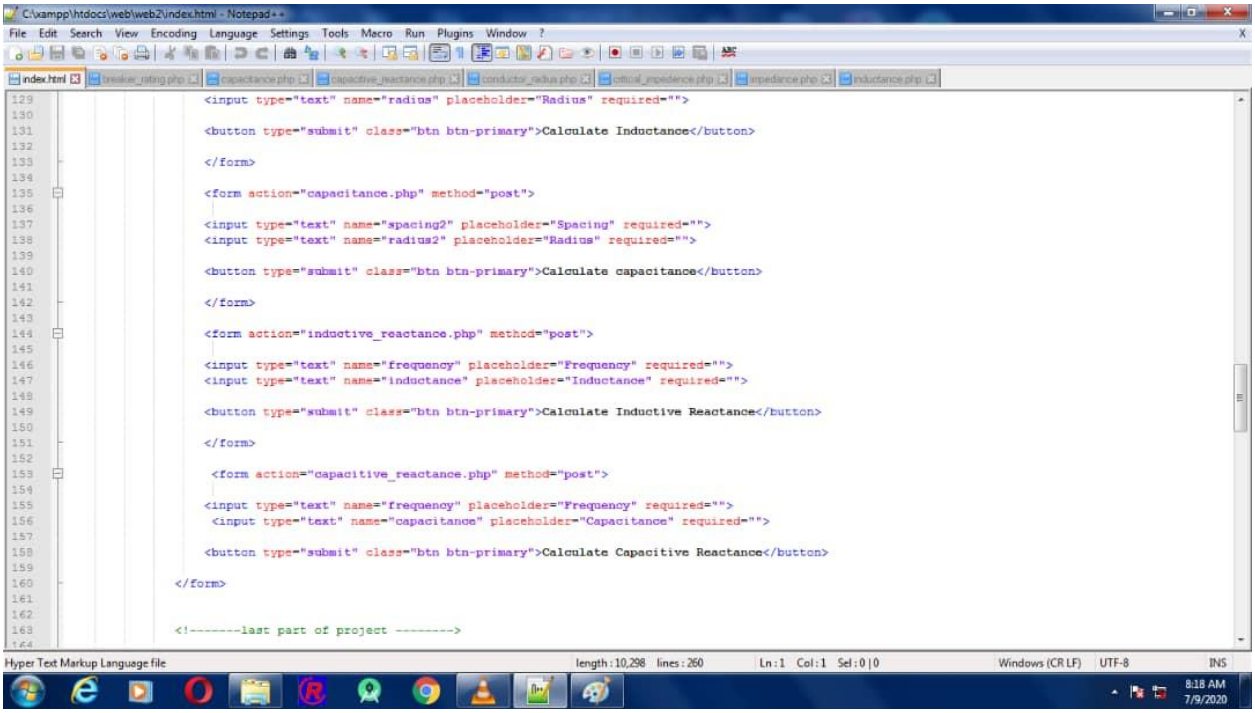


Figure 4.1. 2 Code for formula

the above figure shows how to insert a formula on to the work space

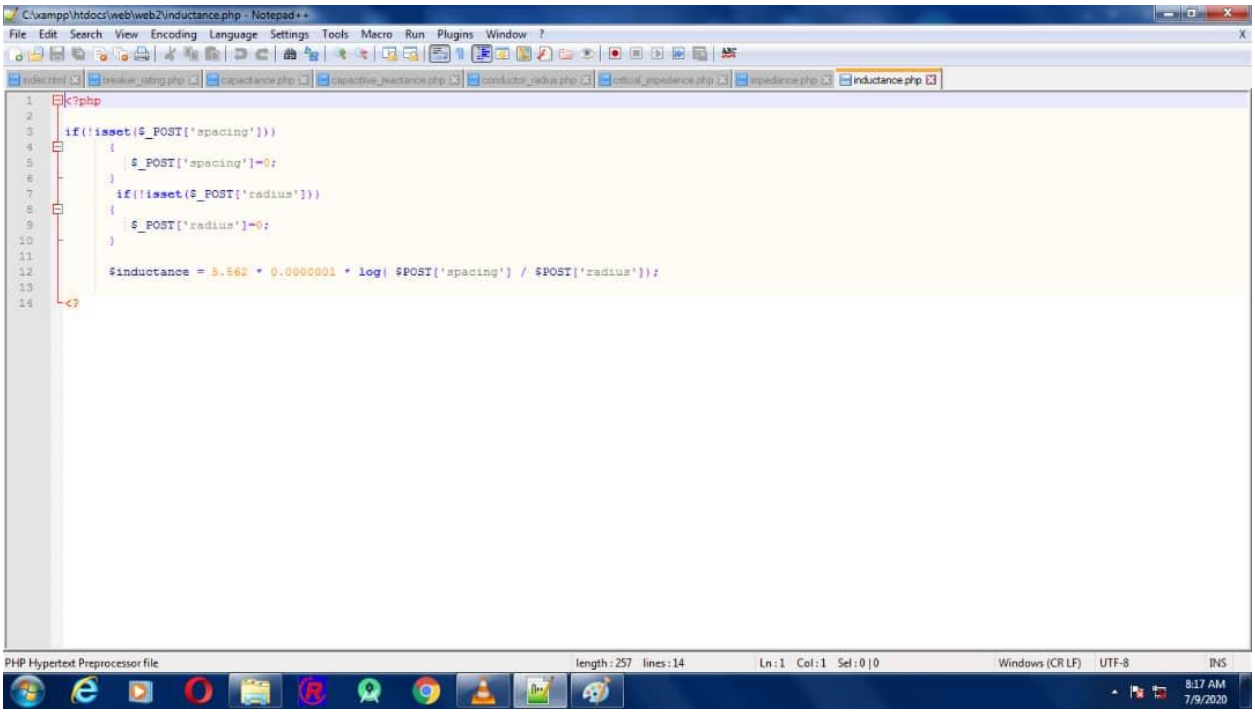


Figure 4.1. 3 Calculating

The above code shows the commands for calculating

Figure 4.1.4 shows xampp opening and starting other modules which include Apache, FileZilla, MySQL, mercury. After starting these modules, the calculator is now accessed via the browser local host.

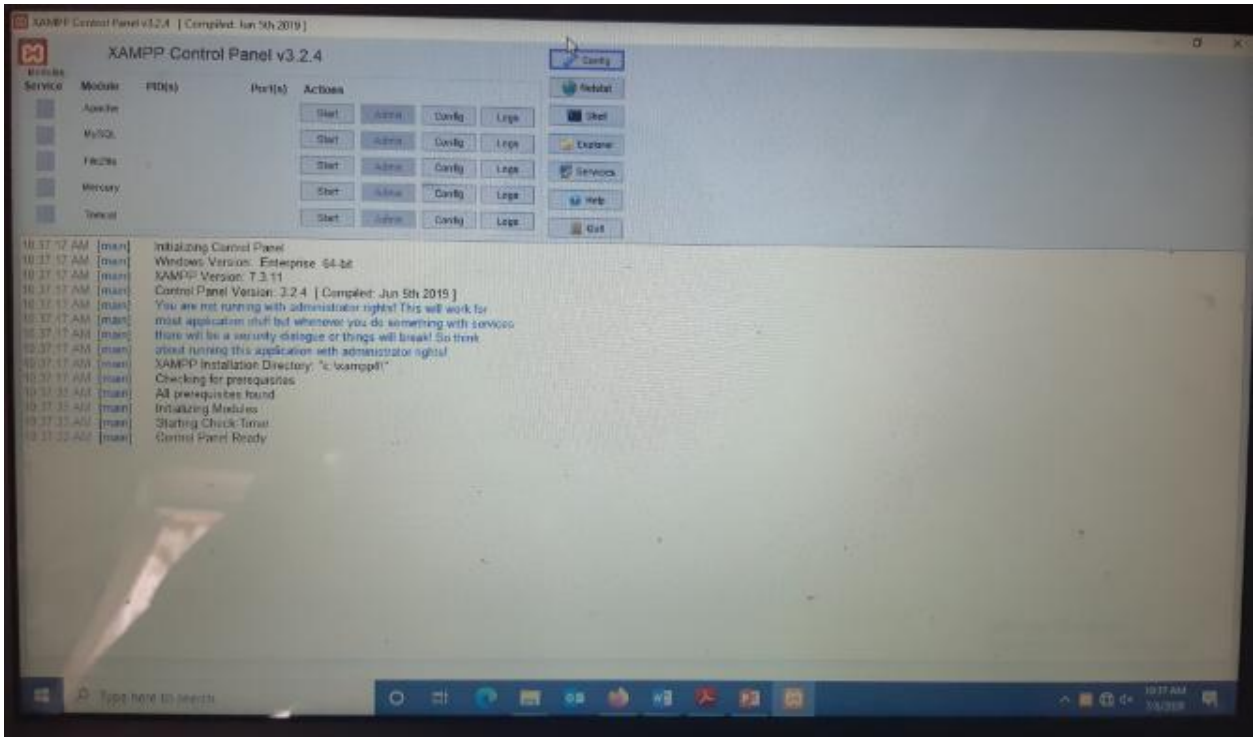


Figure 4.1.4 Xampp opening

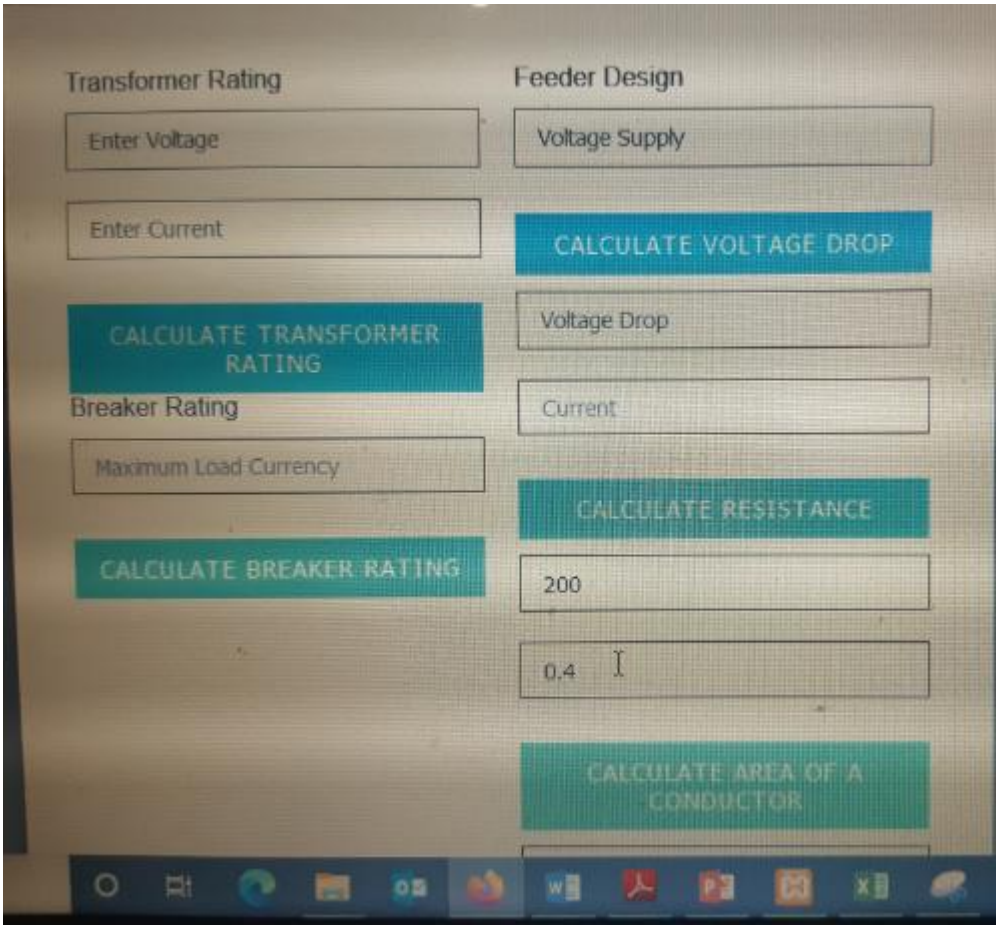


Figure 4.1. 5Calculating conductor size

Fig 4.1.5 shows the feeder design page, and the illustration is for conductor cross sectional area calculation using R = (ρ*l)/A. the inputs required are length and the resistance since from the formula resistivity of an aluminum is a constant. For overhead line copper is rarely used that is why aluminum constant was used.

