DESIGN AND IMPLEMENTATION OF THREE PHASE APPLIANCE PROTECTOR

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05/22059EE

A THESIS SUBMITTED TO THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

OCTOBER, 2011

DEDICATION

This project is dedicated to my Uncle, Sylvester Ginika whom God used to see that I complete this first degree.

DECLARATION

I, NNOKE UCHECHUKWU FRIDAY declare that this project work was carried out by me and has never seen or heard it presented elsewhere for the award of a degree. I also hereby release the copyright to the Federal University of Technology, Minna.

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ACKNOWLEDGEMENT

Of course, my special thanks goes to the HOD and the entire crew of Electrical and Computer Engineering department of FUT Minna. They exposed me to the electrical engineering knowledge in my own opinion – the way it should be done.

Not forgetting also, is the staff of APO transmission substation Abuja. Badamosi (Late), Johnson, Samuel to mention but a few, they ensured that my I.T [Industrial Attachment] period was maximized.

Finally, my sincere greeting goes to my supervisor and my technician. They gave me all I needed to have a successful project.

ABSTRACT

This three phase appliance protector consists of majorly power supply unit, diodes arrangement that perform an OR-gate functionality, variable resistor arrangement that perform voltage setting function, microcontroller that detects when and when not to energize the relays, transistor, relay and set of relays that serves each of the phases in a 3-phase load. It does the protection in such a way that so long as the three phases at the supply of within the range of 100 – 220V, the 3-phase load gets no supply, otherwise it will have supply. From the name, its function is to protect these industrial expensive 3-phase loads from damaging and it find use majorly in industries.

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CHAPTER ONE

INTRODUCTION

1.0 PREFACE

Electric power has, arguably, equal advantageous and disadvantageous impact in man's life. This is evident in the large efforts being put in to generate it and almost commensurate, if not more, efforts also put in to curtail its disasters

Over the years, from the advent of electric power, a lot of disasters, both on consumers and their properties, have happened. This has necessitated the quest for ways out. In transmission stations, protection engineers are very few and are in utmost demand.

Numerous protection devices have been developed such as circuit breakers, isolators, relays, fuses etc. Of all these, we can still say that the problem is only reduced and not eliminated because it still occurs.

It has been shown that fuses, Miniature Circuit Breakers (MCBs), Residual Current Device (RCDs), and Residual Current Breaker with Overload protection (RCBOs) are all devices used to protect users and equipment from fault conditions in an electrical circuit by isolating the electrical supply. With fuses and MCBs, only the live feed is isolated; with RCDs and RCBOs, both the live and neutral feeds are isolated.

1.1 AIMS AND OBJECTIVES

The primary objective of this project is to design and construct a device that can prevent damages due to electrical fault in the 3-phase supply to the 3-phase load used in industries. Consequently, it helps avert the huge expenditure that would have been incurred in the event of damage to such expensive 3-phase apparatus.

1.2 METHODOLOGY

The fundamental working principle of this device is based on break and make of the connections to 3-phase loads. The device consists of the following section; power supply unit, voltage setting (potential divider) unit, control unit and switching unit.

The device is provided with three phase supply source each with a rectification circuit. It also has a LED at each phase to indicate whether there is supply or not in the respective phase. The voltage setting unit consists of two sets of 3-doides connected in parallel. The output of a set supplies the relays through a 12 v regulator while the other set supplies the programmable microcontroller IC through a 5 v relay.

The sets of diodes functions as OR-gate such that if any of the phases at the supply unit is having supply, the microcontroller will be on.

The variable resistor monitors the voltage levels at each phase to ensure that neither unbalance voltage supply nor abnormally high voltage level is fed to either the load or the microcontroller.

The microcontroller decides whether the loads get supply or not. It is programmed in such a way as to allow supply to the load only when there is balance supply in all the 3-phases.

The switching unit consists, majorly of relays. Other components are diode and transistor. The diode is connected to act as a snubber circuit. When current to the inductive load is rapidly interrupted, a large voltage spike would be produced in the reverse direction (as inductor attempt to keep current flowing in the circuit). This spike is known as induction kick. Placing the snubber diode in reverse parallel with the inductive load allows the current from the inductor through the diode rather than through the switching element, dissipating the energy stored in the induction load over the series resistance of the inductor and the (usually much smaller) resistance of the diode, (over voltage protection).

All the components used were gotten from the local market. With the help of my friends and my technician, it was ensured that the circuit worked both on the breadboard and on the veroboard.

As should be expected, this work is not without steps which this recipe surely spared no detail. This process involves conceptualization, research through economy to the actual design.

1.2.1 Conceptualization

It is against the backdrop of massive global growth in the world of technology that the expediency of joining the rest of the world, by the technologically handicapped nations, became salient. The inconveniency, which is the aftermath of the event in which expensive three phase appliances get impaired for avoidable cause, necessitated the project concept.

1.2.2 Research

As would always be the case for project of this nature, at this point, consultation of the various sources of information such as more experienced persons in the field, journals, internet etc were carried out. All with the sole aim of obtaining the necessary theories that would be of help to the achievement of the goal.

1.2.3 Economy

Just as the name implies, at this phase, the greatest concern is how to achieve the desired goal with the least possible cost. This is very important since we have witnessed projects being brought to a halt due to the financial involvement that could not be met.

Also, the intention is to come up with something that is affordable to at least a reasonable category of the people. This can be pictured from the few and cheap components used which translated into cheap device.

1.2.4 Design

At this phase, all can be said to be set. It began with the computer simulation where the components are assembled and test-run in a computer system.

This is to eliminate try and error method and mistake during the actual construction. The specific components are looked up from the data sheet.

Bread board follows for more assurance, then comes the final stage which is soldering on the veroboard. The type of casing is also put into consideration here.

It was ensured that the casing provided necessary protection for the circuit and at the same time possess an appealing and easy – to use quality. It could be visualized from the light, colourful plastic used.

