DESIGN AND CONSTRUCTION OF A MICROCONTROLLER DRIVEN 3-PHASE AUTOMATIC PHASE CHANGER WITH ACTIVE PHASE DISPLAY

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2003/15483EE

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A THESIS SUBMITTED TO THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING DEGREE IN ELECTRICAL AND COMPUTER ENGINEERING.

NOVEMBER 2008

DEDICATION

I am dedicating this project to my family the Shittus. Thank you for your continuous support and understanding

DECLARATION

I Shittu Zumu-Ngaih declare that this work was done by me and has never been presented anywhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna.

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(Signature and Date)

AKNOWLEDGEMENT

I give thanks to the Almighty for life and the opportunity to live.

I am expressing my gratitude to my Family The Shittus for their continuous support.

I will also like to express my gratitude to the HOD and members of staff of the department for their continuous impartation of wisdom and Knowledge.

I thank my colleagues and friends for their guidance, support and cooperation.

Thank you

ABSTRACT

The project is a microcontroller driven 3-phase automatic phase changer with an active phase display. It is a one of three cold parallel redundant system used to create a back up supply for houses electric power by utilizing a three phase supply.

The project includes an 89C51 microcontroller to coordinate the automatic switching between phases and a display that indicates the active phase and also if all the phases have failed.

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CHAPTER ONE: INTRODUCTION

1.1 EXPOSITION.

Nothing a human being ever conceived and created is perfect and without need for improvement. In electrical power supply, like every other area of human endeavor, constant attempts have always been made to improve reliability and availability. The use of inverters, automatic and standby generator and UPS (uninterrupted power supply) systems are examples of systems aimed at such improvements. A not too obvious system employed by homes and business premises is the installation of three or two phase systems in places where only a phase is utilized at a time.

This latter option has been a very popular one considering firstly the ease of such a setup i.e. if we have power failure in a phase caused by say the tripping of a switch which came about by any of the numerous reasons ranging from over loading of the phase line, to probably a short in any of the locations the phase is utilized, all the consumer has to do is change his phase to one that is still active without much ado, pending when the faulty phase will be fixed. He/she doesn't have to go seeking external help and or call on the power company.

Up until very, recently such phase changes have been done manually and a look at the operation itself will reveal it to be quite a hazardous venture. The standard mode series of operations that are involved in the phase change are

1. Turn off the mains switch
2. Remove the service fuse(board or black fuse) from the service fuse receptacle of the faulty line
3. Insert the service fuse in the receptacle of any of the phases that are still active
4. Turn on the mains switch

However problems that may be encountered in carrying out this series of steps are varied viz.

1. There may not be light in the new assumed phase and you have to go over the same process again to check the third phase
2. The three phases may all not be active and all your actions will be in vain.
3. In Nigeria where more often than not the transformer phases are overloaded, you will probably have to change phase several times in a day
4. A common practice among locals is to bridge the service fuse with copper wire when the fuse blows open. This completely eliminates the fuse's function in the circuit and considering that they most times use wires of lower diameter than the wires before and after the fuse, the concocted 'fuse' heats up considerably and you may get scalded when trying to remove it.
5. These operations are mostly done by unqualified personnel and at times children who have no idea about precautionary procedures when handling electrical appliances and devices.

6. In homes where the mains switch is indoor and the meter board and service fuse are outdoor(to make it easier for the power company personnel to read off the meter), people may not bother with switching off the mains switch and just pull out the service fuse and reinsert in the appropriate receptacle. The dangers involved in such a venture need only be imagined if this act is done by a child or careless person.

7. The plugs (black fuses) themselves are most times sub –standard and below the rated fuse for such houses and as such becoming very hot.

These problems especially nos. 4, 5 and 6 have caused some power companies to even issue a warning about service fuse removal and change. Situations even occur (in places where power supply is fairly constant) where locks have been put on service fuses to prevent consumers from tampering with them (fig 2.1).