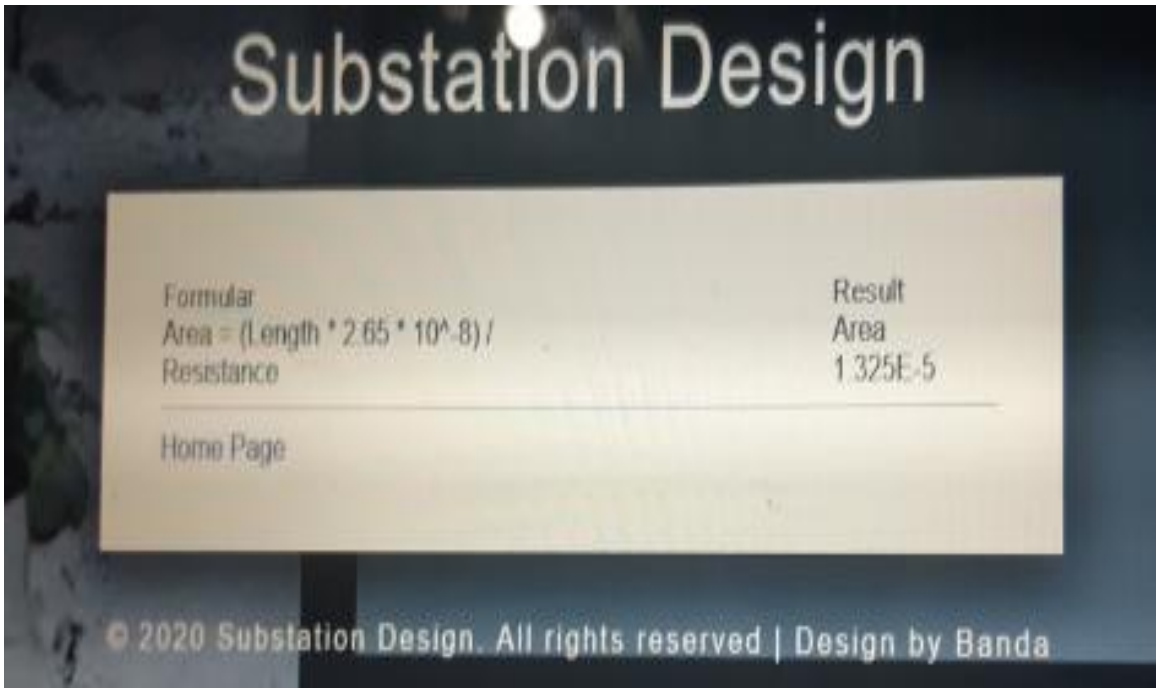


Figure 4.16Conductor size result

Figure 4.1.6 shows the calculated result for conductor cross sectional area for a voltage drop of 40 volts, current of 100 amps over a distance of 200 meters. A required cable size of 16mm^2.

4.2 SCADA SYSTEM SOFTWARE IMPLEMENTATION

This section will specifically discuss the methodology to interface sensors and hardware module. The most important part is to enable the analog sensor to send analog data to the Microcontroller then transfer to the computer with the SCADA software.

```
char input;
int breaker = 11;
int breaker1 = 12;
int breaker2 = 13;
// voltage divider calibration values
#define DIV_1    11.1346
#define DIV_2    11.1969
#define DIV_3    11.0718
#define DIV_4    11.0718
#define DIV_5    11.0718
#define DIV_6    11.0718
// ADC reference voltage / calibration value
#define V_REF    4.991

int sum[4] = {0};               // sums of samples taken
unsigned char sample_count = 0; // current sample number
float voltage[6] = {0.0};       // calculated voltages
char l_cnt = 0;                 // used in 'for' loops

void setup()
{
  pinMode(breaker,OUTPUT);
  pinMode(breaker1,OUTPUT);
  pinMode(breaker2,OUTPUT);
  Serial.begin(9600);
}
```

Figure 4.2.1 Arduino pin assignment

The figure above shows a code snippet from the code defining the pin and allocating them their respective functions. The functions are commented to explain each line of the code.

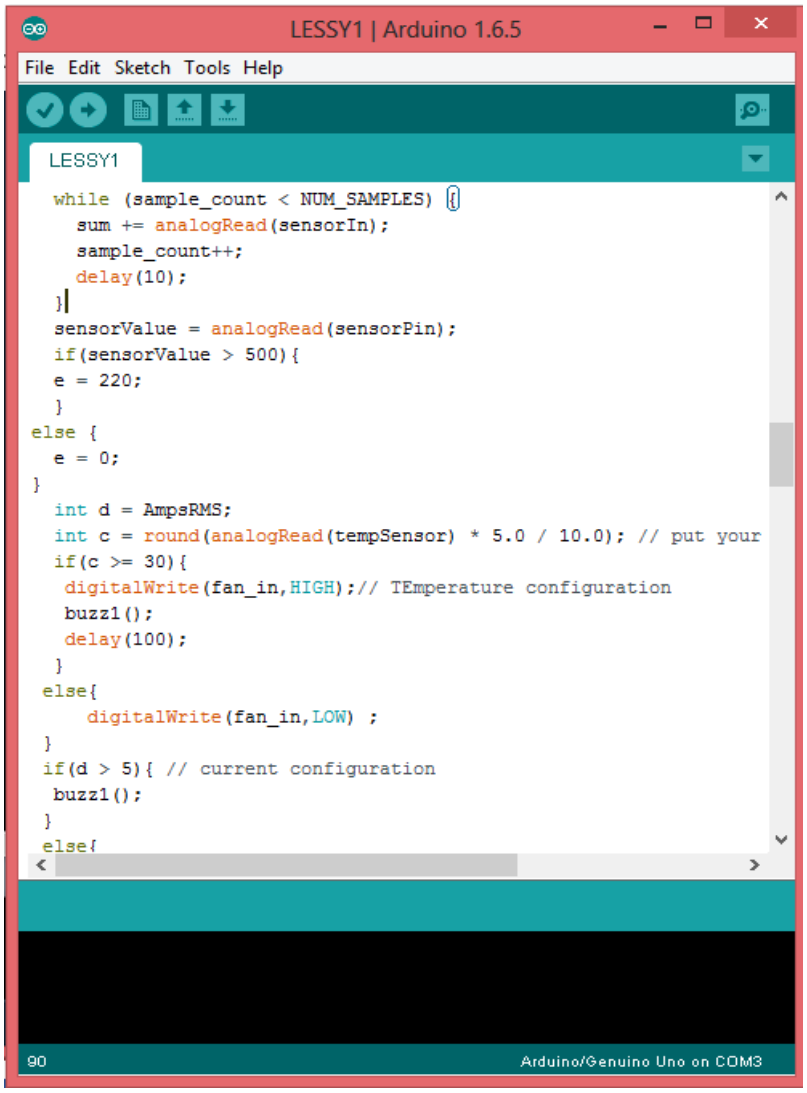


Figure 4.2.2 Code Snippet for ADC

The snippet above shows the conversion for the LM35, Voltage and Current Sensor Analog to Digital Conversion. “analogRead” is a command that allows the microcontroller port to read form the sensor. “digital Write” is a command for the monitoring limits for the analogue values and giving an output.

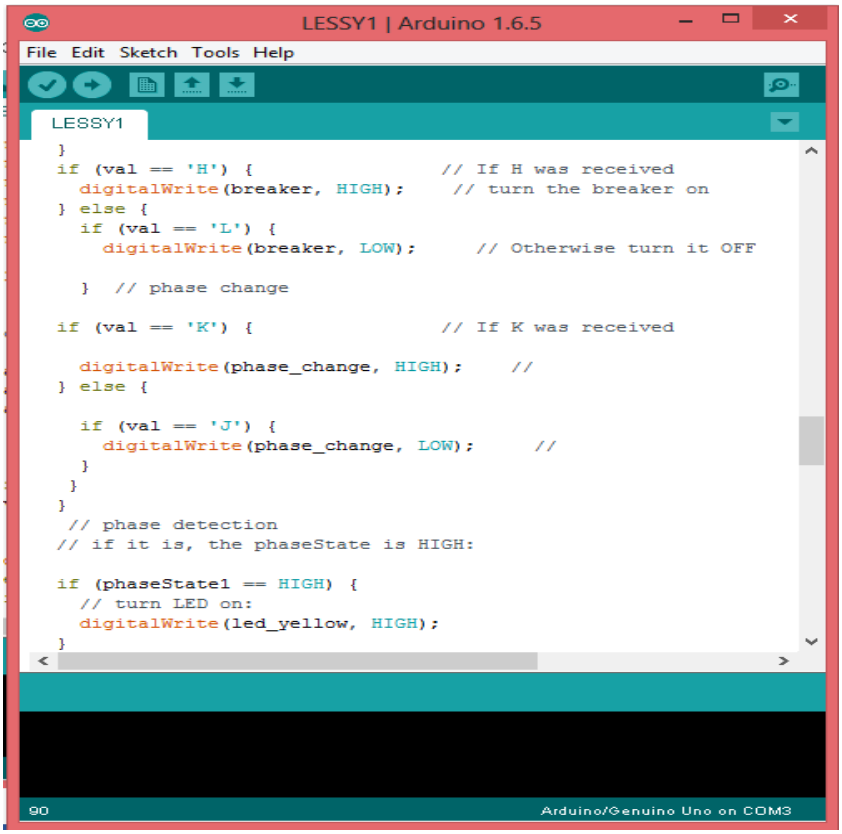


Figure 4.2.3 Code Snippet for communication between SCADA and Microcontroller

The figure above shows how characters are used to give commands to the SCADA system, for example" is used to switch off the Breaker.

```
{
  while (p.available () > 0) {
    // get a single character from the serial port
    rx_byte = ser_port.readChar();
    // determine which channel voltage is from
    if (rx_byte == 'A') {
      volts_index = 0;
      volts[volts_index] = "";
    } else if (rx_byte == 'B') {
      volts_index = 1;
      volts[volts_index] = "";
    } else if (rx_byte == 'C') {
      volts_index = 2;
      volts[volts_index] = "";
    } else if (rx_byte == 'D') {
      volts_index = 3;
      volts[volts_index] = "";
    } else if (rx_byte == 'E') {
      volts_index = 4;
      volts[volts_index] = "";
    } else if (rx_byte == 'F') {
      volts_index = 5;
      volts[volts_index] = "";
    }
```

Figure 4.2.4 Receiving voltage signal

Figure above shows a snippet of the code showing how the Arduino controller will be receiving voltage/current/ temperature signal from the sensors

Figure 4.2.5 Monitoring breaker status

Figure above shows the code which monitors the breaker status that is if it is closed or open. The breaker has normally open contacts and normally closed contacts. These contacts change their status when the breaker is energised hence feeding back to the control to show its status.