The only limitation of this project is that it can work with maximum load current of 30A. For loads of high current, it is advisable to go for contactors instead of relays.

CHAPTER TWO

LITERATURE REVIEW

2.0 ELECTRICITY – HISTORICAL BACKGROUND

If some negatively – charged electrons are removed from the atoms of a body, it is left with a preponderance of positive charge. Then it is said to be positively charged. If, on the other hand, some electrons are added to it, then negative charge out-balances the positive charge and the body is said to be negatively charged.

In brief, we can say that positive electrification of a body results from a deficiency of electrons, whereas negative electrification results from an excess of electrons.

The total deficiency or excess of electrons in a body is known as its charge [II].

Electricity is a general term encompassing a variety of phenomena resulting from the pressure and flow of electric charge. These includes [21] many easily recognizable phenomena, such as lighting, static electrical current in electrical wires. In addition, electricity encompasses less familiar concepts such as the electromagnetic field and electromagnetic induction.

The word from the New Latin electric us, "amber-like", coined in the year 1600 from the Greek word ήλετρο□ (electron) meaning amber (hardened plant resin), because electrical effects were produced classically by rubbing amber.

2.1 ELECTRICAL FAULTS ON POWER SYSTEM

Electrical power systems have a dynamic and complex behavior. Different types of faults can interrupt the healthy operations of the power system. Some of the major faults include phase to phase faults and phase to ground faults and three phase faults. Other electrical faults are of no major significance but still are considered. Open circuit faults occur due to the parting of overhead line or failure operation of the circuit breakers. Interturn faults occurs due to overvoltage or insulation breakdown. Electrical faults as a result of overload is due to the pressing current through the conductor which is above the permissible values and faults due to real power deficit occurs due to mismatch in the power generated and consumed and results in the frequency deviation and collapse of grid.

2.1.1 Phase Faults

Electrical phase faults are categorized as:

- Phase to ground faults
- Phase to phase faults
- Phase to phase to ground faults
- Three phase fault.

a) Phase to ground fault.

In this type of electrical fault, the entire three sequence component (positive, negative and zero components) are present and are equal to each other. In the case of isolated neutral connection to the generator, there will be no return path for the current. So, for such fault, fault current is zero.

b) Phase to Phase Faults

These are unsymmetrical currents (current differ in magnitude and phase in the three phases of power system). In case of phase to phase fault, positive and negative sequence component of current are present, they are equal in magnitude but position in phase zero sequence components are absent.

c) Phase – Phase to ground faults

These faults are of unsymmetrical nature. In this type of faults negative and zero sequence faults are in opposition with positive sequence component.

d) Three Phase faults

This type of faults are called symmetrical fault. This type of fault occurs very rarely but more severe compared to other faults. In this fault, negative component current is absent and [8] positive currents are present.

In summary,

a. Positive sequence current is present in all [5] types of faults

b. Negative sequence currents are present in all unsymmetrical faults.

c. Zero sequence currents are present when the neutral of the system is grounded and the fault also involves the ground, and magnitude of the neutral currents is equal to $3I_o$, where

I_o = neutral sequence current

2.1.2 Open Circuit Faults

Open circuit faults occur either by over head line parting or pole of the circuit breaker not fully closing. This results in load imbalance on generator and motors leading to negative phase sequence component in the stator currents. This negative phase sequence component current rotate at twice the supply frequency in the opposite direction in relation to the rotor and causes additional Eddy current losses, [6] results in temperature rise in the rotor.

2.1.3 Interturn Faults

Inter turn faults occur in machines i.e. transformers, motors and generators. An interturn fault occurs due to the insulation breakdown between the turns of the same phase or between parallel windings belonging to the same phase of the machine. The cause of the interturn fault is usually an over voltage or mechanical damage of the insulation.

Interturn faults are more sever on large alternators, high voltage motors and often experienced in rotating machines where multiple windings are present in the same groove. For large generators generally single winding rod per groove is designed. In such cases, interturn faults can occur only in the winding head region.

Interturn faults can occur at both stator and rotor for rotating machines like generators and motors.

When an inter turn fault occurs on stator of a rotating machine, there is a high probability that such [5] fault can lead into the ground fault.

2.1.4 Overload

Faults due to overload will occur due to exceeding the maximum permissible load current throughout the windings, cables or transmission lines or due to reduction in the cooling offered to the windings.

Electrical conductions are designed in such a manner that the conductors allows permissible amount of current without getting over-heated. In this manner, the current carrying rating of the conductor is decided when the current passed through the conductor is above permissible level, no immediate damage occurs but over a period of time, conductor insulation will be damaged due to the excess heat generated [4]

In large generators and power transformers of large MW ratings, the heat generated is enormous, so forced cooling is provided in such cases. For larger generators, Hydrogen cooling is provided and for large transformers, forced cooling is provided.

2.1.5 Real Power Deficit:

Under normal operation, the power generated by the generators is equal to the load connected and the losses in the power system. Real power is the part of the power which does useful work - the power absorbed by the load of the power system.

Real power deficit occurs when the [16] supply is less than the demand or loss of generating unit in the grid.

When real power deficit occurs, the frequency level in the grid start falling down. The rate of falling of the frequency depends on the magnitude of the deficit in real power. In this case, primary frequency control is carried by the generators connected to the grid. Governor mechanism connected to the turbine will try to drive the turbine with rated speed by accepting more fuel. In this manner, little frequency deviation (real power deficit) is managed. In case [8] of still frequency falling down scenario, spinning reserves available at the plant will start delivering power to the grid within few seconds of frequency collapse (mainly gas turbine plants and Hydel plants). If still, the demand and supply gap is not taken care of, then load shedding will follow in the grid by shedding the load of one part of that power system to maintain the relation between the supplies of real power.

