ODA BULTUM UNIVERSITY

INISTITUTE OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING (Power Engineering)

BSc Thesis

Title: Design and simulation of Automatic load sharing of power Transformer Microcontroller Based Relay

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DECLARATION

The under signed declare to the department of electrical and computer engineering *(power engineering)* at Oda Bultum university is that this final project is our own work and all source of material used to the final project have been done by:

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ABSTRACT

The transformer is a static device, which converts power from one level to another level. The aim

of the thesis is to protect the transformer under overload condition by load sharing. Due to overload on transformer, the efficiency drops, windings get overheated even get burnt and the working life expectancy of the transformer shortened as well. Thus, by sharing load to another

transformer, the transformer is protected consequently, the quality and reliability of supply of distribution transformer well use. This will be done by connecting another transformer in parallel through a micro-controller. The microcontroller compares the load on the first transformer with a reference value and if the load exceeds the reference value, the second transformer will be online and share the load symmetrically. Therefore, the two transformer work efficiently and damage is prevented. The advantages of the load sharing are transformer protection, uninterrupted power supply, and short circuit protection. When designing low-voltage power system to the supply large load currents, paralleled lower-current modules are often preferred over a single, large power converter for several reasons. These include the efficiency of designing and manufacturing standard modular converters which can be combined in any number necessary to meet a given load requirement and the enhanced reliability gained t. Proteus- simulation software has been used to test whether the designed works appropriately before its implementation on hardware. Arduino has been used to upload program into the microcontroller .All these make system very efficient and reliable.

KEYWORDS: Transformers, Short circuit, Microcontroller, Reliable power supply

Acknowledgement

First and foremost, we would like to thank God for giving us the strength and helping us in every aspect of our work time. Then we have a special thanks to our advisor Mr. Umar Abdi (MSc) who helped us by giving important ideas and supports to succeed to this final project in good approach of guidance. And finally we want to give our thanks for everyone who involves directly and indirectly in the process of the project.

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Contents

LIST OF FIGURE

LIST OF ABBREVIATION

AC	Alternating current
A	Ampere
ASCII	American Standard Code for information interchange
ADC	Analog to digital converter
CM	Cent meter
CT	Current transformer
EMF	Electro motive force
EMR	Electromagnetic relay
HZ	Hertz
KV	Kilo volt
LED	Light emitting diode
LCD	Liquid crystal display
MVA	Mega volt ampere
TOV	Temporary over voltage
VAC	Alternating voltage
VDC	Direct voltage
VR	Rated voltage
VT	Voltage transformer
Z	Impedance
ZB	Base Impedance

CHAPTER ONE

INTRODUCTION

1.1 Back ground

Electric energy demand is now a day increasing over every year. The installed power transformer in distribution network of the any substation is not capable of carrying this over increased load. When we see in some substation and distribution many malfunction or burnt power transformers are seen that are stored in the store of the office. Most of these malfunction happened due to overload and over current. To combat this problem many option are there like protective relay protection, breaker installation. Of these the most cost effective, simple and efficient project entitled "design and simulation of automatic load sharing of power transformer using microcontroller is chosen [1]. Every transformer is designed to comfortably supply a given load. Cases of overload or short circuits can lead to transformer being damaged. To combat such occurrence, an elaborate system that monitors these excesses in supply parameters needs to be built. Such a device controls the flow of electrical power to the load so that the transformer is not overworked. Over current relays and overvoltage relays have been used for a long period of time and have been electromechanically controlled. In this system, a microcontroller is used to monitor cases of electrical faults and communicate to a switch to isolate the transformer from the system [2].

Electricity is an extremely handy and useful form of energy. It plays an ever growing role in our

modern industrialized society. So the demand for electrical energy is ever increasing. The electrical power systems are highly non-linear, extremely huge and complex networks. Such electric power systems are unified for economic benefits, increased reliability and operational advantages. However, some of the electrical energy generated is lost in transmission and distribution due to a widely dispersed power sources and loads. The consumer service interruptions in the city are mostly due to failure in the distribution network. Distribution systems have suffered mainly from the following:

voltage and current imbalance, poor voltage regulation, peak power or energy losses, conductor heating or equipment, etc. The phase voltage

and current unbalances are major factors leading to extra losses, equipment overloading. The transformer is a static device, which converts energy at one voltage level to another voltage level. The thesis is all about protecting the transformer under overload condition. Due to overload on the transformer, the efficiency drops and the secondary winding gets over heated and may burn. So, by reducing the load on the transformer, the transformer is protected. To minimize these problems, the structures of a distribution network of the city may have to be modified. This will be done by arranging another transformer through a micro-controller [3]. The microcontroller compares the load on the first transformer with a reference value. When the load exceeds the reference value, the second transformer will share the extra load. Therefore, the two transformers work efficiently under overload condition and the damage is prevented. In this thesis three major components will be used to control the load current. The first is sensing unit, which is used to sense the current of the load. The second is control unit; in this Electromagnetic relay is the main role, and its function is to change the position with respect to the control signal. The last is microcontroller, which will read the digital signal and perform some calculation and finally gives control signal to the relay. When designing low-voltage power systems to supply large load currents, paralleled lower-current modules are often preferred over a single, large power converter for several reasons. These include the efficiencies of designing and manufacturing standard modular converters which can be combined in whatever number necessary to meet a given load requirement; and the enhanced reliability gained through redundancy [1].

1.2 Statement of Problem

Transformer failures are particularly critical at sites where the environment and public safety are

at risk. Monitoring and controlling of transformer is an important task for supplying healthy power to the consumers. The risk of blackouts, brownouts and fire due to transformer abnormality are rapidly increasing. The transformer fluid leaks or internal insulation breakdown cause overheating that leads to failures. But there is a need for an optimal solution or technique for this problem is to design automatic load sharing of power transformer using microcontroller based relay scheme.

Sub-Problem

- ✓ Inadequate service quality and reliability;
- ✓ Transformer burning due to overload;

1.3 Objective

1.3.1 General Objective

- ✓ The general objective of this thesis is design and simulation of automatic load sharing of power transformer using microcontroller-based relay.

1.3.2 Specific objective

- ✓ Investigate how arrangement of consumers load can be carried out among the phases.
- ✓ Identification of materials required to design the system
- ✓ Simulation of the designed system
- ✓ To test load sharing of transformer and etc.

1.4 Contribution of the thesis

This thesis is contribute a technique for distribution utilities at the low voltage distribution network that will bring the following point:

- ➢ Increase quality and reliability of supply service to the consumers.
- ➢ Unbalance will be considerably minimized thereby ensuring that voltage drop and power losses are reduced. This will result in increase in the life span of the utility installations.
- ➢ Maximization of the capabilities of the existing distribution station in terms of the infrastructures and equipment.
- ➢ Resourceful distribution of power flow.

1.5 Significance of the project

This thesis will contribute a technique for distribution utilities at the low voltage distribution network that will bring the following point:

- Automatic load sharing of transformer in distribution
- Structural on load sharing and benefit of automatic load sharing
- Increase quality and reliability of supply service to the consumers.
- Unbalance will be considerably minimized thereby ensuring that voltage drop and power losses are reduced.

1.6 Scope of the project

The project is all about design and simulation automatic load sharing of power transformer under peak load to protect the transformer during overload condition with microcontroller. By introducing this method it have advantage to maintain a stable level of short circuit current, reduces the voltage drop and imbalances the current and it is reverse power protection etc. So the project deals from theoretical, code, until simulation.

1.7 Importance of Protection System

Fault impose hazard to both user and the system itself and when it comes to user, life is the concern and when it concern the system it is merely to provide stable .Electrical power system on top of that prevent damage to the expensive equipment used

1.9 Scope of the project

The project is all about design and simulation of automatic load sharing of power transformer under peak load to protect the transformer during overload condition. By introducing this method it have advantage to maintain a stable level of short circuit current, reduces the voltage drop and imbalances the current and it is reverse power protection etc. So the thesis deals from theoretical and mathematical method, code, until simulation.