- Following Snippets are for the processing 2.1 application

```
import processing.serial.*;

Serial ser_port;                  // for serial port
char rx_byte;                     // stores single byte received from serial port
String volts[] = {
  "", "", "", "", "", ""
};// 4 voltages from the 4 channels
int volts_index = 0;              // current channel
boolean got_volts = false;        // flags received voltage
int graph[][];                    // graph values for each channel
int graph_x = 0;                  // current x position of graph
PFont fnt;                        // for font
// voltage scale for channels, default set to 30V
int ch1_scale = 30;
int ch2_scale = 30;
int ch3_scale = 30;
int ch4_scale = 30;
```

Figure 4.2.6 Code Snippet for Pin Assignment

Processing 2.1 application which is used to design the SCADA page, is also programmed using MikroC. Figure above shows pin assignment and declaration for “current channel”, font type etc.

```
void setup()
{
  size(1500, 700);  // change window size
  background(0);
  fnt = createFont("Arial", 16, true);
  println(Serial.list());
  // modify Serial.list()[0] to select correct serial port
  ser_port = new Serial(this, "COM11", 9600);

  // initialize graph array
  graph = new int[4][400];
  for (int i = 0; i < 4; i++) {
    for (int j = 0; j < 400; j++) {
      graph[i][j] = -1;  // fill graphs with invalid values
    }
  }
}
```

Figure 4.2.7 Assigning serial ports for communication from Arduino to PC

```
void draw()
{
  // update voltage in window if voltages received from USB por
  if (got_volts) {
    got_volts = false;
    background (255);
    stroke(0);

    // display voltages
    voltage(1, volts[0]);
    voltage(2, volts[1]);
    voltage(3, volts[2]);
    voltage(4, volts[3]);
    voltage(5, volts[4]);
    voltage(6, volts[5]);

    // draw the displayboxes
    DrawGraphAxis(880, 100, 400, 80);
    fill (0);
    text("Portal A trends", 1050, 90);
    text("Voltage (V)", 850, 90);
    text("Time(s)", 1250, 200);
    DrawGraphAxis(880, 280, 400, 80);
    text("Portal B trends", 1050, 230);
    text("Voltage (V)", 850, 270);
    text("Time(s)", 1250, 380);
    DrawGraphAxis(880, 460, 400, 80);
    text("Portal Q trends", 1050, 410);
    text("Voltage (V)", 850, 450);
```

Figure 4.2.8 Drawing and labelling

The code above creates the work area for the SCADA page, it shows the dimensions for the substation and the graphs. It shows were there graphs are to be located on the working space.

```
{
  while (p.available () > 0) {
    // get a single character from the serial port
    rx_byte = ser_port.readChar();
    // determine which channel voltage is from
    if (rx_byte == 'A') {
      volts_index = 0;
      volts[volts_index] = "";
    } else if (rx_byte == 'B') {
      volts_index = 1;
      volts[volts_index] = "";
    } else if (rx_byte == 'C') {
      volts_index = 2;
      volts[volts_index] = "";
    } else if (rx_byte == 'D') {
      volts_index = 3;
      volts[volts_index] = "";
    } else if (rx_byte == 'E') {
      volts_index = 4;
      volts[volts_index] = "";
    } else if (rx_byte == 'F') {
      volts_index = 5;
      volts[volts_index] = "";
    }
```

Figure 4.2.9 Receiving voltage from the Arduino microcontroller

```
void DrawGraphAxis(int pos_x, int pos_y, int width, int height)
{
  stroke(0);
  line(pos_x, pos_y, pos_x, pos_y + height);      // vertical axis
  line(pos_x, pos_y + height, pos_x + width, pos_y + height);    // horizontal axis
}

void DrawGraph (String voltage, int channel, int pos_x, int pos_y, int scale)
{
  int y_start;  // temporary index into graph array when drawing graph

  graph[channel][graph_x] = int(voltage);
  // select colour, depending on channel number
  if (channel == 0) {
    stroke(255, 0, 0);
  } else if (channel == 1) {
    stroke(0, 255, 0);
  } else if (channel == 2) {
```

Figure 4.2.10 Drawing graphs

```
if (mouseX >= 470 && mouseX <= 500 && mouseY >= 170 && mouseY <= 190) {
  fill (0, 255, 0);
  rect (470, 150, 30, 20);
  println("Main Sub breaker on");
  ser_port.write('x');
}
if (mouseX >= 530 && mouseX <= 560 && mouseY >= 170 && mouseY <= 190) {
  fill (0, 255, 0);
  rect (530, 170, 30, 20);
  println("Main Sub breaker off");
  ser_port.write('y');
}
```

Figure 4.2. 11 Breaker control

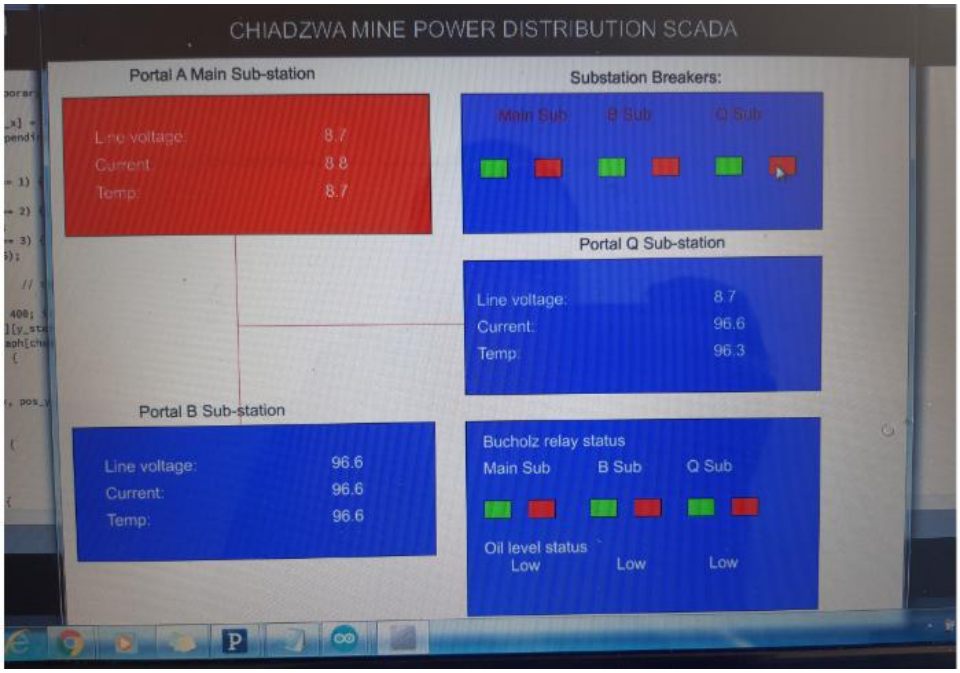


Figure 4.2.12 SCADA simulation

.

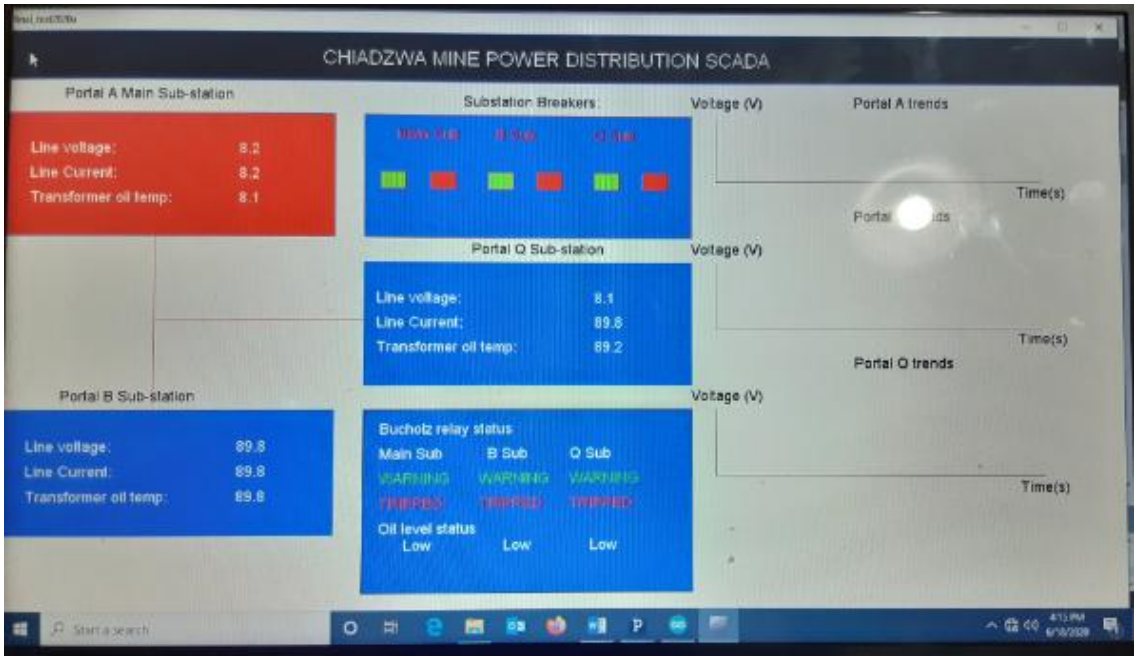
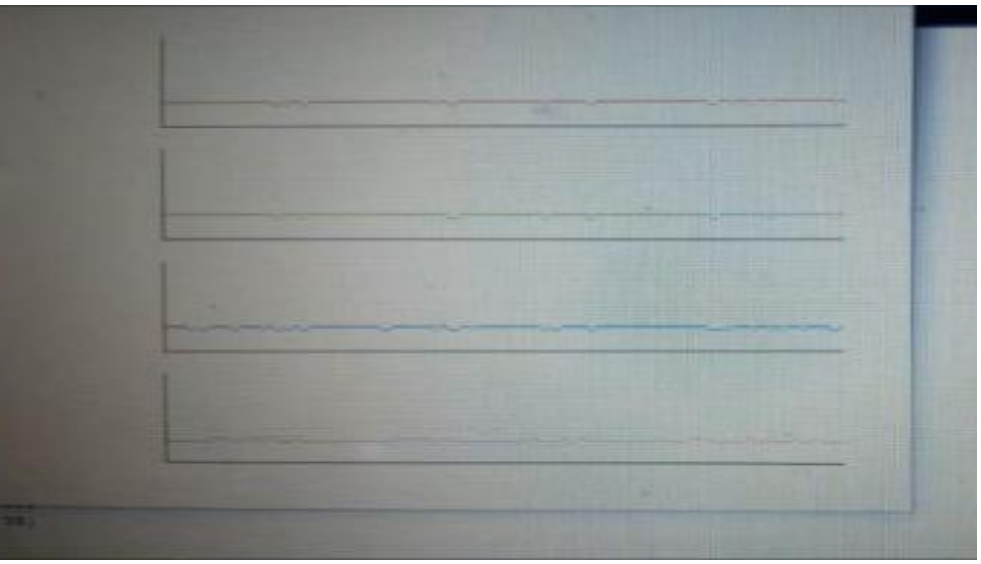