2.2 ELECTRICAL LOAD PROTECTION

Presently, there exist many types of electrical load protection devices designed to protect an electrical apparatus from over voltage and under voltage conditions. More particularly, U.S Pat. No 3, 657, 603 disclose an electrical load protection device connected to a switching relay which disconnects the supply voltage to the electrical apparatus when the line voltage is either below a bottom limit for a definite length of time or above a top limit. The device then automatically reconnects the line voltage to the electrical apparatus a predetermined time after the supply voltage returns to a value between the predetermined top and bottom limits. U.S. Pat. No. 4, 584, 623 discloses another electrical load protection device which provides for a selection of normal voltage which then determines the actual minimum and maximum pressure threshold voltages. This device also includes a delay circuit for delaying [17] the reconnection of supply voltage to the electrical load for a period of time after the supply voltage returns to a normal level.

More voltage [9] protection devices particularly adaptable for D.C. operation are disclosed in U.S Pat. Nos. 3, 590, 325; 3, 341, 748; 3, 679, 964 and 3, 800, 198.

Each of the [10] load protection devices disclosed in the above referenced patents are operable in conjunction with only single phase supply voltages. Such devices are not capable of determining when such phases have been improperly connected to the electrical load.

2.2.1 Fuses

A fuse is a very basic protection device which is destroyed (i.e. it blows) and breaks the circuit should the current exceeds the rating of the fuse. Once the fuse has blown, it needs to be replaced.

In other equipments, the fuse may just be a length of appropriate fuse wire fixed between two terminals (normally screw terminals). These are becoming scarce as electrical installations are updated – the presence of such fuses usually indicates that it is about time the installation is updated.

Modern fuses are generally incorporated within sealed ceramic cylindrical body (or cartridge) and the whole cartridge needs to be replaced.

Cartridge fuses are used in older type consumer unit, fused socket, fused plugs etc

2.2.2 Miniature Circuit Breakers (MCB)

An MCB is a modern alternative to fuses used in consumer units (Fuse Boxes). They are just like switch which switches off when an overload is detected in the circuit. The advantage of MCBs over fuses is that if they trip, they can be reset. They also offer more precise tripping value.

2.2.3 Residual Current Device (RCD)

Modern alternative better than Earth Leakage Circuit Breakers (ELCB), and fuses in the consumer unit – RCDs – are tripped if they detect a small current imbalance between the live and neutral wires above the trip value. This is typically 30mA.

RCDs can be wired to protect single or a number of circuits. The advantage of protecting individual circuits is that if the circuit trips, it will not shut down the whole house, just the protected circuit.

RCDs are available in at least 4 basic configurations viz;

1. Hard Wired Unit, where both the inputs and outputs are wired into the unit. It's ideal for a workshop etc where all the sockets within can be protected.

   Each individual circuit taken from the RCD is protected by an MCB of an appropriate value.

2. As protected outlets – normally a protected socket can be fitted as a direct replacement for a standard, non-protected outlet socket.
3. As a plug-in unit which can convert any socket into a protected circuit – this gives good flexibility as for instance, a lawn mower at different times. However, as the individual appliance could still be plugged into an unprotected socket, you need to remember to fit the RCD.

4. As a plug for wiring on to the lead of an individual appliance, this does make it less flexible than the plug- in unit above, but it does ensure that the piece of equipment is always protected.

   One usually use to fit it to the end of an extension cable, then whatever you plug into the extension lead is protected.

2.2.4 Residual Current Breaker with Overload Protection (RCBO)

An RCBOs combine the functions of an MCB and an RCD in one unit. They are used to protect a particular circuit instead of having a single RCD for a whole building. Generally, these are used more often in commercial building than domestic ones.

This is a tip of an iceberg as regards to the efforts being put in place to minimize electric power disasters.

Therefore, the following protection devices have been developed to overcome some the short comings of the aforementioned once.

1. A three phase electrical load device for monitoring three phase supply mains connected to an electrical load apparatus which disconnects the electrical load apparatus from supply mains if any phase of the mains fall outside predefined over or under voltage.
2. Three phase electrical load protection device which monitors the three phase supply mains to prevent voltage from being supplied to the electrical load when the direction of such phase rotation is improper.
3. Three phase electrical load protection device including means for automatically restoring the three phase supply and means for a different predetermined delay after disconnecting

and a predetermined time after the mains is restored to prevent the electrical load from being cycled too rapidly, and so on.

2.3 THEORETICAL BACKGROUND

The three phase electrical appliance protector consists of austere, cheap, easy to use and efficient components viz;

- Step down transformer (not centre tapped)
- Capacitor
- Diode (point contact diode and LED)
- Regulator (12V and 5V)
- Micro processor (DIP) –Dual-in-Package.
- Resistors (Fixed and variable resistors)
- Transistor (PNP)
- Relays

2.3.1 Transformer

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled conductors – the transformer coils. A varying current in the primary winding creates a varying magnetic flux in the transformer's core and thus varying magnetic field through the secondary winding. This varying magnetic field induces a varying electromagnetic force (e.m.f.) or 'voltage', in the secondary winding. [18][11][14] This effect is called mutual inductance.

Since the transformer used is not center tapped, a bridge rectifier is used to rectify its secondary voltage. It steps down a 220v to 15v

2.3.2 Capacitor

A capacitor essentially consists of two conducting surfaces separated by a layer of an insulating medium called dielectric. The conducting surfaces may be in the form of either circular (or rectangular) plate or of spherical or cylindrical shape. The purpose of a capacitor is to store electrical energy by electrostatic stress in the dielectric.

For the purpose of this project, an electrolytic capacitor is used for filtering purpose at the power supply unit. The pulsating nature of the output voltage produced by the rectifier circuit is not suitable for most electronic circuits.

A simple way to reduce the variation of the output voltage is by means of filtering. Filtering is usually accomplished by placing large electrolytic capacitor across the power supply output. This will smoothen out the ripples, though not all.

2.3.3 Regulator

Usually, capacitor filtering may be sufficient for some applications, however, there are other applications where even a small amount of ripples can [14] be troublesome. The voltage regulator ICs of different values are for the purpose of removing such troublesome ripples.

Voltage regulator ICs used are positive regulators and are characterized by three terminals; the input, the output and the common terminal.