1.10 limitations

The project deals with load sharing of transformers to ensure the safety of the power transformer. There by protecting the distribution system when there exist a state of over load. The project does not encompass other power transformer failure reasons like lightning, short circuit of winding, tree, birds and others. The project also does not try to show the implementation in substations since it is complicated and it would take

1.11 Outline

The first chapter is the overview of the whole project. It introduces the topic, motivation, objectives, statement of problem, contribution, hypothesis and methodology of the thesis. Chapter2 the review of articles in the open literature and field survey which are relevant to the current investigation such as phase unbalance, overload and transformer damage. Chapter 3 is the design of automatic load sharing of power transformer that contains major designing component, mathematical model of load sharing and analysis of case study. Chapter 4 presents the interfacing of microcontroller 16F877A with LCD LM016. This proposed technology is used for investigation incorporating all the relevant aspect for switching, monitoring, evaluation, analysis and communication for the purpose of achieving the development. Chapter 5 discusses the simulation and results of this project. Chapter 6, Conclusion and recommendation for future work.

CHAPTER TWO

LITERATURE REVIEW

Automatic transformer load sharing issues and remedies are relevant project topics and a lot of advanced researches are being carried out in this area. These issues are mainly due to increased usage of power system utility and unbalanced loads occur in power system. Dynamic loads cause power quality problems usually by voltage or current variations such as voltage dips, fluctuations, momentary interruptions. Various publications define transformer load sharing in different aspects. The project entitled **"power transformer protection using microcontroller designed with peripheral interface controller (pic 16f877a)"**.This project is mainly used to protect transformer from getting worn out due to electrical disturbances. The electrical parameters like current, voltage of the transformer are fed as base values, using a keypad to the peripheral interface controller and the output signal is provided to operate a relay comparing the base value with the operation electrical parameters. **“Transformer protection and monitoring"** this project uses the distance protection function which is used as back-up protection for faults within the transformer. This solution provides efficient protection and control in facts installations. The distance protection function can also be used as back-up protection for faults in the connected lines. The parameters related to line distance protection are mostly set as primary ohms, which significantly reduce the need to re-calculate the current and voltage values. This allows the IEDs to be quickly taken into operation. Furthermore in 2007 S.M. Bashi et al, —**designed and built a microcontroller based system for power transformer protection**. The system includes facilities for discrimination between internal fault current and magnetizing inrush current, differential protection, over current protection has been included. The performances of the proposed system have been examined and from the experimental readings and observation, it was understood that the proposed system monitors and controls the transformer when there is any fault (Bashi et al 2007).

Abhishek G. et al proposed an Automatic Transformer Distribution and Load Sharing Using Microcontroller in which a number of transformers were operated in parallel in order to avoid overloading. It is same like parallel operation of transformers where the number of transformers shares the system load. In the suggested approach slave transformers will share the load when the load on the main transformer will rise above its rated capacity. [1] Automatic transformer load sharing issues and remedies are relevant project topics and a lot of advanced researches are being carried out in this area. These issues are mainly due to increased usage of power system utility and unbalanced loads occur in power system. Dynamic loads cause power quality problems usually by voltage or current variations such as voltage dips, fluctuations, momentary interruptions. Various publications define transformer load sharing in different aspects. The project entitled "power transformer protection using microcontroller designed with ardiuno. This project is mainly used to protect transformer from getting worn out due to electrical disturbances. The electrical parameters like current, voltage of the transformer are fed as base values, using a keypad to the peripheral interface controller and the output signal is provided to operate a relay comparing the base value with the operation electrical parameters.

Contribution in our case comparing with the above publication

Overload is hazard to both electric power user and electric system itself. Many transformers are damaged (warn out) frequently in different part of the city due to overload. This may the city is on fast growing and its population increase rapidly from time to time. This is due to establishment of different industries, hotels resorts and formation of new university should be considered time to time in order to give reliable and sustainable power system. Therefore in our case we have to increase quality and reliability of supply service to the consumer and unbalance will be considerably minimized thereby insuring that power loss are reduced.

CHAPTER THREE

DESIGN OF AUTOMATIC LOAD SHARING OF POWER TRANSFORMER

3.1 Methodology

3.1.1Introduction of the methodology

Automatic load sharing of transformers is an integral part of the power system control process,
allowing smooth and immediate transfer of electrical current between multiple sources and the
load. Initially transformer 1 is connected to the load, the loads run with this power. If the load on
transformer 1 is increase beyond its rating (or some specified reference value) then controller
will find out that and it will connect the sharing transformer parallel to the main

transformer.

And controller will continuously monitor the current flowing in the load and when the load

current decreases below the transformer 1 rating (or reference value) then it will turn off the

sharing transformer.

Current transformer is used for measuring and protecting the load current, and the output of CT

is given to ADC of the microcontroller for converting analog output of CT into digital data. The

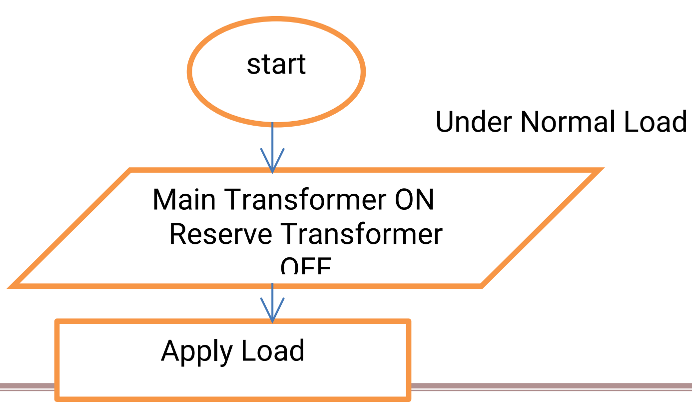
CT is used for monitoring purpose.

The design consists of:

- Flow chart
- Block diagram description (components)
- General criteria of design(parallel operation of transformers)
- Circuit diagram for simulation

Methodology is about how the system is organized and the flow of the steps in order to complete the thesis. The methodology is diverged in different parts, which are the analyzing and modeling of automatic power transformer load sharing and the other is simulation of automatic load using proteus software.