Figure 4.2.13SCADA with graphs



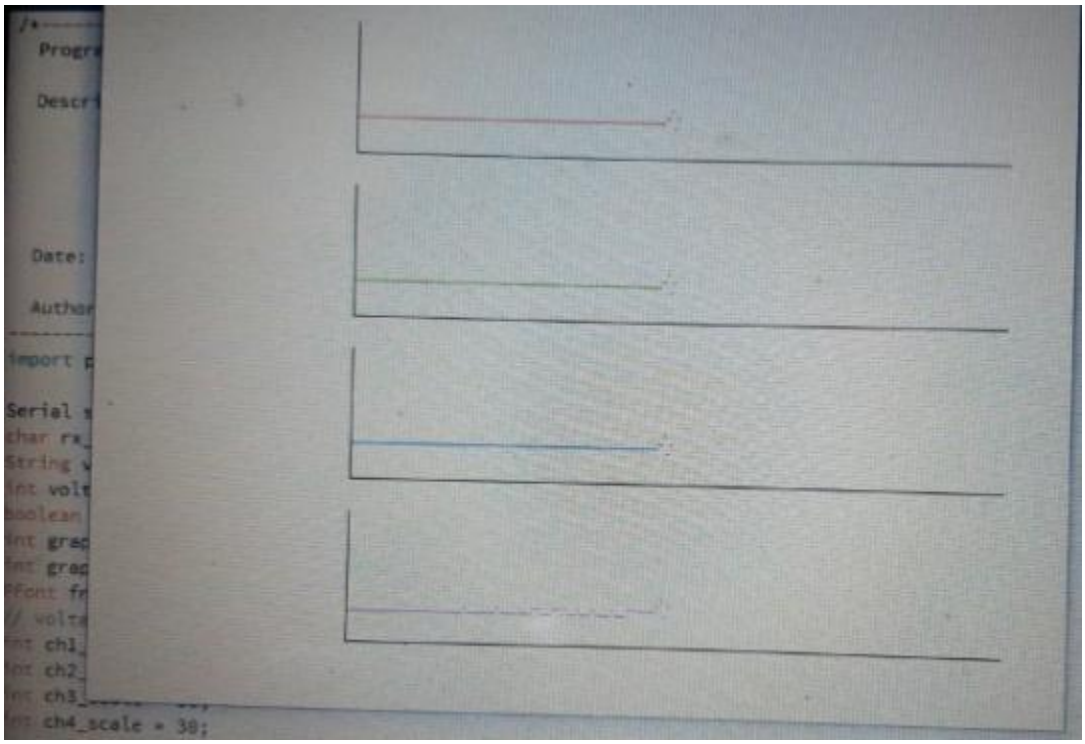


Figure 4.2.14 SCADA graphs

Above figures show the control room computer with SCADA system which is used for - substation control and monitoring which was developed by Processing 2.1 software. On the SCADA system there are 3 substations (Main, B and Q) and each is monitoring voltage, current, temperature, oil level, buchholz status and controlling breakers.

4.3 *HARDWARE IMPLEMENTATION*

The system design covered in chapter 3 was further developed by testing each module on the breadboard level, after which each module was successfully implemented at PCB development level. The sections to follow describe the implementation of each hardware module in this system.

4.3.1 PCB DESIGN

A modular approach was implemented in the PCB development process. In this approach, the system was broken down two modules according to the voltage levels each

module handles. Each module was then designed on its own board and electric wires were used to connect these boards. The low voltage modules are the main board onto which the microcontroller circuitry resides together with the low dc voltage interfacing circuitry, the LED indication circuitry and the signal conditioning circuitry. The high voltage module is the high output relay circuitry which links the control board to the high power switch gear via galvanic isolation.

The program used to design the PCB's was EAGLE CAD software. The most appealing feature of this software package is that it is user friendly and has various components in the library. Custom components are easily designed and assigned appropriate layout patterns in case of unavailable component footprints in the components library. The width of the traces and the footprint pads was of particular importance during the design process. The thickness of the traces had to be enough to safely carry the current flowing through the PCB design in EAGLE is a three-step process, schematic capture, layout editor and fabrication process.

4.3.2 SCHEMATIC CAPTURE

This is the first stage in the PCB design process. In this part of the development cycle, a blueprint for all the electrical components and connections to be present on the printed circuit board are drawn and interconnected accordingly. At this stage, all the necessary components and any necessary electrical requirements that will need to be fulfilled in the design (that is connectors, buttons, power, antennas, and others) are identified and captured at this stage. Fig 4.1.1 shows the schematic capture of the main board module.

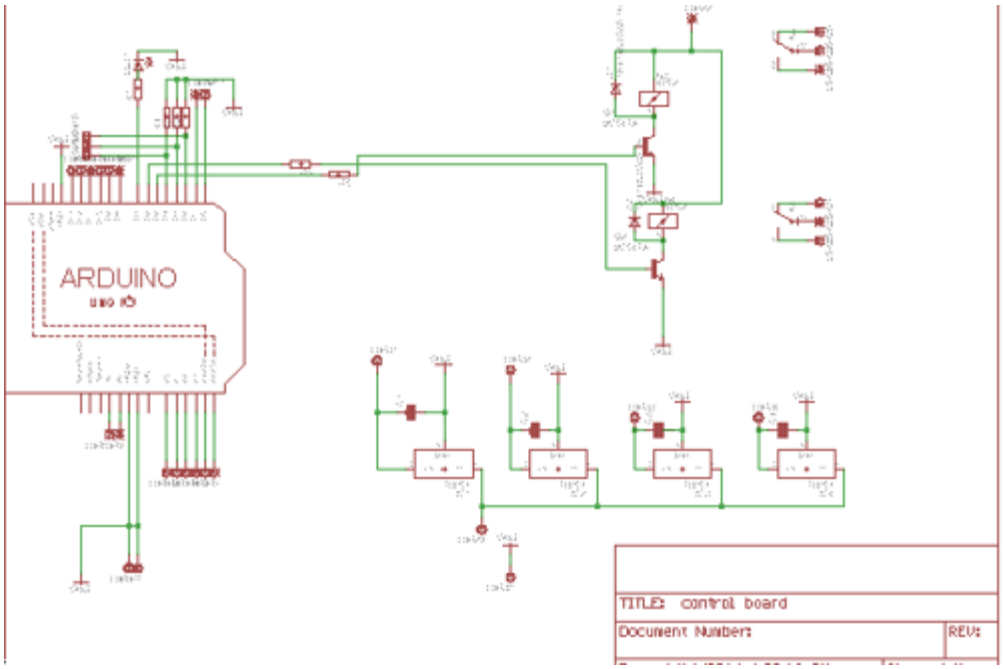


Figure 4.3.1 Control board schematic capture

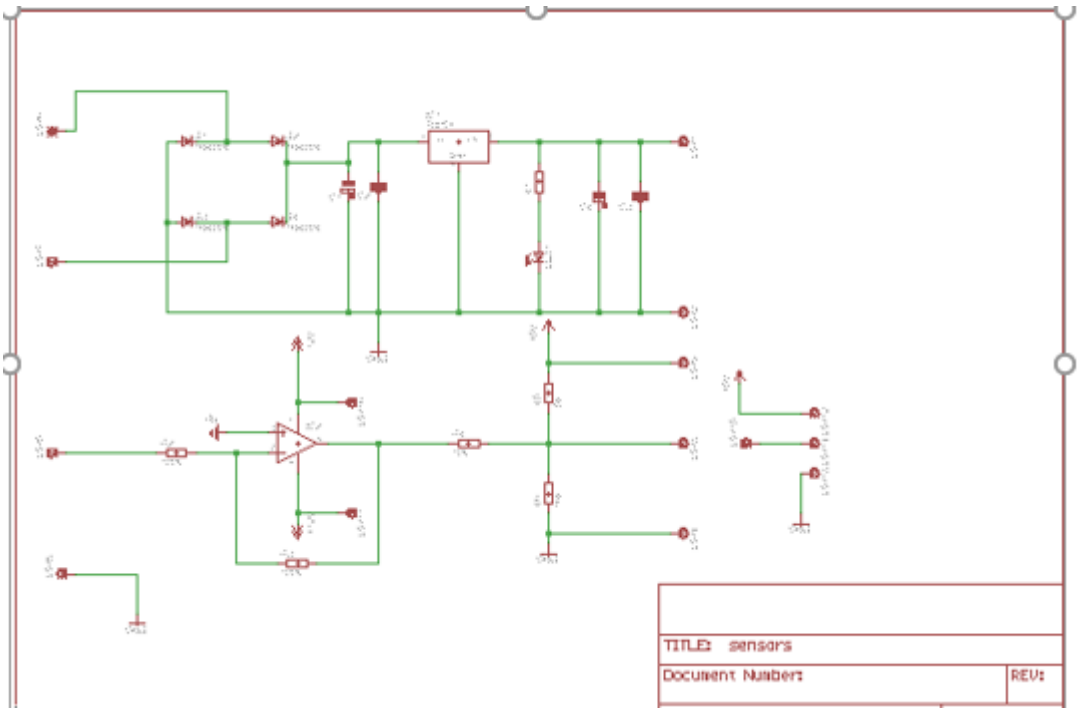


Figure 4.3.2 Voltage sensor and current sensor signal condition circuit

4.2.3 TRACK LAYOUT EDITOR

This is the second stage of PCB fabrication, based on the schematic. EAGLE's board and schematic editors work hand-in-hand. This stage includes a complete schematic and a BOM (bill of materials) full of components to be placed on the PCB, which is then arranged in a logical and technically sound manner. It was important at this stage not to only route traces that match the schematic but make sure that the layout was able to be fabricated.