2.3.4 Diodes

Diodes allow electricity to flow in only one direction. Diodes are the electrical version of a valve and early diodes were actually called valves.

The diodes in the device or circuit are used for various purposes. For instance the diodes involved in the bridge circuit are used for rectification, the two sets of three point contact diodes, used in this project, connected in parallel, function as an OR-gate, the light emitting diodes, LED, are used to indicate whether a phase is having supply or not while the diode connected in the reverse position with the relay functions as a snubber.

2.3.5 Microcontroller

A microcontroller (sometimes abbreviated as μC, UC and MCU) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Programmed memory, in form of NOR flash or OTP ROM, is also often included on chip, as well as a typically small amount of RAM. Micro controllers are designed for embedded applications in contrast to micro-processors used in personal computers or other general purpose application.

The micro controller used in this circuit is 40 pins DIP – dual in – line package – used to control the operation of the relays.

2.3.6 Resistors

Like [11][18] capacitors and inductors, resistors are passive components. It comes in different forms and of varied type e.g.

- Fixed resistor
- Variable resistor
- Thermistor
- Light dependent resistor, LDR

Only fixed and variable resistors were put to use in this circuit.

The fixed resistors [1] functions as a current limiting component. It limits the current that enters delicate components like LEDs and transistors.

The variable resistor [4] functions as a voltage setter. It monitors the voltages at each phase to ensure that the only balanced 3 phase supply is applied to the 3 phase device.

2.3.7 Transistors

A transistor is a semi conductor device used to amplify and switch electronic signals. It is composed of semi conductor materials with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of [16] the terminals of the transistor changes the current flowing through another pair of terminals.

The transistor used is for triggering or switching. It triggers the relays to operate.

2.3.8 Relays

A relay is an electrical switch. Many relays use [4] an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

The relays used here [6] connects the output of the circuit to the 3 – phase appliances.

2.3.9 Limitation

The challenge recorded here is the fact that the device can put up with loads of up to 30A, but for load of higher load current, a contactor may be used. Also, protection of the device against high voltage input –say 250v and above- can be included.

CHAPTER THREE

DESIGN AND IMPLEMENTATION

3.0 CIRCUIT DESIGN ANALYSIS

The three phase load protector is broken down into five modules, viz;

1. Power supply unit (PSU)
2. Voltage Setting Unit
3. Control Unit
4. Switching Unit

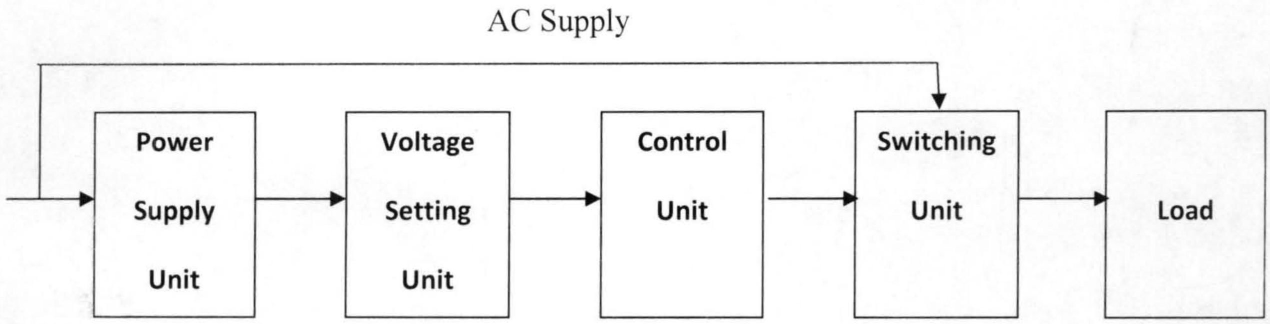

Fig. 3.0 Block Diagram of the Circuit

3.1 POWER SUPPLY UNIT

Of course, the source of power could either be 3-phase supply from mains or from a 3-phase generator (alternator). The three phases are usually yellow, red and blue in that order. Each phase has its own rectification circuit which is subsequently x-rayed.

It consists of transformer, full wave rectifier, capacitor and regulators. The rectification circuit of each phase has an LED which indicates whether there is a supply in the phase or not and a set of diodes that tied the output of each phase to a regulator.

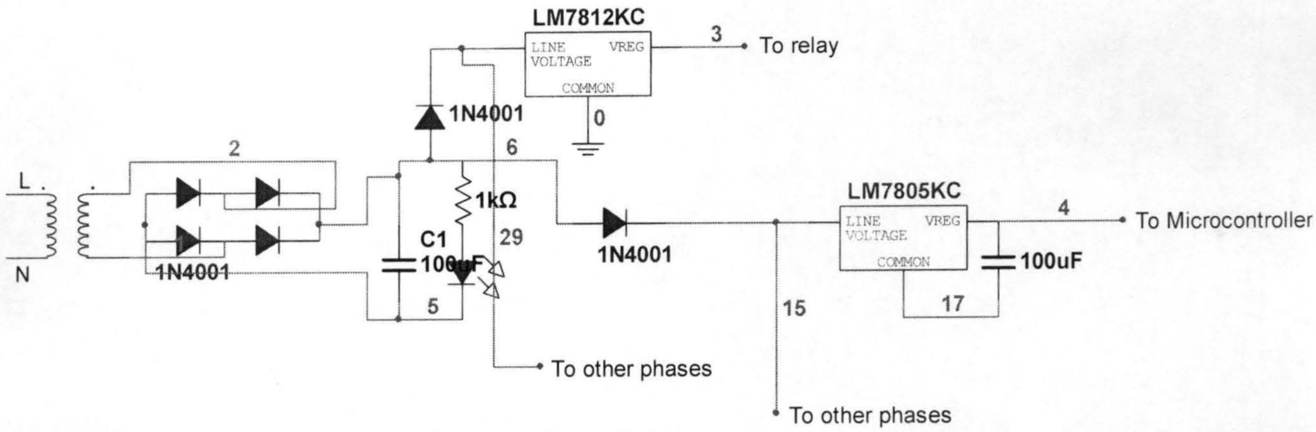

Figure 3.1 Power supply circuit diagram

3.1.1 Transformer

Since the maximum d.c voltage required is 12V, it becomes ideal to select a 220/15V, 1000mA step down, non center tapped transformer which help to step down the 220V from the mains (or otherwise) to 15V at its secondary.