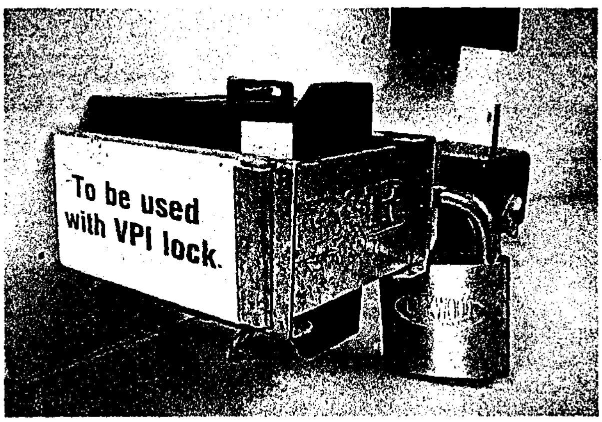

Figure 1.1 Service Fuse with Lock

The above setup defeats the whole purpose of the three phase system because where there is a power failure in a phase and other phases are active, you have to call or notify the power company to send a technician to come change the phase.

Furthermore, this process is not very suitable for power supply to sensitive machines e.g. computers as it takes some time before you can change a phase(at least 5 minutes) and valuable work may be lost.

Recent improvements in all of the human society have been towards computerization and Automation has become the norm. Virtually every gadget from a Hair drier to Cars having a computer of one form or another embedded within it, and automatic response by everyday gadgets is common everywhere- hand driers sense your hand and come on automatically, doors slide open automatically as you approach, cars automatically open their doors and start up, etc.

This project is a phase changer which utilizes a microcontroller to sense power failure in any of three phases and automatically switch over to any phase that is active then displays a number that corresponds to the active phase or displays a '0' if there isn't any active phase.

Advantages it presents includes the following

A. It eliminates all manual operations involved in changing phases, curbing the danger involved therein.

B. It effectively shortens the time interval between phase changes to nanoseconds-fast enough to make the changeovers unnoticed by human senses.

C. It is economical.

D. It saves the technician a trip(in places with the service fuse lock system)

E. Service fuse tampering can be checked

1.2 OBJECTIVE

The project is aimed at the design and construction of a circuit which functions as an automatic phase switch and is targeted at integrating a microcontroller and Led display into the circuit.

1.3 METHODOLOGY AND SCOPE OF WORK

A modular method of approach is used in the implementation of the design. Each section is taken separately and implemented and finally each of units (modules) were integrated together to give the final circuit. The block diagram is as below.

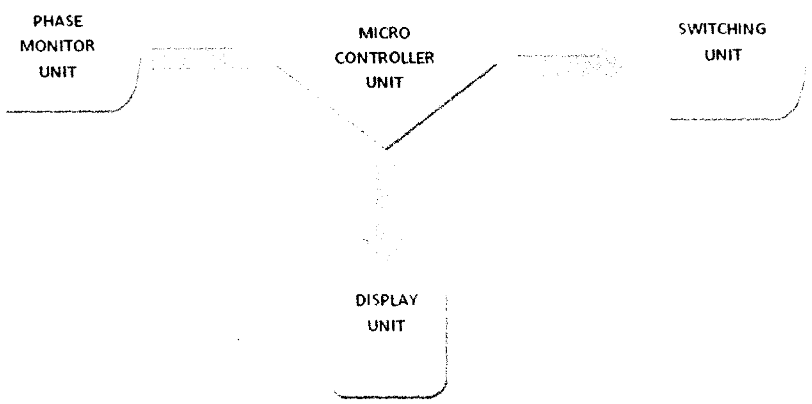

Figure 3.1 Block Diagram

1.4 SOURCES OF MATERIAL

All materials were sourced locally from Minna, Kaduna and Lagos State.

1.5 EXTERNAL AND INTERNAL INVOLVEMENT

a. Engr. Abraham Ezekiel (external) CEO Hamstring Engineering Company.

b. Engr. Eronu Emmanuel (internal)

c. Engr. E. O. Nwozor (internal)

d. Mrs C.O. Alenoghena (internal)

CHAPTER 2 LITERATURE REVIEW

2.1. HISTORICAL BACKGROUND

INVENTION OF THE LIGHT BULB

On October 21, 1879, Edison created his now famous incandescent light bulb, which burned for 40 hours. During 1880, Edison continued work to refine his light bulb. He also began exploring ideas for an equally important invention: a way to generate and transmit the electricity his light bulb would need. A practical and reliable electricity supply was essential if the light bulb was ever to become a practical appliance for homes and businesses.