Fig 4.3.3 shows the sectionalised track layout of the main control board. The component placement was made compact so as to reduce the overall PCB size and hence increase the portability of the prototype. The functional circuit blocks were also sectionalised so as to lessen the complexity of the manual routing process during design and also to ease troubleshooting during prototype testing or use after project completion.

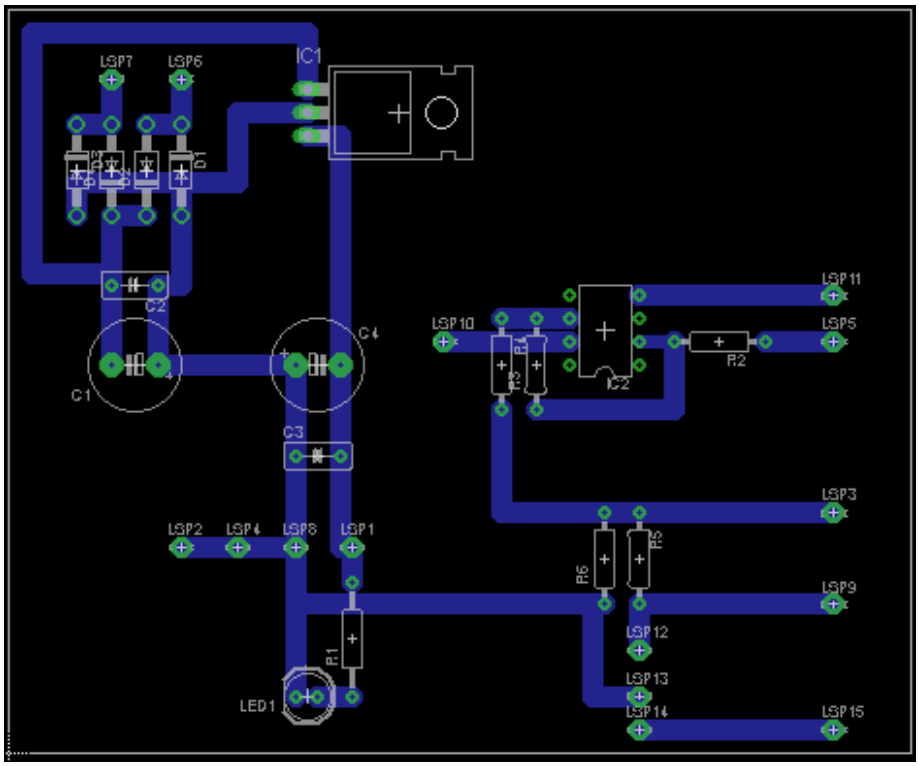


Figure 4.33 Voltage sensor and current sensor signal condition circuit

4.2.4 *PCB FABRICATION*

The press and peel method was used in the fabrication of the project PCBs. It was selected to be the simplest considering the available resources. Figure 4.3.4 shows the PCB of the voltage sensor board tracks side while Figure 4.3.5 shows the voltage sensor board after completion of the fabrication process. It can be noted that the copper tracks correspond exactly to the track layout of Fig 4.3.3. The drill-hole diameters were according to the component pin thickness as specified in the components library properties of the EAGLE CAD software. Generally, the con-wagon connectors drill-hole diameter was 1.2 mm while for the rest of the circuit, 1 mm was chosen. The circuit was free from any short circuits.

Figure 4.3.4 voltage sensor conditioning PCB

Figure 4.3.5 voltage sensor conditioning PCB

Figure 4.36 Circuit diagram of the power supply

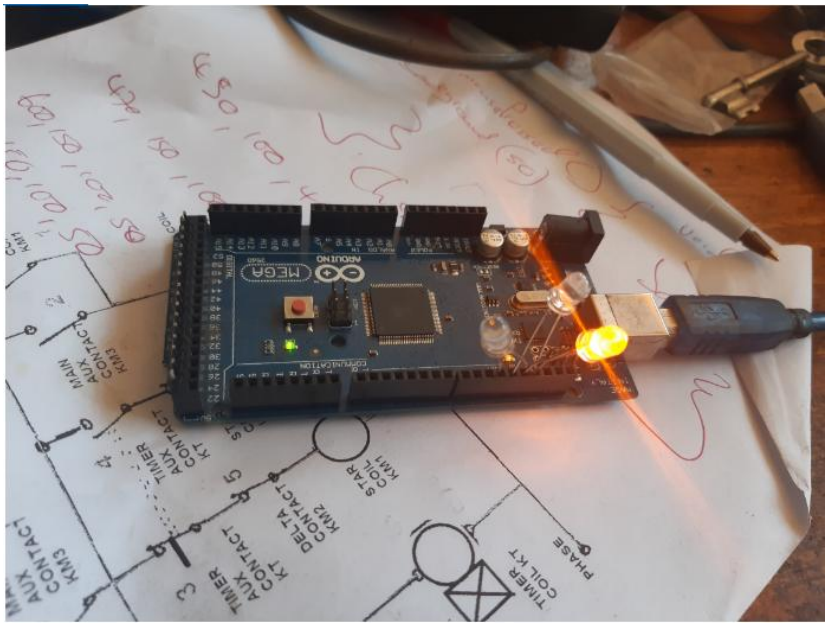


Figure 4.3.7 Arduino board processing inputs from the field sensors and sending them to the PC

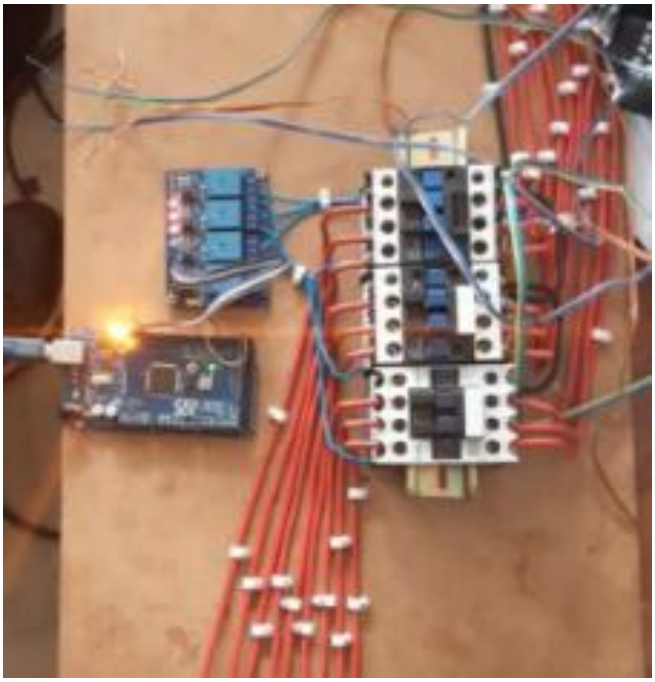


Figure 4.3.8 Arduino, relay drive controlling contactors resembling breakers

Figure above represents 3 substations; the three contactors represent breakers which are being controlled from a central control room via Arduino board. From the Arduino board a 5volts signal is sent to the driver relay which the use contacts to power the 220volts coil and energise the contactor(breaker). The contactor contacts status then changes hence sending a feed back to the control room that breaker is on. If the breaker trips the normally open contactor maintains its status hence sending a signal to the control room that the breaker is now open. This described the main function of the project.

CHAPTER 5 RESULTS, DISCUSSION AND COMPARISON WITH EXISTING

5.1 SUMMARY OF THE CHAPTER

This section will be a summary of the results obtained from the 2 software developed thus substation and feeder design and also the SCADA based substation monitoring and control system.

5.2 LOAD ANALYSIS, FEEDER DESIGN AND SUBSTATION DESIGN SOFTWARE

This software was designed such that users can easily enter their values and obtain desired results for the substation and feeder bill of quantity. Load analysis was done using the electrical power load analysis flow chart (load estimation, load factor analysis, mine area load analysis, determination of components size). The software page has a list of almost every equipment required in a substation and all equipment required on a feeder. Below are a number of calculations done and what the results they were showing.

5.2.1CHIADZWA MINE ELECTRIC LOAD LIST

This is a load database for the equipment in Chiadzwa mine as shown below.

Plant/ resident	Power (kW)	Curren t(A)	power kVA
Mine A plant	4332	7816.10855	5415
Mine B plant	1200	2165.12702	1500
Mine A residential camp	74.8	340	74.8
Portal Q barracks	60	27.2727273	60
Executive camp	98.5	44.7727273	98.5
	5765.3	**10393.281**	**7148.3**

figure 5.2.1. 1 total power required

Equipment	Quantit	KW	KVA	FLA	total amps	Total pow
scrubber feed con	1	22	25.882	39.694	39.6	22
scrubber	2	55	64.706	110	220	110
double deck screen	2	9	10.588	16	32	18
oversize conveyor	1	15	17.647	39.6	39.6	15
product conveyor	1	15	17.647	39.6	39.6	15
vibro feeder	2	0.4	0.4706	1.85	0.74	0.8
degrit pump	1	55	64.706	99.235	99.234988	55
spillage pump	1	7.5	8.8235	13.532	13.532044	7.5
Dms feed conveyor	1	15	17.647	39.6	39.6	15
feed prep scren	2	3	3.5294	0.78	2.34	6
correct medium pump	1	75	88.235	130.63	130.62606	75
cyclone feed pump	1	75	88.235	134.06	134.06359	75
effluent pump	1	75	88.235	134.06	134.06359	75
densifier pump	1	30	35.294	53.625	53.625437	30
degrit pump	1	110	129.41	196.63	196.6266	110
spillage pump	1	7.5	8.8235	13.406	13.406359	7.5
sinks screen	2	9	10.588	16.088	32.175262	18
floats screen	2	1.6	1.8824	2.86	5.7200466	3.2
degrit screen	2	3	3.5294	5.3625	10.725087	6
tailings con	1	15	17.647	26.813	26.812719	15
pipe con	1	4	4.7059	7.1501	7.1500583	4
mag sep	1	3	3.5294	5.3625	5.3625437	3
demag coil	1	3	3.5294	5.3625	5.3625437	3
slimes disposal pump	1	110	129.41	196.63	196.6266	110
slimes booster pump	1	110	129.41	196.63	196.6266	110
Total		**828**	**974.1**	**1525**	**1675.22**	**909**