3.1.2 Bridge Rectifier

This consists of four 1N4001 rectifying diodes. Bridge rectifier is used since the transformer is not center tapped. The equations governing the output voltage from a bridge rectifier is given below:

$$\mathbf{V_{Peak} = Vrms \times \sqrt{2} - 1.4} \qquad \text{---- 3.1.1}$$

Where V_{peak} = Voltage amplitude

V_{rms} = Effective or Root Mean Square voltage value

Each diode has a voltage drop of 0.7V. At any instant, two of the diodes functions. Total voltage drop from two of such diodes is 1.4v. Hence we have minus 1.4

$$\mathbf{V_{peak} = Vrms \times \sqrt{2} - 1.4}$$

$$= 15 \times \sqrt{2} - 1.4$$

$$= 19.8v$$

This value is fed to the filtering capacitor.

3.1.3 Filtering Capacitor

A 1000μF, 50V electrolytic capacitor is used. It has a tolerance range of ±20% and working voltage of range of 6V – 600V with a moderate leakage current. With such large value, it means less ripple voltage across it, [14] less heat and consequently, longer lifespan.

The following formula is used to calculate value for the filtering capacitor.

$$\mathbf{C} = \frac{5i}{Vpf} \quad \text{----- 3.1.2}$$

$$V_{dc} = \frac{Vp}{1 + (\frac{1}{4FCRload})} \quad \text{----- 3.1.3}$$

Where; C = Capacitor value

Vp = Peak voltage. (Bridge output maximum voltage)

f = frequency of the AC supply

i = Load current

R_{load} = Resistance of the load presented to the rectifier

Since 0.5A flows through the capacitor,

$$C = \frac{5i}{Vpf} \qquad \text{----3.1.4}$$

$$= \frac{5 \times 0.1}{19.8 \times 59}$$

$$= \mathbf{0.0005 = 500\mu F}$$

Therefore a large value (say 1000μF) is advantageous as explained above.

3.1.4 Diode

The two different diodes used here are exclusively for different purposes.

LED, a.k.a. solid state lamp, is included in each phase to indicate whether supply is available in their respective phase. Generally, an LED will take 10 – 15mA with a voltage drop of about 2V to give a small amount of light. If a voltage greater than 2v is to be used, there must be a resistance (330Ω – 1KΩ) connected in series with the LED. For the project sake, a 1KΩ resistor, which is well within the range, is used to limit the current passing through it to avoid damage.

Also, included is a simple rectifier diode, one per phase, connected in such a way that the output of the filtering capacitor of each phase is coupled to a regulator, (12V and 5V). It is in two sets, one supplies the 12v regulator while the other supplies the 5v regulator. The idea behind this is that if at least one of the phases is having supply, the micro controller should turn on. Hence it functions as an OR-gate logic gate.

3.1.5 Regulator

The positive regulators (7812 and 7805), were used which provides 12v and 5v respectively. The 12v regulator supplies the relay and it is without a surge capacitor while 7805 supplies the MCU and it is provided with a surge capacitor of 100µF which filters out sudden surges that can show up [16] at the regulator output during power-up and power-down. The 19.8v input to the regulators is being reduced to a clean 12v and 5v dc output.

3.2 VOLTAGE SETTING UNIT

This unit comprises of a fixed and a variable resistor. This combination is made available one per phase. The combinations of the two resistors form potential divider which is used to obtain a voltage of 4.5v (max) or 3v (min) from the output of the filtering capacitor at the power supply unit. This minimum and maximum voltage values are range of voltage values that the micro-controller will accept as an input high. Anything outside this range is seen as fault and will not respond.

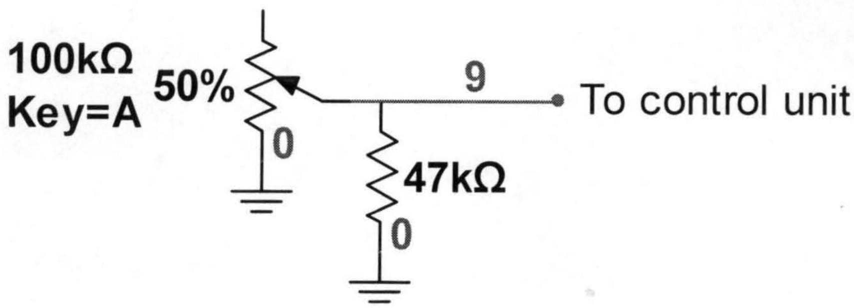

Figure 3.2 Potential divider circuit diagram

The variable resistor is 100KΩ with 50% tolerance range, while the fixed resistor is 47KΩ with 10% tolerance range. The tolerance range is the range of values within which the given resistor can serve. For instance, 100KΩ, 50% means that 50% of 100KΩ can be added to 100KΩ for maximum value or removed from 100KΩ for minimum value that it can serve.

For mains supply of 220v, an output of 15V is expected at the capacitor terminal. Therefore voltage across the 47KΩ is given as

$$V = \frac{47 \times 10^3 \times 15}{147 \times 10^3}$$

$$= 4.78V$$

For a mains supply of xV, an output of yV is expected.

The minimum high input voltage to the micro controller is 3V. For this value, the voltage at the capacitor terminal of the power supply unit is given as;

$$3 = \frac{47 \times 10^3 \times Y}{147 \times 10^3}$$

$$Y = \frac{3 \times 147 \times 10^3}{47 \times 10^3}$$

$$= 9.38V$$

220V produces 15V across the capacitor

XV produces 9.38V across the capacitor

Therefore;

$$\frac{220}{15} = \frac{\times}{9.38}$$

$$X = \frac{220 \times 9.38}{15}$$

$$= 137.57$$

$$\approx 138v$$

This is to say that the a.c mains voltage supply range for the circuit is 138 – 220V

3.3 CONTROL UNIT

The control unit is composed of a programmable microcontroller chip or IC and the characteristics crystal oscillator.