3.1.2 Flow chart



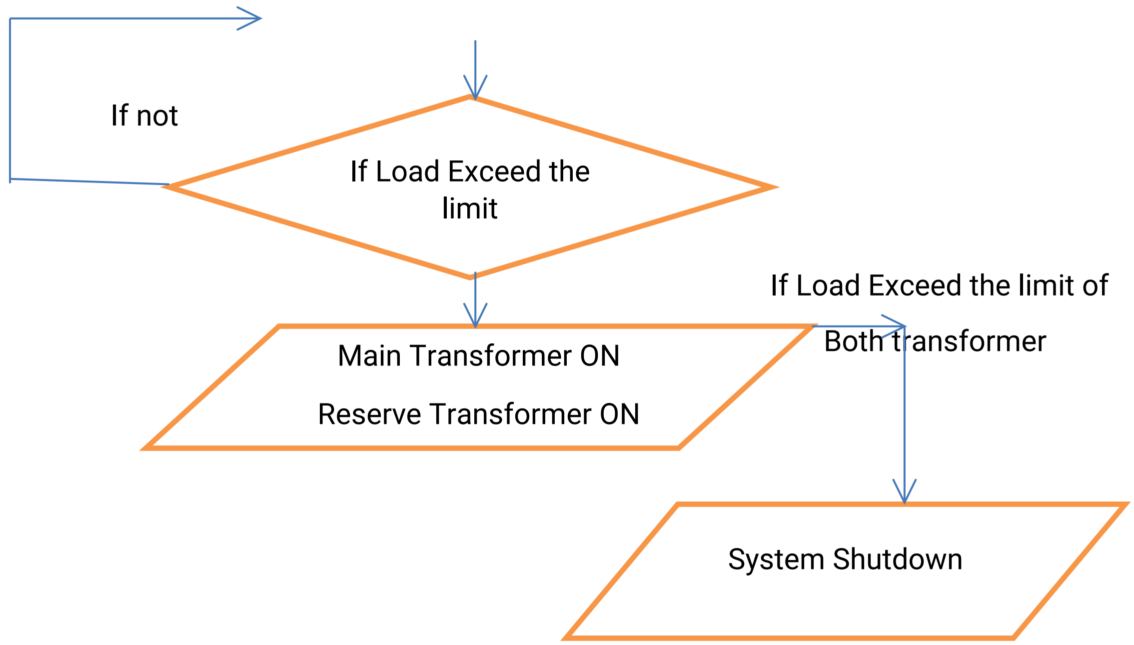


Figure 3.1 flow chart

3.1.3 Block Diagram

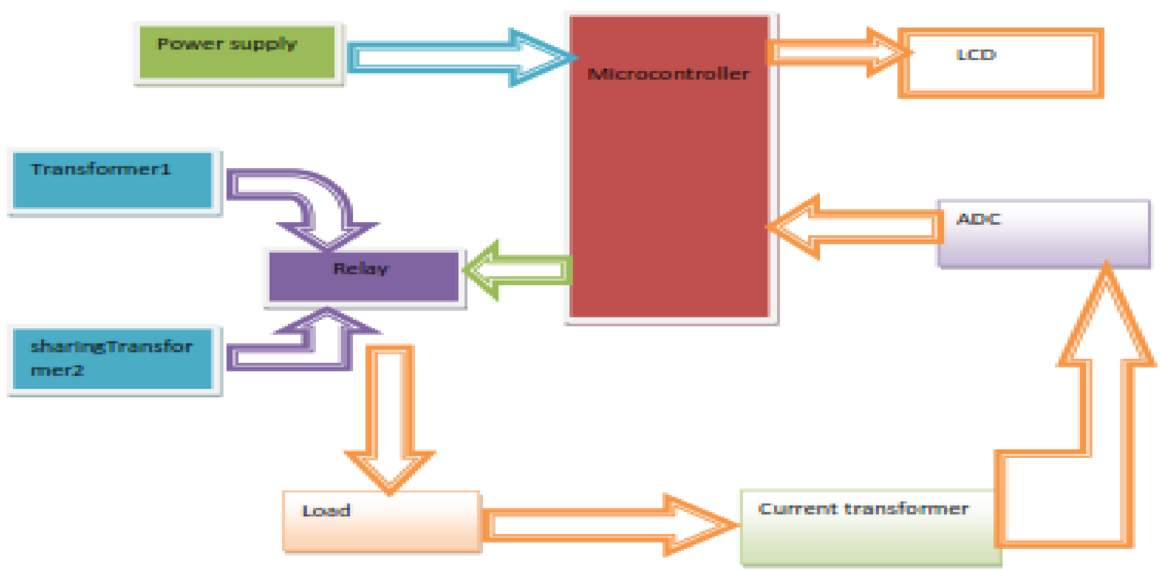


Figure 3.2 Block Diagram

3.1.4 Operating principle of block diagram

In the proposed system, only one transformer is operating to feed the loads. Standby transformer is connected in Parallel through a circuit breaker and relay. The current transformer continuously measures the load current and feeds it to the microcontroller ADC pins. The reference value or the maximum load limit is entered by the user and priority Level of the load is also set by the user or concerned authority. As the load demand increase during peak hours, a single Transformer would not be able feed all the load. During this condition, when the load demand exceeds the reference Value, the microcontroller will give a control signal to energize the relay coil. Thus the standby transformer will be connected in parallel and will share the load equally since the transformers are the same ratings. Thus all the loads are fed efficiently providing un-interrupted power supply sharing the load and shown in the LCD display. When the load increases further to a value which is greater than the capacity of the two transformers, priority based load shedding will be implemented. The loads which have the lowest priority will be shut down by opening the respective circuit breakers, when the load decrease comes to normal working condition, first transformer will be shut down in order to avoid thermal overloading.

3.2 Components used

3.2.1. Power supply

Power supply circuit design is one of the important parts of this project, without a power supply the electronic devices such as microcontroller, relay, ADC, LCD etc. display will not function. Similarly a wrong power supply design will lead to the damaging of the electronic devices used in this project. The main power supplies needed for this project is 5VDC in order to power on the relay and other electronic devices such as microcontroller, LCD and ADC etc. The design is done using a transformer, bridge rectifiers, filter capacitor and a voltage regulator.

Most of the power supply is designed to convert high voltage AC mains electricity to a suitable low voltage supply for electronic circuits and other devices. A power supply can be broken down into a series of blocks, each of which performs a particular function

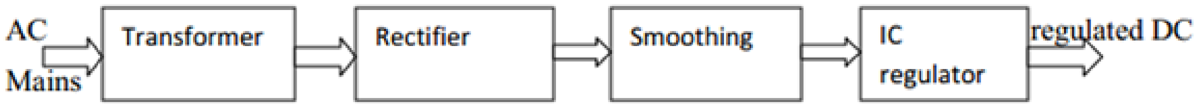


Figure 3.3 block diagram of power supply

3.2.2 Transformer

Power supply input voltage is obtained from the main supply 220VAC outlet and then connected to the transformer. A step down transformer is used in stepping the 220VAC to a 12VAC.The 12VACservesas an input voltage to the bridge rectifier.The transformer primitive requires properties for inductances of each coil plus the coupling coefficient properties for inductances of each coil plus the coupling coefficient between the coils

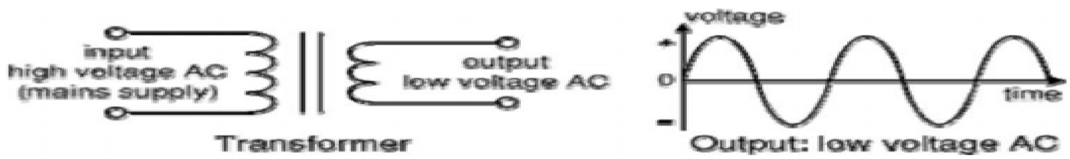


Figure 3.4 Output of transformer

3.2.3 Bridge rectifier

When four diodes are connected the circuit is called as bridge rectifier. The input to the circuit is applied to the diagonally opposite corners of the network, and the output is taken from the remaining two corners. Let us assume that the transformer is working properly and there is a positive potential, at point A and a negative potential at point B. the positive potential at point A will forward bias D3 and reverse bias D4. The negative potential at point B will forward bias D1 and reverse D2. At this time D3 and D1 are forward biased and will allow current flow to pass through them; D4 and D2 are reverse biased and will block current flow. The path for current flow is from point B through D1, up through RL, through D3, through the secondary of the transformer back to point.

One advantage of a bridge rectifier over a conventional full-wave rectifier is that with a given transformer the bridge rectifier produces a voltage output that is nearly twice that of the conventional full-wave circuit.

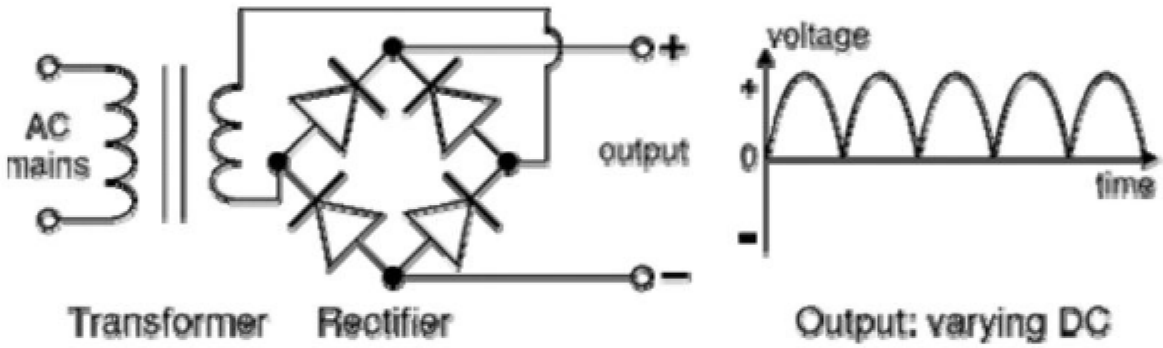


Figure 3.5 Output of rectifier

3.2.4Filter

Filters are electronic circuits which perform signal processing functions, specifically to remove unwanted frequency components from the signal, to enhance wanted ones, or both. The most common types of electronic filters are linear filters, regardless of other aspects of their design.