figure 5.2.1. 2Scrubbing and DMS plant load

Equipment	Quantit	KW	KVA	FLA	total amp	Total pow	offload running a	offload running power
apron feeder	1	18.5	21.765	39.6	39.6	18.5	16.1	9.480968
apron feeder spillage con	1	5.5	6.4706	11	11	5.5	5.94	3.4979472
rotary screen feed conveyor	2	11	12.941	16	32	22	12.64	7.4434432
rotary screen vibrating feeder	2	8.5	10	17	34	17	16.8	9.893184
rotary screen drive	1	55	64.706	104.5	104.5	55	39.6	23.319648
rotary screen product conveyor A	1	11	12.941	22.3	22.3	11	12.3	7.243224
rotary screen product conveyor B	2	15	17.647	14.6	29.2	30	29.5	17.37196
rotary screen o/s conveyor to jaw crusher	2	18.5	21.765	17.7	35.5	37	33.2	19.550816
jaw crusher	1	160	188.24	292	292	160	96.1	56.591368
jaw crusher product conveyor A	1	15	17.647	29.2	29.2	15	13.4	7.890392
jaw crusher product conveyor B	1	15	17.647	29.2	29.2	15	21.4	12.602032
jaw crusher product sizing screen	2	12.85	15.118	26.1	52.2	25.7	28.64	16.8655232
product sizing screen product conveyor /	1	15	17.647	29.2	29.2	15	14.07	8.2855416
product sizing screen product conveyor E	1	15	17.647	29.2	29.2	15	19.6	11.542048
rotary screen product conveyor C	1	15	17.647	29.2	29.2	15	14.3	8.420984
product sizing screen o/s conveyor A	1	15	17.647	29.2	29.2	15	17.4	10.246512
product sizing screen o/s conveyor B	1	15	17.647	29.2	29.2	15	20.9	12.307592
cone crusher surge bin	2	1.7	2	3.5	7	3.4	6.1	3.592168
cone crusher A	1	280	329.41	577	577	280	108	63.59304
cone crusher B	1	280	329.41	577	577	280	14.3	8.420984
cone crusher A&B product conveyor	1	15	17.647	29.2	29.2	15	14.63	8.6153144
cone crusher sizing screen	2	12.85	15.118	26.1	52.2	25.7	29.2	17.195296
cone crusher sizing screenprod con A	1	15	17.647	29.2	29.2	15	15.08	8.8803104
cone crusher sizing screenprod con B	1	15	17.647	29.2	29.2	15	15.47	9.1093736
cone crusher sizing screen o/s conveyor	1	15	17.647	29.2	29.2	15	17.79	10.4761752
surge bin A vibrating feeder	2	1.7	2	3.5	7	3.4	6.2	3.651056
surge bin B vibrating feeder	2	1.7	2	3.5	7	3.4	6.1	3.592168
scrubber feed con	1	22	25.882	41.7	41.7	22	20.4	12.013152
scrubber drive	2	75	88.235	135	270	150	63	37.09344
sizing screen	4	16.1	18.941	30.17	120.68	64.4	68.6	40.397168
sizing screen product con	1	18.5	21.765	33.6	33.6	18.5	16.5	9.71652
sizing screen o/s conveyor A	1	15	17.647	29.2	29.2	15	18.01	10.6057288
sizing screen o/s conveyor B	1	15	17.647	29.2	29.2	15	15.6	9.186528
sizing screen underpan pump	1	90	105.88	159	159	90	113	66.54344
floor spillage pump	1	7.5	8.8235			7.5		0
process water pump	1	90	105.88	159	159	90	52.47	30.8985336
Total		**1408**	**1656**	**2695**	**3043.1**	**1615**	**1012.34**	**596.1467792**

figure 5.2.1. 3 Crushing plant load

5.2.3 CALCULATING CABLE SIZE

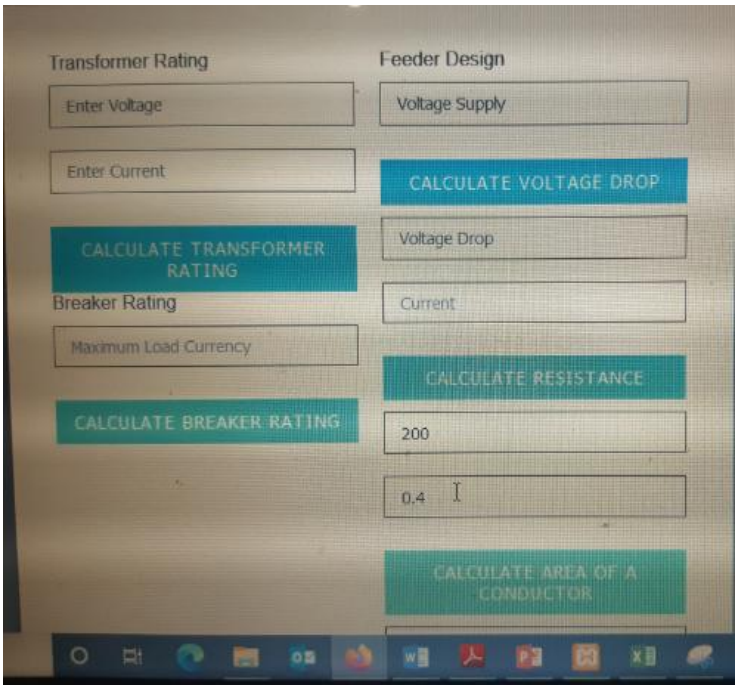


Figure 5.2.1calculating conductor size

the above shows required parameters for calculating conductor size using R = (ρ *l)/A. below is the fig of the calculated results

Figure 5.2.2 conductor size calculated results

5.2.2 CALCULATING TRANSFORMER SIZE

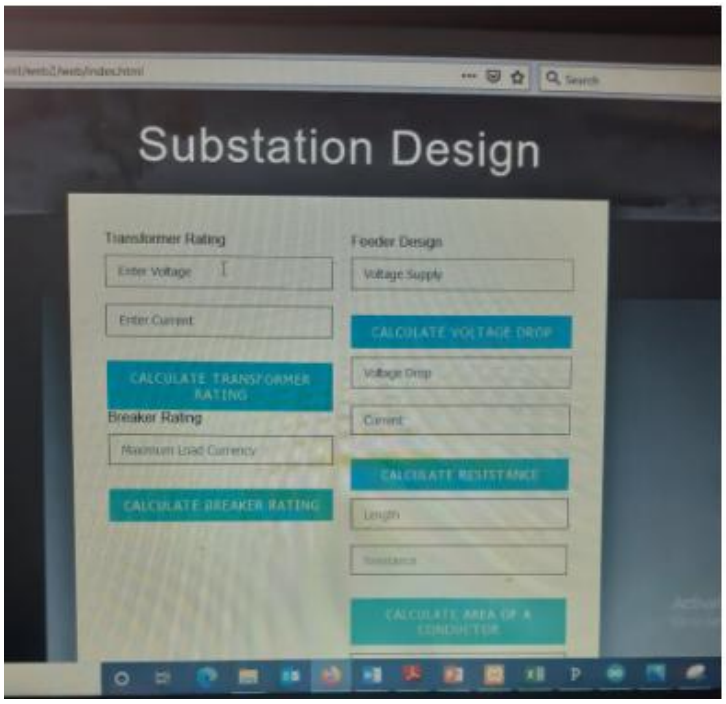


Figure 5.2.3 transformer rating calculation

figure above shows that under transformer rating, one is guided on what values to enter, which are voltage and current and the 1.732 factor for 3 phase system.

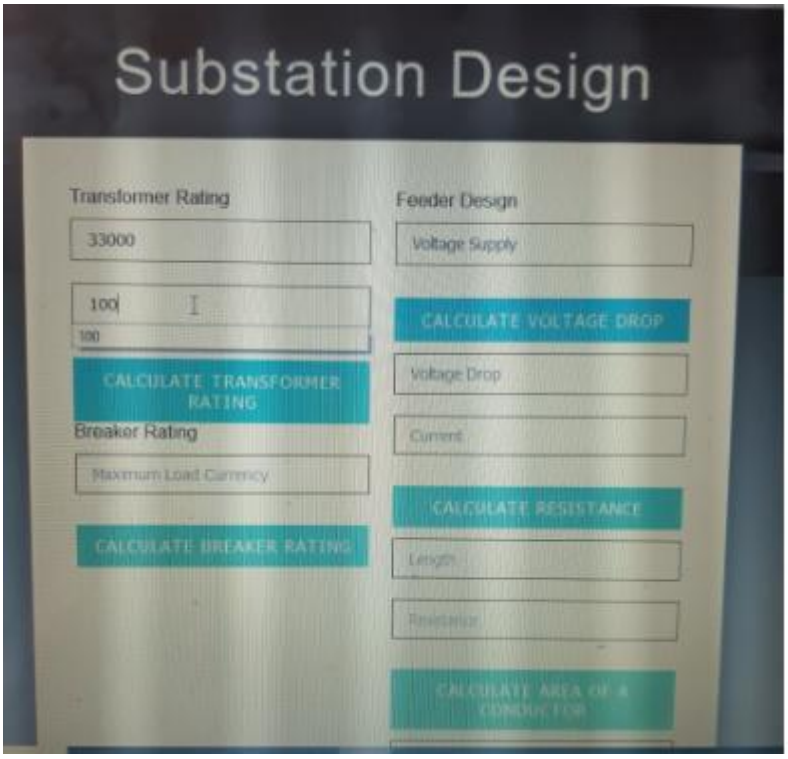


Figure 5.2.4 Entering values for calculation

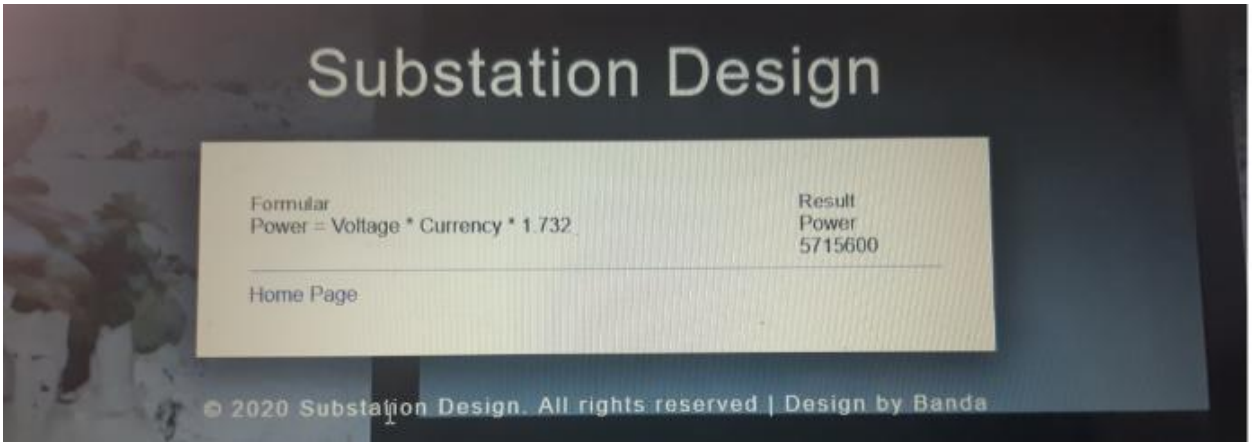


Figure 5.2.5 Displayed results

The calculated result is displayed and it shows a 5.72MVA, the user will have to look for the next size available on the market after the 5MVA

The design software results all came accurately as per objective. The software covers the load forecast, substation and feeder equipment calculations which was another objective.

5.2.3 COMPARISON WITH RELATED WORKS

Various software has been developed which help in substation system design, simulation and load analysis e.g. etap. Below is a table which compares etap to the software that I developed. From the results attached on this document it stands as evidence of what the software is capable of.