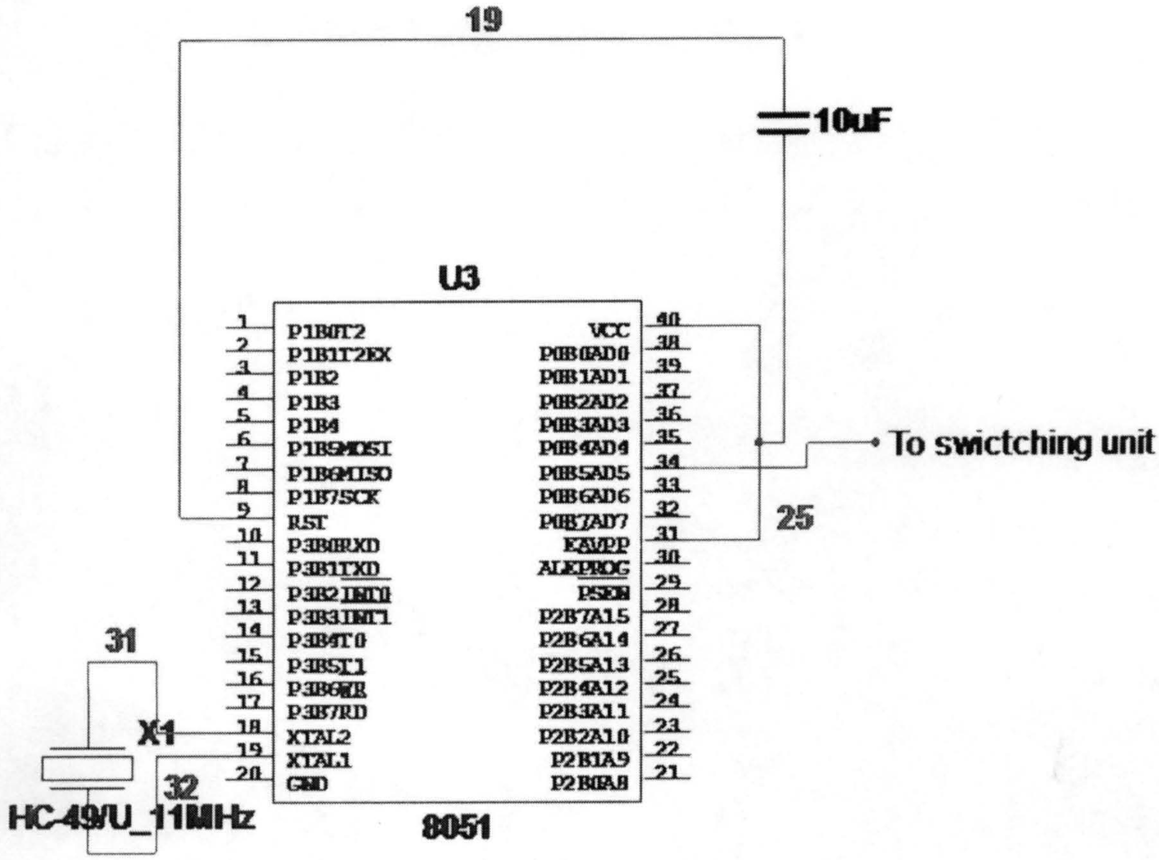

Figure 3.3 Microcontrooler circuit diagram

3.3.1 8051 Microcontroller

The 8051 microcontroller is packaged in a 40 pins DIP. It's a programmable chip, meaning that its pins are multipurpose function pins. It is a small computer on a single integrated circuit containing a processor core, memory and programmable input/output peripherals. Programmed memory in the form of NOR flash or OTP ROM is also often included on chips, as well as a typically small amount of RAM.

The 8051 micro controller allows the relay to operate through the transistor, only when it receives an input high of between 5 – 3V at its input pins (pin 21, 22 and 23) simultaneously, otherwise, the relays will not operate. Pin 40, 31 and 9 are tied to the 5v regulated supply with 10uF capacitor and filters out sudden surges that can show up on the V+ line during power up and power down. The +5V supply is the supply source of the micro-controller.

3.3.2 Crystal Control Oscillator

A crystal oscillator is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a very precise frequency. This frequency is commonly used to keep track of time, to provide a stable clock signal for digital integrated circuit, and to stabilize frequencies for radio transmitter and receiver.

The crystal oscillator used is a 12MHz. The 8051 requires the existence of an external oscillator circuit. The oscillator circuit usually runs around 12MHz, although the 8051 is capable of running at a maximum of 40MHz. Each machine cycle in the 8051 is 12 clock cycle, giving an effective cycle rate at 1MHz – for a 12MHz clock – to 3.33MHz – for the maximum 40MHz clock. The oscillator circuit generates the clock pulses so that all internal operations are synchronized. It is connected to the pin 18 and 19 of the microcontroller.

3.4 SWITCHING UNIT

This consists, majorly of relays of 12V ratings. Other components are transistor and the current limiting resistor and a protective (snubber circuit) diode.