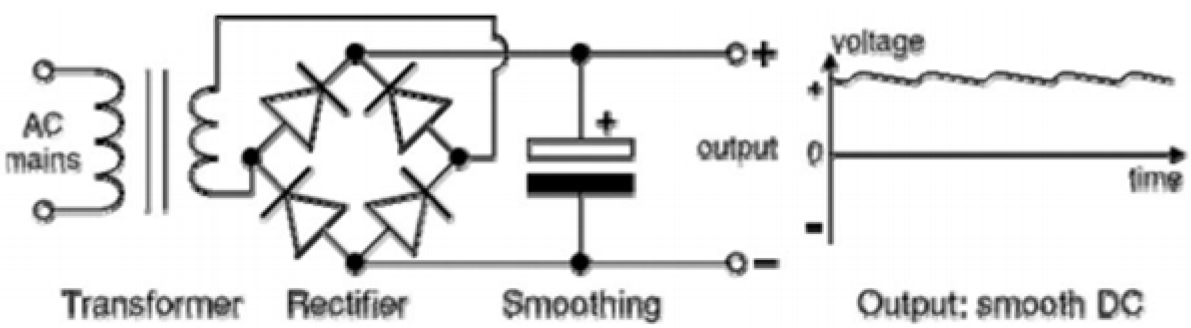


Figure 3.6 output of filter

3.2.5 IC Regulator

An IC regulator is an electrical regulator designed to automatically maintain a constant voltage level. A voltage regulator may be a simple “feed-forward” design or may include negative feedback control loops. Negative voltage regulators are available, mainly for use in dual supplies. Voltage regulator ICs are available with fixed (typically 5, 12 and 15V) or variable output voltages. They are also rated by the maximum current they can pass.

Most regulators include some automatic protection from excessive current ('overload protection') and overheating ('thermal protection').It may use an electromechanical mechanism, or electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages.

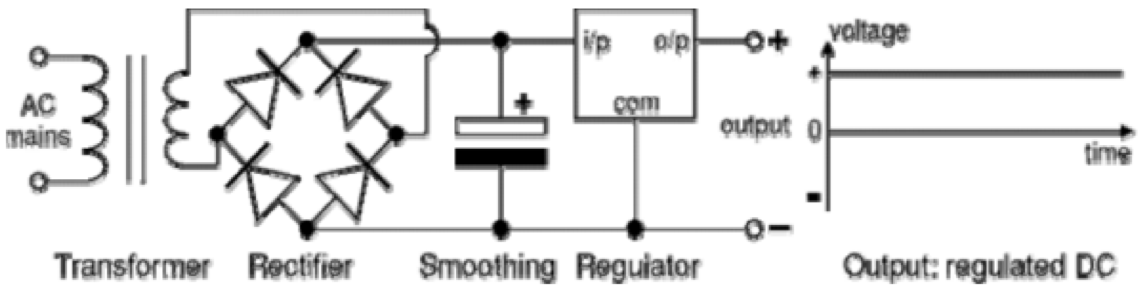


Figure 3.7 Output of IC regulators

3.2.6 The Electromagnetic Relay

The relay is an electrically controllable switch widely used in industrial controls, automobiles, and appliances. It allows the isolation of two separate sections of a system with two different voltage sources. It used to opens and closes under the control of another electrical circuit. In the original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. It was invented by Joseph Henry in 1835. Because a relay is able to control an output circuit of higher power than the input circuit, it can be considered to be, in a broad sense, a form of an electrical amplifier.

Diagram that a relay uses an electromagnet. This is a device consisting of a coil of wire wrapped around an iron core. When electricity is applied to the coil of wire it becomes magnetic, hence the term electromagnet. The A, B and C terminals are an SPDT switch controlled by the electromagnet.

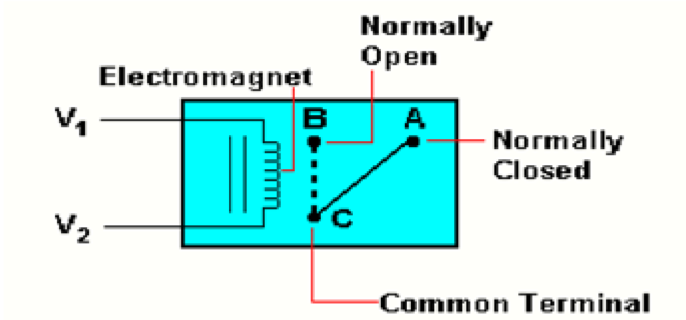


Figure 3.8 Electromagnetic relay

3.2.7 Current Transformers

Current Transformers (CT) are instrument transformers that are used to supply a reduced value of current to meters, protective relays, and other instruments. CT's provide isolation from the high voltage primary, permit grounding of the secondary for safety, and step-down the magnitude of the measured current to a value that can be safely handled by the instruments. The protection of the transformer against over current is concerned with the detection and measurement of fault, where the measurement can be dangerous and indeed impossible to measure if the actual load and fault currents are very large. A professional way of avoiding these difficulties is to use the current sensor.

The current transformer is used with its primary winding connected in series with line carrying the current to be measured and therefore the primary current is dependent upon the load connected to the system and is not determined by the load connected on the secondary winding of the current transformer . The primary winding consists of very few turns and therefore there is no appreciable voltage drop across it. The secondary winding of current transformer has large number of turns, the exact number being determined by the turn's ratio.

3.2.8 Current Transformer operation

The instrument current transformer CT steps down the current of a circuit to a lower value and is used in the same types of equipment as a potential transformer. This is done by constructing the secondary coil consisting of many turns of wire, around the primary coil, which contains only a few turns of wire. In this manner, measurements of high values of current can be obtained. A current transformer should always be short-circuited when not connected to an external load. Because the magnetic circuit of a current transformer is designed for low magnetizing current when under load, this large increase in magnetizing current will build up a large flux in the magnetic circuit and cause the transformer to act as a step-up transformer, inducing an excessively high voltage in the secondary when under no load.

The current sensor is capable of measuring up to 50A.The monitored current values are displayed on the LCD display and as soon the voltage transformer is overloaded the current transformer sends the information through the ADC and the microcontroller energizes the relay, thereby the load is shared by another transformer. Over current protection circuit An ammeter cannot be used in measuring the load current in this project because an analogue signal must be fed into the ADC of the microcontroller for monitoring the load current. A current sensor was found to be the suitable current sensing device for this purpose. The current sensor used can measure up to 50A. The ACS750 comes with one set of dean-T connector and a 3 ways right angle pin header. The ACS750 is power up with 5VDC and gives out voltage to indicate the direction and current value. The output of the current sensor is fed to Micro-controller ADC unit for taking the necessary action.

3.3 Power Transformer

Power transformers are used for conversion of voltage and current from high to low and vice versa. A transformer is a static device that transfers electrical energy from one circuit to another through inductively coupled conductors the transformer's coils. A varying current in the first or primary winding creates a varying magnetic flux in the transformer's core and thus a varying magnetic field through the secondary winding. This varying magnetic field induces a varying electromotive force (EMF) or voltage in the secondary winding. This effect is called mutual induction. If a load is connected to the secondary, an electric current primary circuit through the transformer to the load.

For transmission and distribution networks to transfer large amounts of alternating current electricity over long distances with minimum losses and least cost, different voltage levels are required in the various parts of the networks.

For example, the transfer of electricity efficiently over a long transmission line requires the use of high voltages. At the receiving end where the electricity is used, the high voltage has to be reduced to the levels required by the consumer. Transformers enable these changes in voltage to be carried out easily, cheaply and efficiently. We normally use the step down transformer that converts 15kv to 220v AC supply.