Characteristics	**Etap**	**My developed software**
Load listing	✓	✓
Load schedules	✓	x
Bus loading	✓	✓
Bus summary	✓	✓
Cable list	✓	✓
MCC tabulation	✓	x
System load	✓	✓
Demand factors	✓	✓
Diversity factor	✓	✓
Operating loads	✓	✓
Configuration	✓	Covered by developed SCADA
Receiving and supply voltage calculation	x	✓
Conductor spacing	x	✓
Switch gear rating calculation	x	✓
Transformer list	✓	✓

table 5.2.3 comparison of Etap and my work

5.3 SCADA BASED SUBSTATION MONITORING AND CONTROL

Microcontroller based substation monitoring and control system with SCADA system was designed such that the devices can be monitored and also controlled from a PC remotely. This system monitors 3 substations and various parameters.

5.3.1 BREAKER BUTTON CLICKED

After the breaker 'ON' mouse button is clicked breaker switches on and voltage power is supplied to the load. The relay breaker is switched on with a 5Vsignal from the micro-controller. The relay contacts are connected 220V supply to the load. Figure below shows the Arduino sending a signal to the relay drivers which then send 220volts signal to the breaker coil

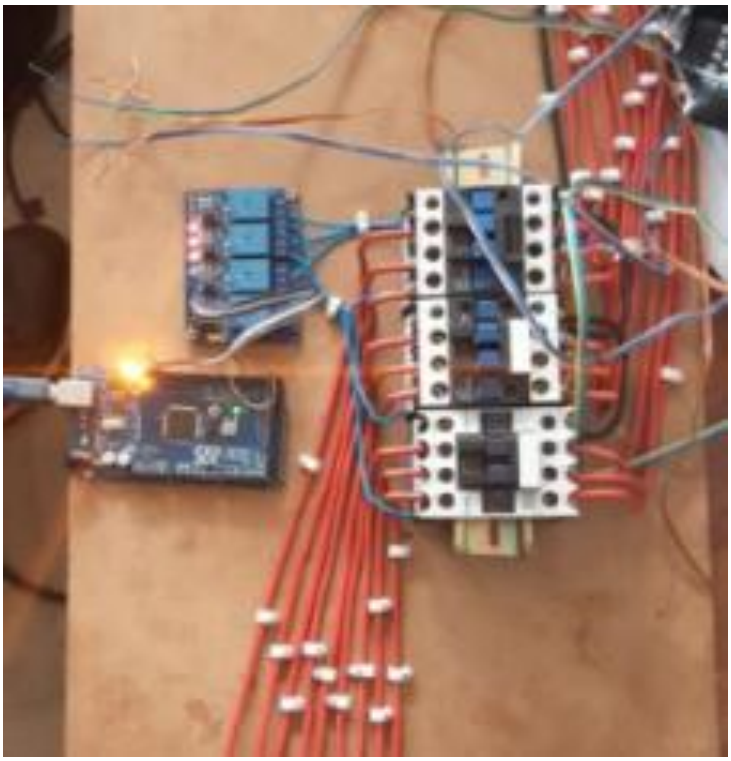


Figure 5.3.1 Breaker "ON" command

5.3.2 *BUCHHOLZ RELAY ACTIVATED*

After a fault occurs, bubbles are formed and they move into the conservator, depending with the quantity of bubbles, the 2 contacts are activated differently. Float switch contact 1 is activated when the bubbles are fewer than those which activate the second contacts. Figure below shows simulation for warning light.

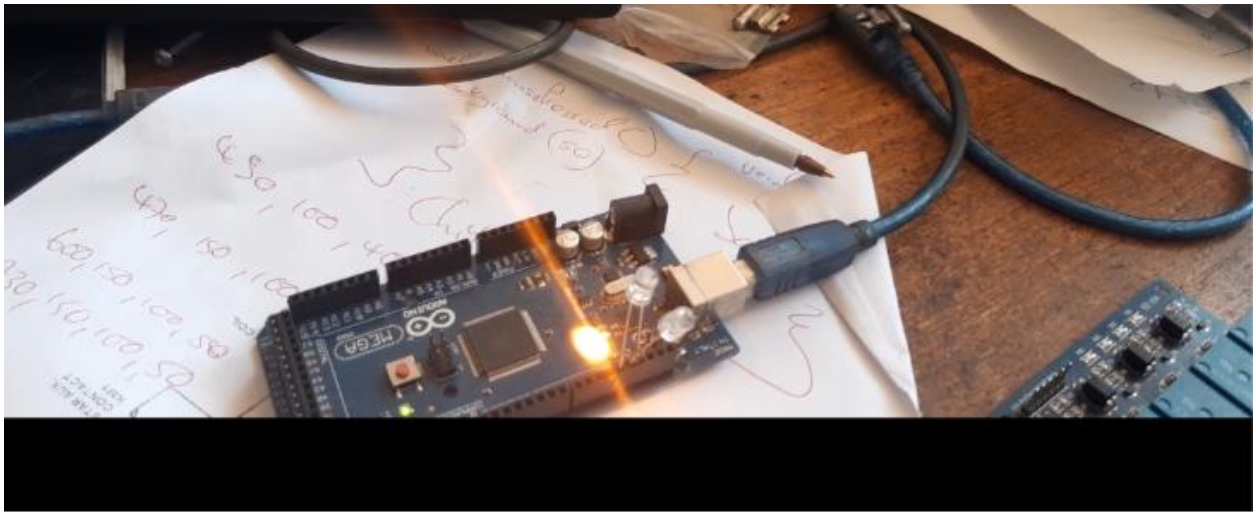


Figure 5.3. 2 Buchholz warning light

5.3.3 *TEMPERATURE LIMIT AND OIL LEVEL LOW*

When the temperature value goes above the limit but 5°C less than trip point a warning light and fan is activated. after it reaches the trip point a signal is sent from the SCADA automatically to trip the feeder breaker.

When oil level drops to 50% a medium contact opens hence activating the warning light as a warning sign to top up oil on opportunity maintenance. If the oil level drops below 30% then a signal for tripping the breaker is actuated. Figure below shows a simulation of temperature high and low oil level.

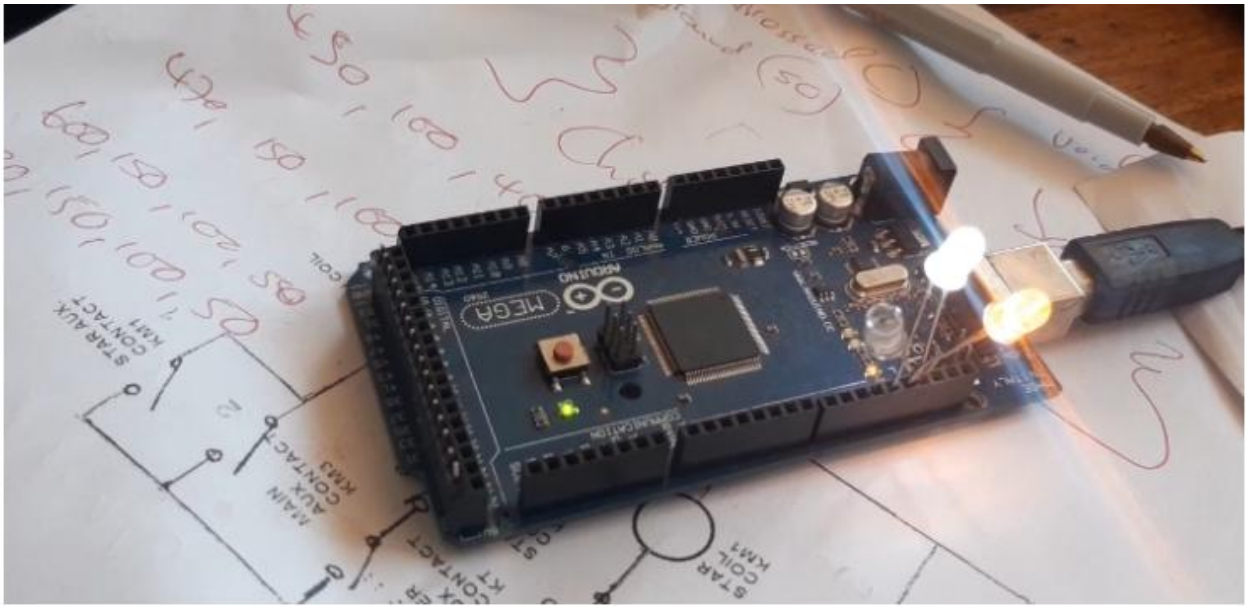


Figure 5.3.3 Temperature high and oil level low warning lights

5.3.4 *CURRENT HIGHER THAN LIMIT*

When current value rises 15amps below the trip point a warning light switches on to prepare for load reduction but if it continues to rise above the limit the breaker switches off to avoid damage of equipment. Figure below shows simulation of the current overload warning light.

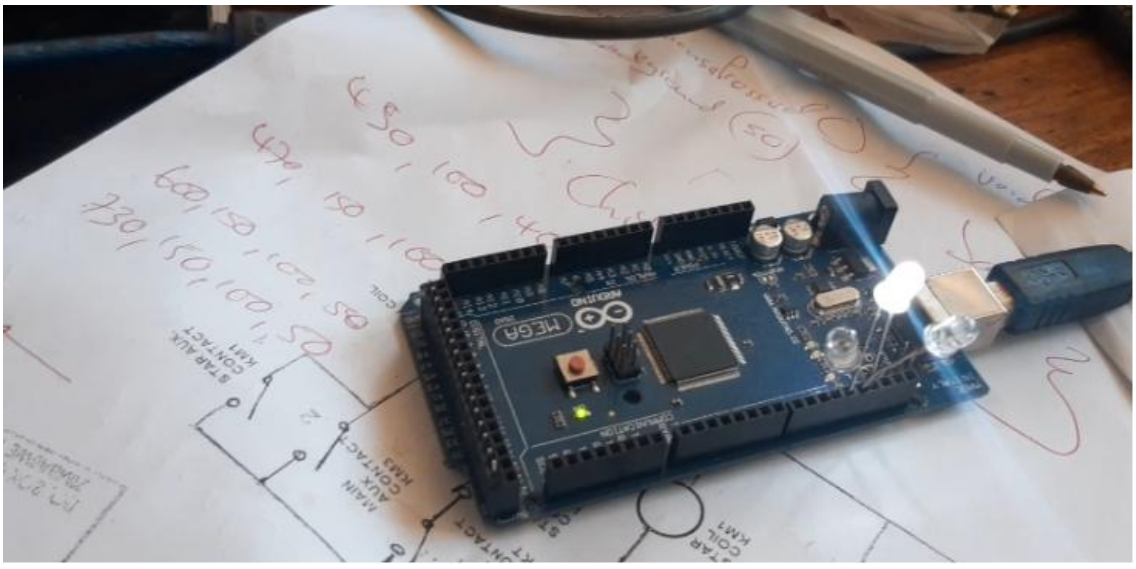


Figure 5.3.4 Current high warning light

5.3.5 Table of results SCADA

Description	**Expected results**
Oil level at 50%	*Warning lamp*
Oil level at 30%	*Trip feeder breaker*
Buchholz relay 1st contact "open"	*Warning light*
Buchholz relay 2nd contact "open"	*Trip breaker*
Temperature at 60°C	*Warning light and fan "on"*
Temperature above 65°C	*Trip feeder breaker*
Current at 200Amps	*Warning light "on"*
Current at 250Amps	*Trip feeder breaker*
Breaker "On" button clicked	*Relays switch on and supply voltage to load*
Voltage breaker on	*220V display on SCADA*
Load current	*Current value displays on SCADA*
Temperature	*Temperature value displays on SCADA*
Trends	*Displays graphs for each parameter*