AC vs. DC

Edison's method for generating and transmitting electricity was called direct current, or low voltage. George Westinghouse, a consolidator of his time, built Westinghouse Electric by purchasing other inventor's patents, including the poly-phase alternating current (AC) system invented by Nikola Tesla.

In an alternating current system, transformers were used to step up, or increase the voltage that left the power plant. This enabled the electricity to travel over long-distance wires. When the electricity reached its destination, another transformer would then step down, or decrease the voltage so that power could be used in homes and factories.

Edison's direct current system was unable to use transformers. With Edison's system, the voltage dropped as it traveled further and further from the generator. To overcome this disadvantage, power plants would have to be built close to the power users-a costly solution.

The first alternating current distribution system was installed in 1886 in Great Barrington, Massachusetts. That same year AC power at 2kV of 30km was installed at Cerchi, Italy.

Soon, the Westinghouse alternating current system—rather than Edison's more expensive, higher-maintenance, and less efficient direct current system—began to get most of the orders. Another advantage with the alternating system soon became apparent: By allowing central stations to serve wider markets, the AC system also encouraged utilities to build larger stations, which then benefited from economies of scale and lowered their operating costs.

POLYPHASE ALTERNATING CURRENT SYSTEMS

At an AIEE(American Institute of Electrical Engineers)meeting on May 16, 1888, Nikola Tesla(the pioneer of alternating current power distribution) delivered a lecture entitled "A New System of Alternating Current Motors and Transformers", describing the equipment which allowed efficient generation and use of Poly-phase alternating currents. The first transmission of three-phase alternating current using high voltage took place in 1891 during the international electricity exhibition in Frankfurt. A 25 kV transmission line, approximately 175 kilometers long, connected Lauffen on the Neckar and Frankfurt [3].

DOUBLE AND THREE PHASE UTILIZATION

The utilization of two and three phases in homes and business premises where only one phase is in use at a time is is a common practice in Nigeria and an effective way of increasing electric power supply availability and availability.

To utilize the multiple phases, consumers have two or three service fuse receptacles installed one for each phase (as shown in figure 2.1.1). Only one service fuse is used however and is inserted in the receptacle of the phase to be utilized by the house or premises while the others are left open.

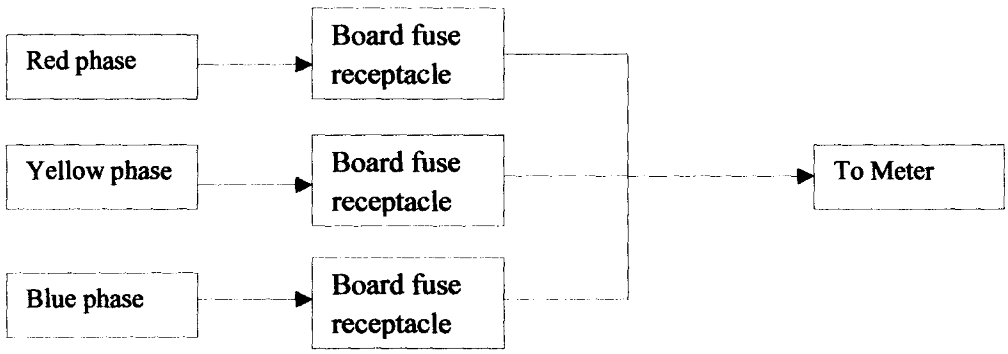

Figure 2.1.1. Three Phase Connection By Single Phase Utilisers

When a phase fails the consumer switches to a phase which is still active. To switch between the three phases the consumer manually by removes and reinserts the black /board /service fuse to the receptacle corresponding to the active phase.

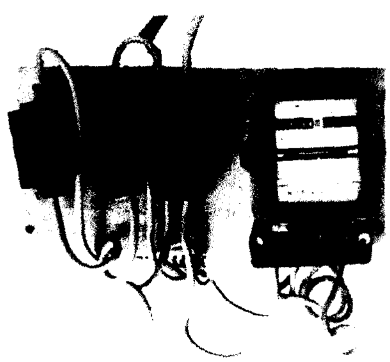

Figure2.1.2. Old Single Phase Meter with three phase connection

Recent development has seen the emergence of an automatic phase changer which senses the power failure and automatically changes the phase provided there is an active phase available.