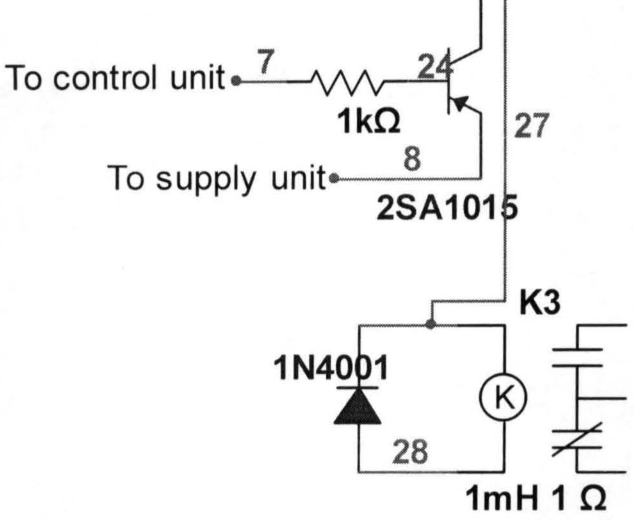

Figure 3.4 Switching circuit diagram

This circuit will activate the relay when the input goes to logic low. The protection diode is used to protect the transistor from the reverse current generated from the coil of the relay during the switch-off time. The values of the resistor and the transistors are calculated as follows;

First, the load current is calculated thus

$$I_L = \frac{V_s}{R_L} \qquad ----.3.4.1$$

The microcontroller is needed to operate a relay with a 160Ω coil. The supply voltage is 5V for the transistor. The IC supply current of 2mA

$$I_L = \frac{V_s}{R_L}$$

$$= \frac{5}{160}$$

$= \quad 0.0312$

$= \quad 31mA$

Since the transistor must have an h_{FE} greater than 5 times the load current divided by the maximum output current from the input to the base of the transistor, that is;

$$\mathbf{h_{FE}(min)} \quad > \quad \frac{5 \times I_L}{input}$$

$$\mathbf{h_{FE}(min)} \quad > \quad \frac{5 \times 31 \times 10^{-3}}{2 \times 10^{-3}}$$

$$\mathbf{h_{FE}(min)} \quad > \quad 77.5$$

So, a transistor with a gain of 200, since the maximum is 500, was chosen and $I_C = 100mA$

Now, for the R_B resistor, since the microcontroller and the transistor are using the same power supply,

$$\mathbf{R_B = 0.2 \times RL \times h_{FE}}$$

$= 0.2 \times 160 \times 77.5$

$= 2480$

An approximate close standard value of 2KΩ was used.

The power develop in a switching transistor is very small. In the off state,

Power = $\mathbf{I_C \times V_{CE}}$

But $I_C = 0$, so the power is zero.

In the full ON state,

Power = $\mathbf{I_C \times V_{CE}}$

But $V_{CE} = 0$ (almost), so the power is very small. This means that the transistor should not become hot when in use and you do not need to consider its maximum power rating.

3.4.1 Relay Switches

A relay switch is normal used for switching heavy loads in A.C. The load rating depends on the current specification of the device. The type in this circuit is rated 12v and 10A. Therefore, if the voltage involved in switching is 220A.C, the maximum power developed is around 2KW

The 10A/28VDC, 5A/220VAC, DC 12v relay is designated as a form C contact SPDT. That is single pole double throw with five pins in all. The first relay switches the other three which are connected in parallel from where each phase of the three phase load is fed.