A transformer consists of two coils electrically separate but linked by a common magnetic circuit of low reluctance formed by a laminated soft iron core. If one coil (the primary coil) is connected to an AC supply, an alternating magnetic flux is set up in the iron core. This alternating magnetic flux passes through the secondary coil and induces and alternating voltage in the secondary coil. The magnitude of the secondary voltage is directly proportional to the ratio of the number of turns in the secondary and primary windings and to the primary voltage.

3.3.1 Operation of power transformer

The present system is designed by two transformers. TF1 is used as the main supply and TF2 is used as sharing transformer. They are connected with the relay which is controlled by the embedded controller. Both transformers are connected with their load through relay. Initially, the loads run with this power.

In order to connect these two transformers the following condition is satisfied:

- The voltage ratio must be the same.
- The per unit impedance of each must be the same.
- Same KVA ratings.
- Identical Position of Tap changer.
- Same Phase sequence

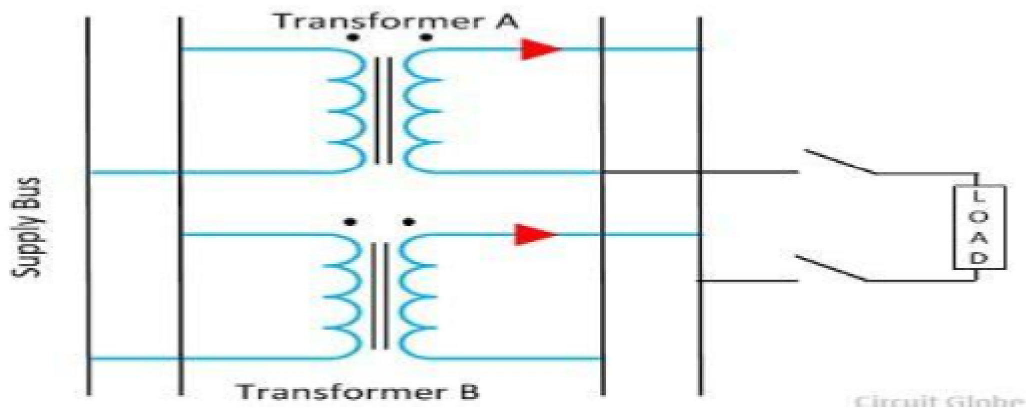


Figure 3. 9 parallel connection of transformer

Same voltage and turn ratio

If the voltage rating of primary and secondary would be different, large circulating current will
flow due to unequal EMF induced.

Same percentage impedance

A different phase angle results due to a difference in ratio of respective reactance and resistance.
Power factors of two transformers will be then different. For connecting single phase T/F's in three phase banks, we should try to match the X/R ratios of the three series impedance to keep the three phase output voltages balanced.

Same Polarity

Polarity of the T/F means the direction of induced emf in the secondary is same as primary. If
direction is different to other T/F at secondary side, then it is in opposite polarity. If opposite
polarity exist, then there will be circuiting current and produces a short circuit.

Same Phase Sequence

The phase sequence or the order in which phases reach their maximum voltage must be same for
parallel transformer. [12]

Mathematical modeling for Load sharing of two transformers

Let us consider the following two cases

Case1: Equal voltage ratios.

Case2: Unequal voltage ratios.

Case1: Equal Voltage Ratios

Assume no-load voltages EA and EB are identical and in phase. Under these conditions if the

primary and secondary are connected in parallel, there will be no circulating current between them on no load.

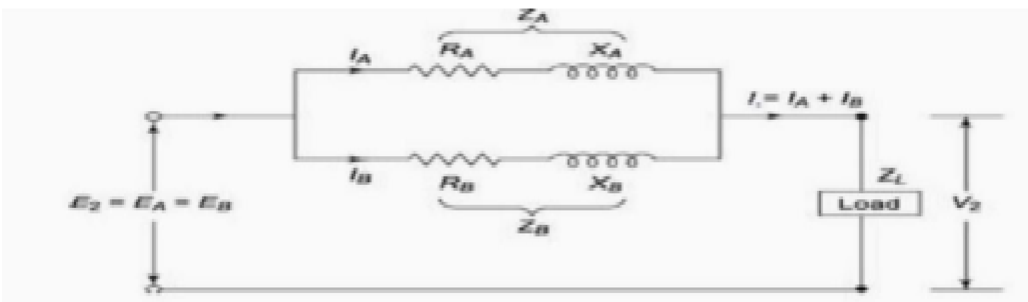


Figure 3. 10 Equivalent circuit of parallel transformer

The Figure shows two impedances in parallel. Let RA, XA and ZA be the total equivalent resistance, reactance and impedance of transformer A and RB, XB and ZB be the total equivalent

resistance, reactance and impedance of transformer B. From the Figure we have

EA =V2 +IAZ.......eq.1

EB =V2 +IBZB

IAZA =IBZB

Since they are in parallel

IA/IB =ZB/ZA

ZA = RA + XA

ZB = RB + XB

IA/IB =

(RB +XB)/(RA +XA)………………………………………………….eq.2

Suppose that if two transformers with different KVA rating are connected in parallel, the total load will be divided in proportional to their KVA rating and their equivalent impendence are inversely proportional to their respective rating.

$$IA/IB = ZB/ZA$$

$IA/IL = ZB/ZL$ by current division formula

$$IA / (IA + IB) = ZB / (ZA + ZB)$$

$$IA = IL (ZB / (ZA + ZB)) \text{ ………………………………………eq.3}$$

$$IB = IL (ZA / (ZA + ZB)) \text{ ………………………………………eq.4}$$

Substituting for ZA and ZB above by KVAA/ %ZA and KVAB/ %ZB into equations (3) and (4) Produces the following equations

$$IA = (KVAA/\%ZA)\ IL/ (KVAA/ \%ZA + KVAB/ \%ZB) \text{ ……………………eq.5}$$

$$IB = (KVAB/\%ZB) \times IL/ (KVAA/ \%ZA + KVAB/ \%ZB) \text{ …………………....eq.6}$$

Similarly, the load share of the main transformer

$$(TRA)\ SA = V2IA \times 103 \text{ KVA}$$

$$=V2I (ZB/ (ZA + ZB)) \times 103 \text{ KVA ………………………………………eq.7}$$

Therefore, the total load will be

$$S = SA + SB \text{ ………………………………………………………………eq.8}$$

$$S = VS = V^2 * 10^3 \text{ KVA ……………………………..eq.9}$$

Case 2: Unequal Voltage Ratios

For unequal voltage turns ratio, if the primary is connected to the supply, a circulating current will flow in the primary even at no load. The circulating current will be superimposed on the currents drawn by the load when the transformers share a load. Let V1 be the primary supply voltage, a1 be the turns ratio of transformer A, a2 be the turns ratio of transformer B, ZA be the equivalent impedance of transformer A (= RA + jXA) referred to as secondary, ZB be the equivalent impedance of transformer B (= RB + jXB) referred to as secondary, IA be the output current of transformer A and IB be the output current of transformer B. The induced EMF in the secondary of transformer A is

$$EA = V1/a1 = V2 + IAZA \text{ ……………………………………………….eq.10}$$

The induced EMF in the secondary of transformer B is

$$EB = V1/a2 = V2 + IBZB \text{ …………………………………………………eq.11}$$

Again, $V2 = IZL$ where ZL is the impedance of the load

$$V2 = (IA + IB)\, ZL \quad \text{……eq.12}$$

From Equations 7, 8 and 9 we have

$$EA = IAZA + (IA + IB)\, ZL \quad \text{……eq.13}$$

And

$$EB = IBZB + (IA + IB)\, ZL \quad \text{……eq.14}$$

$$EA - EB = IAZA - IBZB \quad \text{……eq.15}$$

$$IA = ((EA - EB) + IBZB)/ZA \quad \text{……eq.16}$$

Substituting IA from equation (16) in to equation (14), we have

$$EB = IBZB + ((EA - EB) + IBZB)/ZA * ZL + IBZL$$

$$IB\left(ZB + ZL + \frac{ZB}{ZA} \times ZL\right) = \frac{EBZA - (EA - EB)ZL}{ZA}$$

$$IB = (EBZA - (EA - EB)\, ZL)/ZAZB + ZL\,(ZA + ZB) \quad \text{……eq.17}$$

$$IA = (EAZB + (EA - EB)\, ZL)/\, ZAZB + ZL\,(ZA + ZB) \quad \text{……eq.18}$$

Case Study Analysis for power transformers in distribution: -

This part provides a case study for two power transformers load sharing in distribution. The following assumption parameters for each transformer are considered. [11] [12]