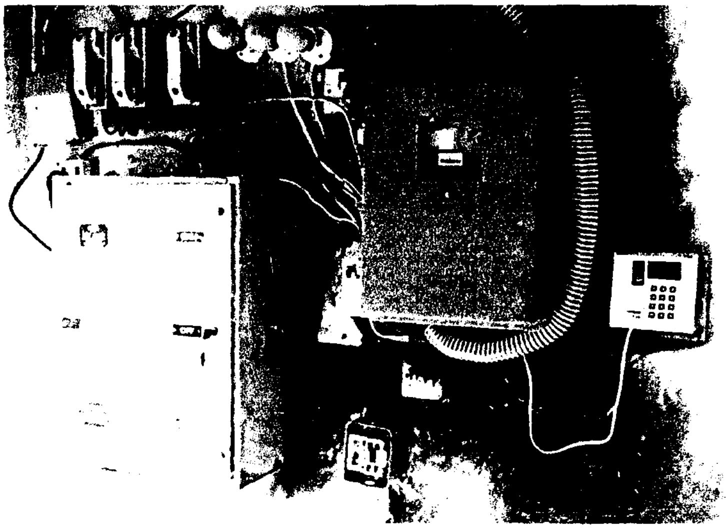

Figure 2.1.3. Recent single Phase Meter with three phase connections

2.2. PRINCIPLE OF OPERATION

The Microcontroller Driven 3-Phase Automatic Phase Changer With Active Phase Display operates by sensing power failure in an active phase and automatically switching the load(house) to a live phase and indicates which phase the house is currently connected to. Where there isn't any live phase, it indicates that no phase has electric current

From the above description of its operation it can be deduced that it is made up of four modules, each of which contain various components that have different principles of operation. These modules are:

a. The phase monitors- made up of

    i. A step-down transformer

    ii. A bridge rectifier

    iii. A smoothening capacitor

    iv. A 7805 regulator

b. The display- made up of

    i. Seven segment display

    ii. Current limiting resistors

c. The switching mechanism- made up of

    i. A transistor

    ii. An electromagnetic relay

d. The logical analyzing unit-made up of

    i. A microcontroller

    ii. Battery bank

    iii. Crystal

A brief description of the principle of operation of the major components is as follows

i. STEP DOWN TRANSFORMER

A transformer is a static piece of apparatus by means of which electric power in one circuit is transformed into electric power of the same frequency in another circuit. The main principle behind a transformer is mutual induction between two circuits linked by a common magnetic flux. Mutual induction is the phenomenon where if two coils are lying close to each other and electric current is passed through one of them, there is a flux link to the other and as the current is varied the flux link varies too and hence EMF is induced in the second coil according to faraday's first law of electromagnetic induction which states that "whenever the magnetic flux linked with a circuit changes. An EMF is induced in it" [8]

ii. **BRIDGE RECTIFIER**

This is made up of four diodes. These diodes are made up of n-type and p-type semiconductor materials they work based on the principle that certain materials conduct partially and when doped with other materials will conduct better. However depending on the type of material you dope it with, it can become a P-type (conducts using holes) or an N-type(conducts using electrons).if you fuse a p-type and n-type semiconductor together, you get a diode which conducts only when current is passed from the positive end of the piece of fused semiconductor and out of the n type material. This is called forward biasing the Diode. [7]

iii. **SMOOTHENING CAPACITOR**

This is also known as a reservoir capacitor. It is used to smooth the pulsating DC from an AC rectifier. The principle of operation of the capacitor can be understood viz: The capacitor does not use energy but stores it so as the rectifier voltage increases, it charges the capacitor and also supplies current to the load. At the end of the quarter cycle, the capacitor is charged to its peak value Vmax of the rectifier voltage. Following this, the rectifier voltage starts to decrease as it enters the next quarter cycle. This initiates the discharge of the capacitor through the load, effectively smoothening the ripple. [3]

iv. **LM 7805 IC**

This regulates the input from the rectifier to 5V. The LM7805 belongs to the 7800 series of three-pin fixed positive linear Voltage regulators. They are ICs which produce fixed output voltage ranging from 5Volts to 24 volts. This family of regulators is commonly preferred because of their low-cost and simplicity. [3][1]

v. ELECTROMAGNETIC RELAY

The relay does the actual switching of the phases. They are electromagnetic devices consisting of a movable armature mounted above the core of an electromagnet. When the core is energized the armature experiences a magnetic force which causes it to close a set of contacts.