Table 5.4. 1 Table of Results

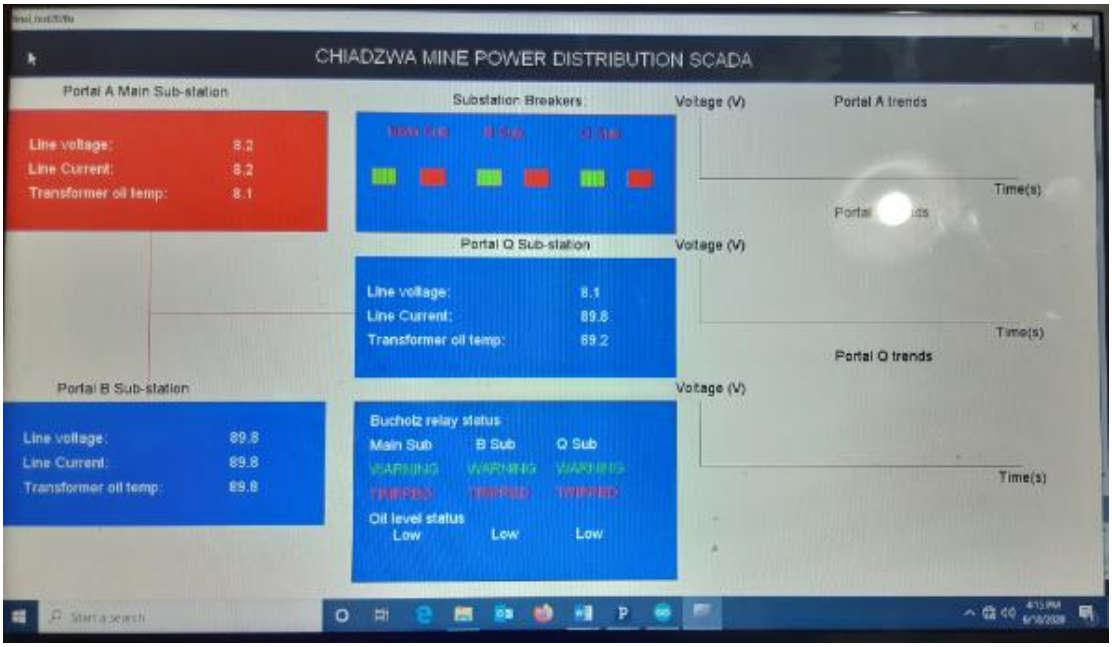


Figure 5.4.2 Developed SCADA page

5.3.6 comparison of existing projects with my work

Various SCADA systems have been developed over the years and many being used in processing plants, only Grid power utility has been focusing on the SCADA for substation monitoring and control. As an electrical engineer there is need to have a trend of the system power, monitor substation remotely for safety of equipment and personnel. Comparison with ABB SCADA system used by ZESA in Zimbabwe

Characteristics	**ABB SCADA**	**MY DEVELOPED**

		SCADA
Oil level display	✓	✓
Pressure build protection	✓	✓
Buchholz relay status display	✓	✓
Winding temperature display	✓	✓
Transformer oil Temperature display	✓	✓
Voltage display	✓	✓
Current display	✓	✓
Power display	✓	✓
Switch gear operation	✓	✓
Load regulation signal to operating plants	In caseof an overload the system alerts the operator who then manually regulates power consumption	Incase of an overload, overload the system alerts the operator and if the load does not reduce it then automatically sends a signal to the plant to regulate power consumption on variable speed drives and isolating non critical processes to avoid complete shutdown.
Trends display	✓	✓
Servers	✓	✓
Processing Device	✓	✓
Transmission Media	Power Line Carrier, Fiber Optic G652D	Power Line Carrier, Fiber Optic G652D
Transmission Back Up	Fiber ring network, 1+ 1 path protection	No ring network
Communication Standard	Serial RS232	Serial Rs232

table 5.3.6 Comparison of ABB SCADA and My work

5.5. *DISCUSSIONS*

5.5.1 DESIGN SOFTWARE TOOL

The design software is a package of load forecast, substation and feeder design which helps as a complete set of determine maxima demand, substation transformer required to cater for determined load and also transmission equipment which can handle the current without interruptions. It also helps to plan for future expansion in the same room which will calculate required equipment. Figure below illustrates the process of planning up to equipment requirement and how advantageous this software tool is as a full package.

Figure 5.5.11 Design process covered by the software package

5.5.2 SCADA BASED SUBSTATION MONITORING AND CONTROL

A considerable amount of effort is necessary to maintain an electric power supply within the requirements of various types of consumers without failure of system. This is achieved through real time monitoring of the system and controlling before power

interruption occurs. The system also looks into the trends of current and voltage which might help the utility supplier in knowing the behavior of the system at a certain period. For the following reasons condition monitoring is important:

5.5.2.1 VOLTAGE SUPPLY WITHIN THE TOLERANT RANGE

One important requirement of a distribution system is that voltage variations at consumer's terminals should be as low as possible with a +/- 5%. The changes in voltage are generally caused due to the variation of load on the system. Low voltage causes loss of revenue, inefficient lighting and possible burning out of motors. High voltage causes lamps to burn out permanently and may cause failure of other appliances. Therefore, a good distribution system should ensure that the voltage variations at consumers' terminals are within permissible limits. The statutory limit of voltage variations is ± 5% of the rated value at the consumer's terminals. Thus, if the declared voltage is 230 V, then the highest voltage of the consumer should not exceed 244 V while the lowest voltage of the consumer should not be less than 216 V. [1]

5.5.2.1 AVAILABILITY OF POWER ON DEMAND

Power must be available to the consumers in any amount that they may require from time to time. For example, motors may be started or shut down, lights may be turned on or off, without advance warning to the electric supply company.As electrical energy cannot be stored, therefore, the distribution system must be capable of supplying load demands of the consumers. This necessitates that operating staff must continuously study load patterns to predict in advance those major load changes that follow the known schedules. [1]

5.5.2.3 RELIABILITY

Modern industry is almost dependent on electric power for its operation. Homes and office buildings are lighted, heated, cooled and ventilated by electric power. This calls for reliable service. Unfortunately, electric power, like everything else that is man-made, can

never be absolutely reliable. However, the reliability can be improved to a considerable extent by

(a) Interconnected system

(b) Reliable automatic control system

(c) Providing additional reserve facilities [1]

The use of PLCs (Programmable Logic Controllers) in substation and distribution automation applications has grown in recent years. The economics of PLC based solutions mean that substation automation and SCADA solutions can be applied even more widely. This will help the utilities respond to the challenges presented by deregulation. As the use of PLCs in substations increases, the criteria for selection of control system integrators, engineering firms and consultants will become an extremely important factor in the success of PLC substation automation and SCADA projects. One of the most important criteria is that the control system integrator, the engineering firm or the consultant has sound business practices in place. They should also have a project management methodology in place to assure the success of these projects

This type of an automatic network can manage load, maintain quality, and detect theft of electricity and tempering of meters. It gives the operator an overall view of the entire network. Also, flow of power can be closely scrutinized and Pilferage points can be located. Human errors leading to tripping can be eliminated. This directly increases the reliability and lowers the operating cost. In short this project is an integration of network monitoring functions with geographical mapping, fault location, load management and intelligent metering

5.3 COST

Component	Quantity	Cost ($)	
Resistors	10	1	
Capacitors	10	1	
Drill Bits	2	1	
PCB	2	30	
Diodes	12	1.8	
Relays	8	20	
LM 35	1	2.5	
Con Wagos	24	7.2	
Cables	6	11.5	
Headpin Connectors	40	2	
LEDs	12	3.6	
Current Sensors	3	30	
Voltage Sensors	3	30	
driver relay board	1	39	
		180.6	

Table 5.3 Table of Components and Cost

CHAPTER 6 IMPROVING DESIGN

6.1 DESIGN SOFTWARE

The design software tool future improvements might look at:

i. calculating earth resistance,
ii. determining fault levels,
iii. determining feeder protection circuit parameters.
iv. It also needs a simulation function for the calculated variables so that one can see how the system behaves under various loading.
v. Have a database where the calculated variables are stored and can be extracted when needed.

6.2 SCADA BASED MONITORING AND CONTROL SYSTEM

SCADA is used as a remote monitoring system for automation, not only must it monitor and interrupt the process but to also control in a way that does not interrupt the process. It should maximise on the up time of the system. Future improvement for the system include but not limited to:

i. To display reactive and apparent power
ii. To have a storage data base for up to 6 months
iii. To display power factor
iv. To be able to automatically notify the overloading substation users as a way of eliminating feeder breaker notification

v. When transformer oil level reduces the system must be able to automatically top oil through a valve.

6.3 SUMMARY

Due to time constraints though those issues were not part of the objectives but as I did the project I realized there is room for such improvements and they will be necessary on the system.

CHAPTER 7 CONCLUSION

The load forecast, substation and feeder software tool facilitates the user with formulas and quicker calculations. It also guides the user with required information or equipment e.g. when doing loadanalysis, it guides on the information required like demand factor maximum load, utilization factor etc. also for the substations it guides on the required equipment/component e.g. breaker size, bus bars, transformer size. On the feeder design it shows the conductor size, spacing. This then helps on installing the correct and adequate equipment required from substation to receiving end.

SCADA provides management with real-time data on production operations; an implement more efficient control paradigms, improve plant and personnel safety, and reduces costs of operation. The security of SCADA systems depends on the effective application of security principles and technology to the SCADA system. This paper has proposed a model that illuminates the categories of data, functionality, and interdependencies present in a SCADA system.

The model serves as a foundation for further research on SCADA systems best application for consistent operations as discussed in chapter 6 for design improvement. Microcontroller based control system to implement the SCADA system for Power Distribution system has been developed before at national grid level at supply demand management systems but this system now focuses on industrial users for efficiency on load management systems. Load management systems is now the best practice as it is used to reduce irresponsible use of energy.

Thus Integrating features of all the hardware components used have been developed in it. Presence of every module has been reasoned out and placed carefully, thus contributing to the best working of the unit. Secondly, using highly advanced IC‟s with the help of growing technology, the project has been successfully implemented, thus the project has been successfully designed and tested.

7.2 RECOMMENDATION

SCADA based substation monitoring should be widely used not only for voltage, current, transformer oil level and temperature, winding temperatures but for better control methods with zero interruptions. It must be networked to the chief operations officer's desk so that he will be in picture of the disturbances in the business due to power availability interruptions.

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