Case 1: Equal Impedances-Equal Voltage Ratios- Different kVA

Although it's not common practice for new installations, sometimes two Transformers with different kVA and the same percent impedances are connected to one common bus. In this situation, the current division causes each transformer to carry its rated load. There will be no circulating currents because the voltages (turn ratios) are the same. In this thesis, the capacity of the two transformers is Capacity of T1 (main transformer) = 600 - 800 kVA and each transformer to only be loaded to its kVA rating. If each transformer have equal impedance and each with the same turn ratios, since current has a direct relationship with kVA, substituting kVA for current into equation (5) and (6) above

kVA1 = KVA1 / (KVA1 +KVA2) x KVAL

kVA2 = KVA2 / (KVA1 +KVA2) x KVAL

Although it's not common practice for new installations, sometimes two Transformers with different KVAs and the same percent impedances are connected to one common bus. In this situation, the current division causes each transformer to carry its rated load. There will be no circulating currents because the voltages (turn ratios) are the same.

Let Capacity of T1= 800 kVA and capacity of T2= 600 KVA.Each transformer with 5.75% impedance and each with the same turn ratios, the total load connected to a common is 1400 kVA.

Since current has a direct relationship with kVA, substituting kVA for current into equation (5) and (6) above

kVA1 = 800 / (800 + 600) x 1400 = 800 kVA

kVA2 = 600 / (800 + 600) x1400 = 600 kVA

It can be seen in the calculations that even though there are different kVA ratings on transformers connected to one common load, that current division causes each transformer to only be loaded to its kVA rating. The key here is that the percent impedances are the same.

Case 2: Unequal Impedances-Equal Ratios-Different kVA

Transformers in industrial and commercial facilities connected to one common bus with different KVA and unequal percent impedances. However, there may be that one situation where two single ended substations may be tied together via bussing or cables to provide better voltage support when starting large motors. If the percent impedances and kVA ratings are different, care should be taken when loading these transformers.

Capacity of transformer 1
800 kVA (kVA1) with 0.571 per unit impedance
Capacity of transformer 2
600 kVA (kVA2) with 0.428 per unit impedance, each transformer with the same turn ratios,
connected to a common 1400 kVA load.
Using equations (5) and (6):

$$kVA1 = 800 / (800 + 450) \times 1400$$
$$= 896 \text{ kVA}$$
$$kVA2 = 450 / (800 + 450) \times 1400$$
$$= 504 \text{ kVA}$$

The load current carried by the combined transformers will be less than their rated kVA. As similar to —case1 because, it is overloaded with a less than combined rated load.

Case 3: Unequal Impedances-Unequal ratios- Different kVA

Although it appears highly unlikely that all of these parameters would be different in practice, we
will address this situation by looking at circulating currents. Unequal impedances equal ratios
different kVA addressed different kVA, but ignored the X/R ratios of the transformer. If both the
ratios and the impedances are different, the circulating current (because of the unequal ratio)
should be combined with each transformer's share of the load current to obtain the actual total
current in each unit. For unity power factor, 10% circulating current (due to unequal turn ratios)
results in only half percent to the total current.
At lower power factors, the circulating current will change dramatically. The effect of having
Parallel transformers with different percent impedances, along with different turn and

X/R ratios

connected to one common load.

We summarize our case study as follows:-

When paralleled transformer turn ratios and percent impedances are the same, equal load division will exist on each transformer. When paralleled transformer kVA ratings are the same, but the percent impedances are different, then unequal load division will occur. The same is true for unequal percent impedance and unequal KVA. Circulating currents only exist if the turn ratio don't match on each transformer.

3.3.2 Ardiuno UNO R3

The Ardiuno is a microcontroller based 14 digital input output pins and 6 analogue inputs, USB

connecting and a reset button. It is used to control the automatic operation this project. It is used

as main component of the project as it connects with a relay to connect the slave transformer in

parallel. [5]

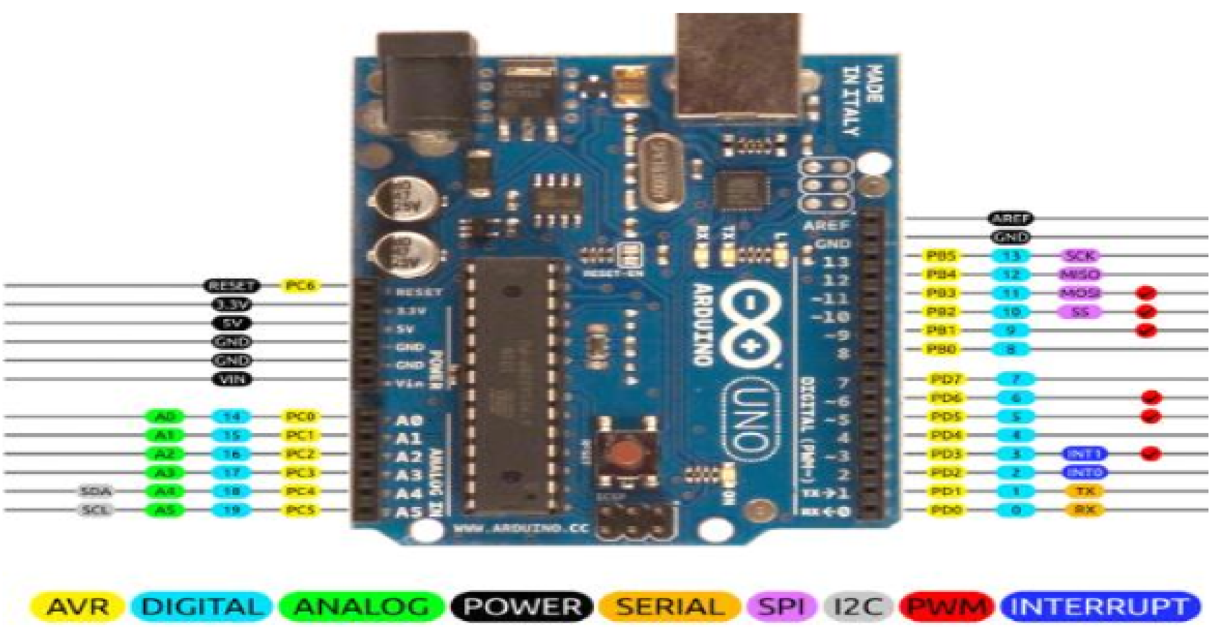


Figure 3.11 Arduino pin configuration

3.3.3 Liquid Crystal Display (LCD) Interface

The alphanumeric 16 character X2line LCD requires 8data lines and also 3 control signals. By
using 2 ports, port 0&3 data pins are connected to LCD as data bus. Port0 can be basically used as I/O port i.e. it can be programmed as an input or as an output port. That means if it is programmed as output port, suppose if it is required to read data from LCD immediately it is not possible. Before reading the data, it is required to make the port as an input port. Data reading from LCD gives an erroneous reading & should not be implemented. Because of this port5 is made as input / output
port depending on the situation. The control signals are connected to port 3 pins. They are EN bar, RS bar & RW bar. At different instance such as data write / command write / data read etc. Various signals are to be provided as indicated by the by the LCD manufacturers. To interface the LCD, to the Micro controller it requires an 8 bit and also three control signals differentiate the data from the control words send to the LCD. The Microcontroller has to send the necessary control words followed by the data to be displayed. Depending on the operation to be performed the control words are selected and passes to the LCD. The data to be displayed on the LCD is to be sent in the ASCII format. Thus, all the character to be displayed are converted into ASCII form and then sent to the LCD. [4]