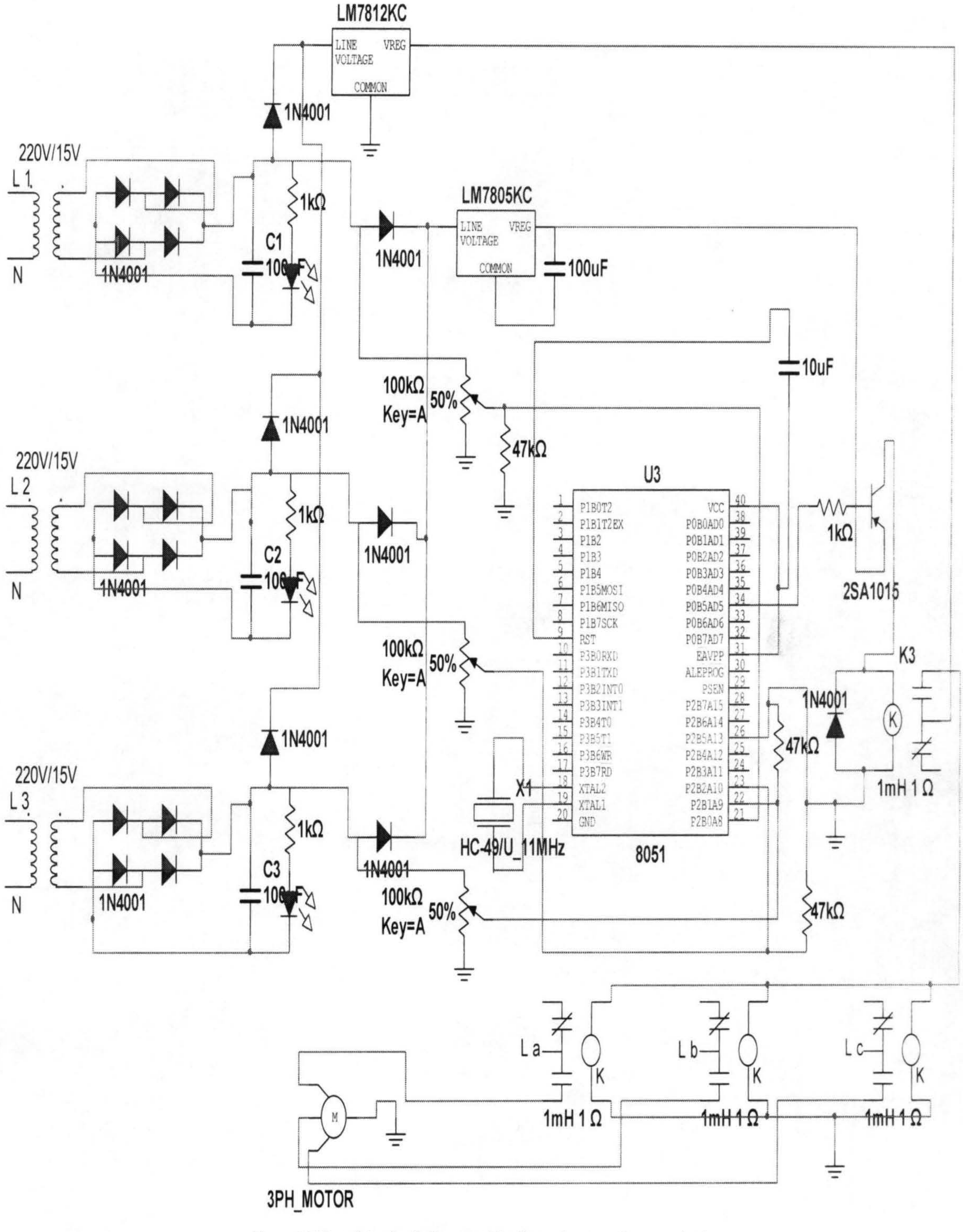

Figure 3.5 Complete circuit diagram of the three phase appliance protector

CHAPTER FOUR

TEST AND RESULT OF DISCUSSION

4.1 TEST

Aside minor tests like test for the normally open terminal of the relays and continuity tests, major tests were carried out on each unit of the project work. These were to ensure that there are no much (if at all) deviations between the technical report and the obtainable condition of the work. The exercise was carried out as follows;

Of course, with the necessary connections and wiring in place, the output of the power supply unit was carried out. This was carried out with a volt meter at the terminals of the filtering capacitor. This would have been carried out in all the phases but a test on a phase sufficed.

Also the voltage setting unit was tested. This likewise, was done with a voltmeter for various supply cases such as under voltage, normal voltage, no supply and varied voltage levels in different phases. The voltage obtained at the potential divider of the voltage setting unit was fed to the micro controller. The voltage was measured across the 100KΩ resistor and between the terminal of the 47KΩ resistor and ground.

The third test was carried out on the control unit. The main aim of the test on this unit is to know the voltage at the supply to the IC (pin 40 and 31) as well as the voltages at the phase terminals (pin 21, 22 and 23) and also the current at the input and the output terminals.

The last test was on the switching unit. The major test here was on the transistor and it is on collector current, Ic, and the output voltage V_{CE}. The parameters help to determine the saturation and the cut-off points of the switching transistor.

4.2 RESULT AND DISCUSSION

When the power unit was tested, the output voltage at the capacitor terminals was 13.6v. The drop was due to the bridge rectifier diode drop. The voltage was enough for the 12v and 5v regulators to work with. When the voltage setting unit was tested, the following were the outcomes:

With a supply voltage of 220v, it was stepped down to 15v and the potential divider helped to obtain a voltage of 4.78v

With mains input voltage of 140v, it was stepped down to 9.4v and the potential divider brought it down to 3v while a supply of 130v produced a voltage of 2.9v at the potential divider terminals. The values are tabulated as follows;

Table 4.1: Measured Value of Mains supply and the corresponding stepped down and potential divider values

Mains supply (Volt)	Stepped down value (volt)	Potential divider value (volt)
220	15	4.8
140	9.4	3
130	8.9	2.9
0	0	0

This ensured that a safe voltage for the micro-collector was possible.

The result of the tests at the control unit was tabulated as below

Table 4.2: Mains Supply and Corresponding Micro-Controller Response

Mains Supply (V)	Stepped down Value (V)	Input voltage (V)	Output Yes or No
220	15	4.8	Yes
140	9.4	3	Yes
130	8.9	2.9	Yes
100	6.8	2.9	Yes
0	0	0	No

The above table shows the responses of the microcontroller. It is seen that the IC produce output when the voltages on the phases within the range of 100 – 220V are applied. Over voltage will damage the device, while under voltage and no voltage in any or all the phase(s) were treated the same i.e no output from the microcontroller. This ensures that none of the coils of the three phase appliance were subjected to damage.

The supply voltage at the pin 40 and 31 from the 5v regulator was found to be 4.95v while the output voltage was 4.5v from pin 34

The last test which is on the switching unit was carried out to know the values at which the transistor operates the relays. The collector current, Ic, is 400mA which is greater than load current, I_L. This ensured that the load would be sufficiently supplied as long as there is output from the microcontroller.

The only cause for troubleshooting was at breadboard stage where a low voltage appeared at the potential divider terminal. It was remedied by changing a 30KΩ resistor with a 47KΩ resistor.

The shortcomings with this project work may be pictured from the power supply unit. A switching regulator power supply is more efficient than the classical power supplies. It limits wasted power by applying power to the load circuit only when necessary to prevent the load voltage from dropping below the preset time.

CHAPTER FIVE

CONCLUSIONS

5.0 SUMMARY OF RESULT AND PROBLEMS

At the end of design, constructions and troubleshooting of the 3 – phase – device protector, the results obtained are approximately equal to the expected value. The deviations could be either due to malfunctioning components or components that are not suited for the applications they were used for.

5.1 POSSIBLE IMPROVEMENT

For more comfortable and efficient use o f this device, more functions could be assigned to the microcontroller, making the components fewer and a less expensive device.

Also, the relay could be done away with and transistor used to turn – on the device. This could be achieved by using a lower current transistor switch to drive a transistor switch used in a high current application in a Darlington pair arrangement.

5.2 RECOMMENDATIONS

Since this device is a 3 – phase load protector, it should be used in factories or any other large commercial settings where three phase loads like 3 – phase motor, 3 – phase pumps, 3 – phase fan, compressors, conveyor drives etc are mostly used.

Since most home appliances are single phase, it may not be of any domestic use.

```
#include <reg52.h>

sbit phase_one      = P1^0;
sbit phase_two      = P1^1;
sbit phase_three     = P1^2;
sbit three_ph_load   = P2^0;
void main()
        {
          three_ph_load = 0;
                phase_one  = 0;
                phase_two  = 0;
                phase_three = 0;
                for(;;)
                  {
                        if(phase_one == 1 && phase_two == 1 && phase_three == 1)
                                {
                                        three_ph_load = 1;
                                }
                             else
                               {
                                  three_ph_load = 0;
                                }
                   }
        }
```

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