LCD pin description

VDD, VSS and VEE While VCC and VCC provide +5V and ground respectively, VEE is used for controlling LCD contrast. RS, register select. There are two very important registers inside the LCD. The RS pin is used for their selection as follows. If RS=0, the instruction command code register is selected, allowing the user to send a command such as clear display, cursor at home, etc., If RS=1 the data register is selected, allowing the user to send data to be displayed on the LCD. R/W, read/write R/W input allows the user to write information to the LCD or read
information from it. R/W=1 when reading; R/W=0 when writing. EN, Enable the LCD to latch

information presented to its data pins uses the enable pin. When data is supplied to data pins, a
high-to-low pulse must be applied to this pin in order for the LCD to latch in the data present at
the data pins. The 8-bit data pins, D0-D7, are used to send information to the LCD or read the
contents of the LCD's internal registers. To display letters and numbers, we send ASCII codes for the letters A-Z, a-z, and numbers 0-9 to these pins while making RS=1.
There are also instruction command codes that can be sent to the LCD to clear the display or force the cursor to the home position or blink the instruction command codes. We also use RS=0 to chew busy flag bit to see if the LCD is ready to receive information.[4]

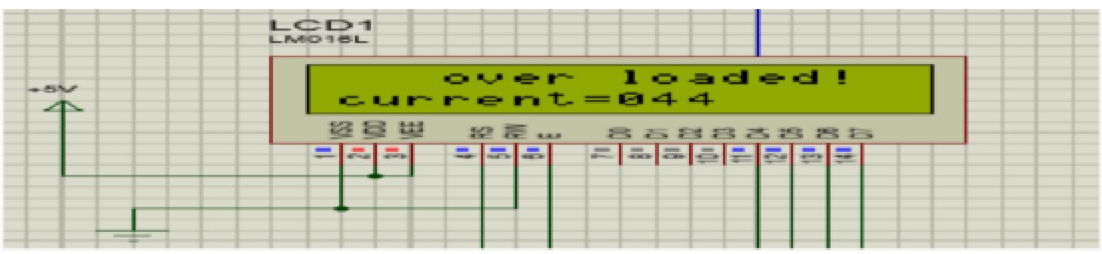


Figure 3.12 LCD display

3.4 Analog to digital converter (ADC)

Analog to Digital Converters are most widely used devices for data acquisition. Digital Computers use Binary values, but in the physical world everything is analog in nature.
A physical quantity which is analog in nature is converted to electrical signals using a device called transducers. Transducers are also referred to as sensors. Sensors produce an output that is voltage or current. Therefore we need an ADC to translate the analog signals to digital numbers so that micro-controller can read and process them. Microcontroller can only perform complex processing on digitalized signals. When signals are in digital form they are less susceptible to the
Deleterious effects of additive noise. ADC Provides a link between the analog world of transducers and the digital world of signal processing and data handling. [8]

Application of ADC

ADC is used virtually everywhere where an analog signal has to be processed, stored, or transported in digital form. Some examples of ADC usage are digital volt meters, cell phone, thermocouples, digital oscilloscope,sound processing,temperature processing. Microcontrollers commonly used 8, 10, 12, or 16 bit ADCs; our micro controller uses an 8 bit ADC. Analog-to-digital ADC converters are used to transform analog information into a form suitable for digital handling, which might involve any of these operations:

- ✓ processing by a computer or by logic circuits, including arithmetical operations, Comparison, sorting, ordering and code conversion,
- ✓ Storage until ready for further handling,
- ✓ Display in numerical or graphical form and
- ✓ Transmission

CHAPTER FOUR

SIMULATION OF DESIGNED SYTEM

4.1 Complete schematic diagram

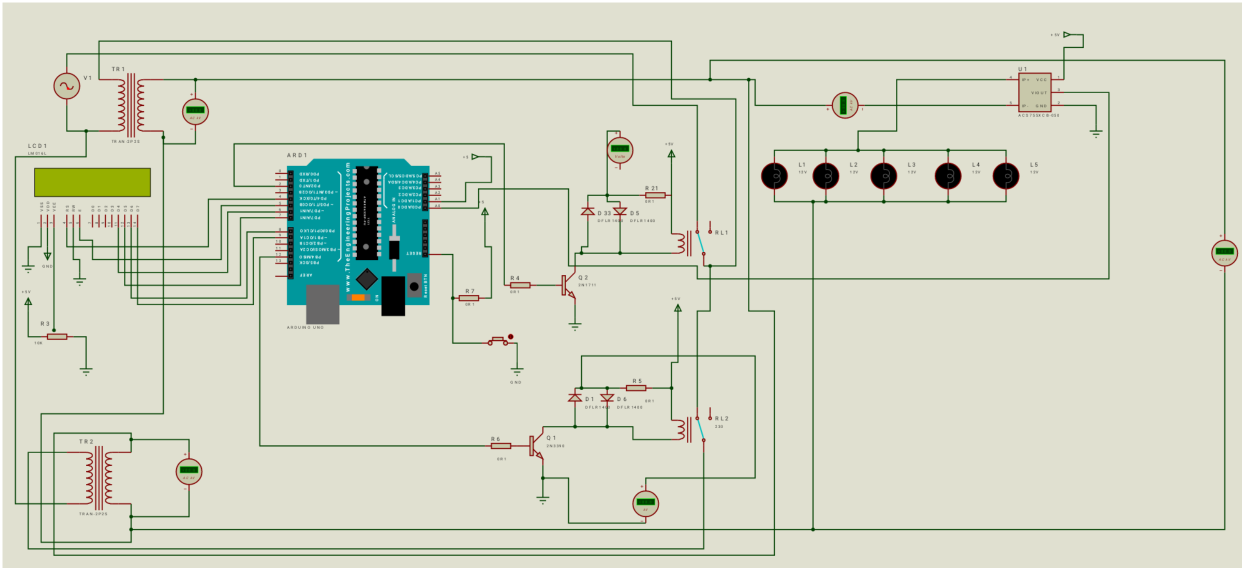


Figure 4.1 complete diagram

Automatic load sharing of power Transformers is designed with two transformers. One transformer TF1 is used as the main supply and the other transformer TF2 is used as sharing
transformer. These two transformers are connected with the relay which is controlled by the
embedded controller. The loads are connected to the main line TF1 and as well as to the TF2
through relay. Initially TF1 is connected to the load, the loads run with this power. If the load on
TF1 is increase beyond its rating then controller will find out that and it will connect the sharing
transformer parallel to the main transformer, then controller will continuously monitor the current flowing in the load and when the load current decreases below the TF1 rating it will turn Off the sharing transformer. Here we are using current transformer CT for measuring and protecting the load current, and the output of CT is given to ADC for converting analog output of CT into digital data. That ADC output is given to microcontroller for monitoring purpose. [8] ,When currents are beyond certain limit then reserval transformer is going to sharing transformer.

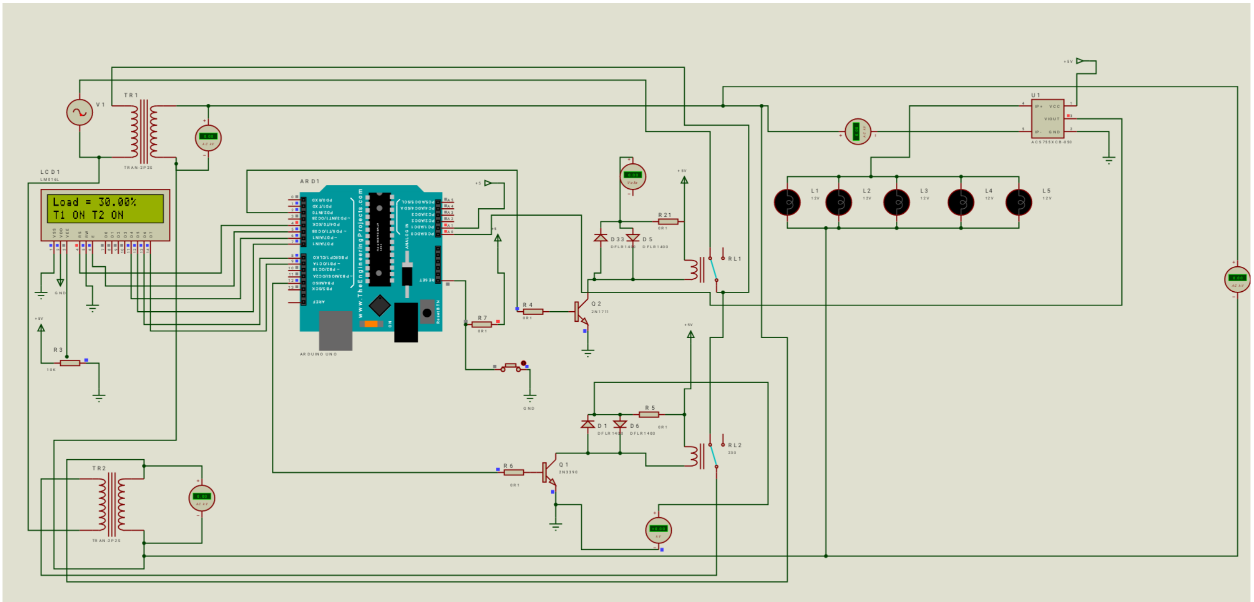


Figure 4.2 Simulation block diagram of the normal load

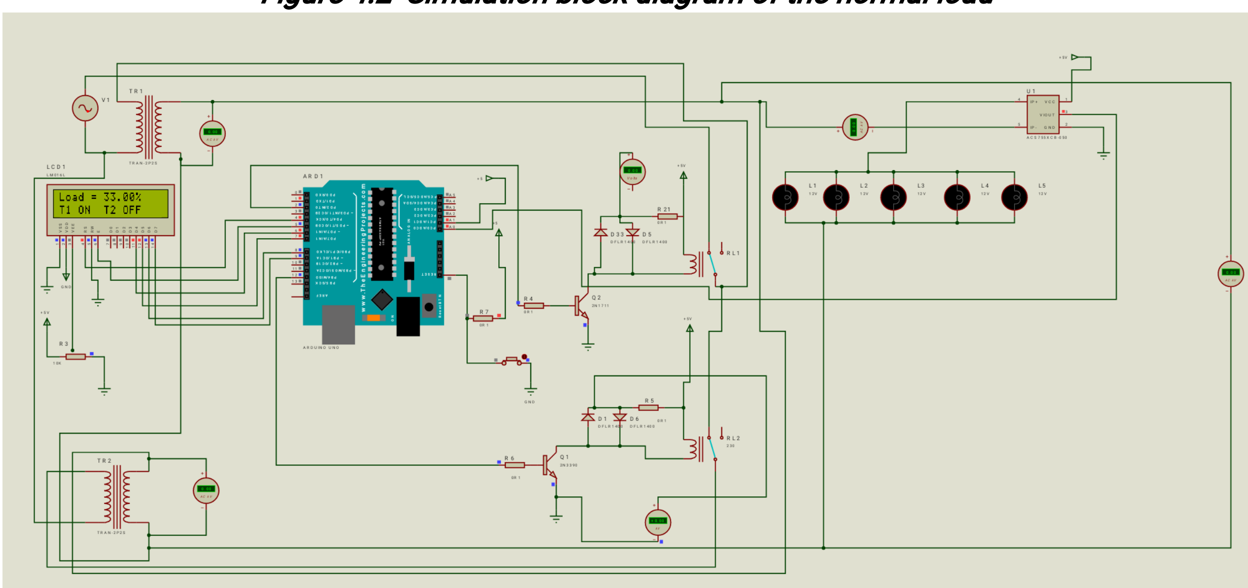


Figure 4.3 Simulation block diagram of the overload load condition

4.2 RESULT AND DISCUTION

From simulation of the designed system we get the following result. When the utility load is increased beyond the rated capacity of the transformer one (main transformer) and interrupted; then the Microcontroller detects the signal that get from the loads through current sensor. Then the microcontroller calculates the received signal compare with the reference voltage; then send signal to the relay (transfer switch). The relay connect transformer two to share the overload power. However, when the utility load became below rated value of transformer one microcontroller send signal to disconnect transformer two and the load is run only by transformer one.

1. When utility power is interrupted due to over current and overload, the transfers switch
senses and starts up the transformer TF2 which acts as a backup transformer.
2. If the utility power remains absent, the transfer switch disconnects the load from the utility and connects it to the Transformer TF1.
3. The transfer switch continues to monitor utility power, and when it is restored, switches the
load from the Transformer TF2 back to the Main transformer TF1. Once the Transformer TF2
is disconnected, it goes through a cool-down routine and is automatically shut down.
4. Initially TF1 is connected to the load, the loads run with this power. Due to any reason this
power is interrupted, then it is identified by the controller and it immediately switches ON to
the TF2 through the relay.
5. The result is displayed on LCD.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The thesis describes about how to use power supply intelligently under peak loads. The designed system automatically connects and disconnects the sharing transformer thus protecting the main transformer from overload.Current transformer plays an important role by sensing the current,through the load and sending feedback signal to the microcontroller through ADC. Microcontroller is so programmed that as soon as the load exceeds a particular current limit it will soon generate a control signals and the signal is fed to the electromagnetic relay. The switching process occurs in the Electromagnetic Relay which automatically connects the transformer in parallel in accordance to the load sensed by the CT. Through the transformer current analysis, we can see that the current of the transformer rises as load increases, whenever
the load current goes above the transformer rated current, and the microcontroller detects an over current and it sends a trip signal to relay thereby the load shared automatically by transformer two and protecting the transformer one from damage. As the load current goes below the rated current of the transformer, the microcontroller detects normal there by sending an on signal to the relay to disconnect the sharing transformer. The results indicate that the microcontroller based transformer automatic load sharing achieves numerous advantages over the existing systems in use: 1) fast response, 2) better isolation.Finally, the results of simulation meet the aim and objectives of the designed system and automated with no manual interface required.

5.2 RECOMMENDATION

Any work and investigation on transformer load sharing is very advantageous and challenging.

Based on the work done in this thesis which automatic load sharing of transformer using microcontroller, some improvements need to be made in the future work. Such as use of switching semiconductor device such as thyristor can be used instead of relay, highly advanced microcontroller such as 16bit PIC microcontroller or a digital signal processor can be used for high speed analogue to digital (ADC) conversion of the transformer voltage and current. Ourproject automatically connects the transformer under critical loads.

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APPENDEX

Code

```
#include <LiquidCrystal.h>
//code developed by electrical power student
// initialize the liquid crystal library &interface LCD pin to Arduino digital pins
Liquid Crystal lcd (4, 5, 6, 7, 8, 9);
Float Load1;

int r1=2;

int r2=12;

// the setup routine runs once when you pr
void setup() {
  // initialize serial communication at 9600
  lcd.begin(16, 2);
  Serial.begin(9600);
  pinMode(r1,OUTPUT);
```

```
  pinMode(r2,OUTPUT);
}

// the loop routine runs over and over agai
void loop() {
  // read the input on analog pin 0:
int sensorValue = analogRead(A0);
  // print out the value you read:
  Serial.println(sensorValue);
  Load1=(sensorValue/100);
  lcd.setCursor(0,0);
  lcd.print("Load = ");
  lcd.print(Load1);
  lcd.print("%   ");
  delay(1);
  if(sensorValue<99)
  {
    digitalWrite(r1,HIGH);
  }
  else
  {
   digitalWrite(r1,LOW);
   // delay in between reads for stability
  }
  if(sensorValue>50)
  {
    digitalWrite(r2,HIGH);
    lcd.setCursor(0,1);
    lcd.print("T1 ON      T2 ON");
}
```

```
  else
  {
   digitalWrite(r2,LOW);
   lcd.setCursor(0,1);
   lcd.print("T1 ON     T2 OFF");//delay in between reads for stability
  }
}
```