The principle behind the operation of the relay is when an electric current is passed through a conductor it produces a magnetic field at right angles to the direction of electron flow.[8]

vi. FREE-WHEELING DIODE

The free-wheeling diode works to clear out the back EMF that appears in the circuit when the field in the coil of the electromagnetic relay collapses.

Principle of operation: This back EMF occurs because the inductor does not use up electrical energy but stores it as an electromagnetic field around the coil. When electric current is cut off the field collapses and appears as a spike in the conductor. This spike can damage the switching transistor. The free-wheeling diode conducts this spike away from the transistor and dissipates it as heat.[7]

vii. **MICROCONTROLLER.**

A Microcontroller is essentially a Computer on a chip. It belongs to the group of computers known as Microcomputers because of their size.

A 89C51 microcontroller was utilized in this project. It belongs to the 8051 microprocessor family which despite it's relatively old age, is one of the most popular microcontrollers in use today.

The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4 Kbytes of Flash Programmable and Erasable Read Only Memory (PEROM). The device is manufactured using Atmel's high density nonvolatile memory technology and is compatible with the industry standard MCS-51Ô instruction set and pin-out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer.

It serves as the logical Analyzer and controller to coordinate all these activities. It is made up of various logical components which operate on varied principles. [10]

viii. **SEVEN SEGMENT DISPLAY**. This indicates the active phase. And is made up of seven LEDs (light emitting diodes) all connected in the common anode configuration. A LED is a special type of diode. Principle of operation: In a forward biased diode, free electrons leaving the n type material to the p type material fall from a higher to a lower energy level. They radiate the excess energy as heat in normal diodes but in LEDs thy radiate it as visible light this is possible because of the type of materials used in the manufacture of these LEDS. The color of light it radiates also is determined by the type of material used in its manufacture. Elements used for the doping to produce LEDs include gallium, arsenic and phosphorus. [7]

2.3. PREVIOUS WORKS

Previous work by others in this area include

1. Design and construction of an automatic 3 phase change over switch by Zola MC reference number 03/035 2003 set
2. Design and construction of an automatic 3 phase change over switch by Suleaman I B reference number 4/127 and 4/108 2004 set.
3. Design and construction of an automatic 3 phase change over switch by Asha R T reference number 4/009 and 4/162 2004 set
4. Design and construction of an automatic 3 phase change over switch by Gbadegesin H A reference number 4/188 and 4/148 2004 set
5. Design and construction of an automatic 3 phase change over switch by Owuoeye A E reference number 4/044 2004 set
6. Design and construction of an automatic 3 phase change over switch by Idachaba Ainoko reference number 45 2005 set
7. Design and construction of an automatic 3 phase change over switch by Raji Mansoor A reference number 7/060 2007 set
8. Automatic phase changer by Roshan Engineering Corporation India
9. Automatic phase changer by MUHAMMAD AJMAL P.[9]

2.3.1 PRINCIPLE OF OPERATION

In all these previous attempts, a common pattern and principle of operation is used

1. The sensors consist of a rectifying circuit and a regulator to supply a certain percentage of the rectified DC voltage
2. The switches consist of electromagnetic relays and transistors acting as switches and boosters for the trigger voltage
3. The logical analyzer consists of Op-amps. Which sense presence of EMF and its value and connects the phase whose voltage is closest to the standard voltage to the load.

However, the commercial model by the Roshan Engineering Corporation also incorporates an automatic generator starter and can supply full 3 phase supply at once.

2.4. IMPROVEMENTS ON PREVIOUS WORKS

This model has various unique features as well as the absence of some features available in other models for reasons that will be stated.

Unique features in this model include

1. The model uses a single IC for ac rectification instead of four diodes, effectively cutting cost and reducing the overall size of the model.

   four diodes per phase=12 diodes(as compared to only three ICs in this model)

2. The model contains a seven segment display to indicate the active phase and also to indicate if when there is no live phase. The advantages this presents include

   a. Time saving: This saves time in checking each line

b. Safety: permits over-inquisitive users to glean this information at a safe distance from the service box.
c. Ease of use in the dark: It can also be read In the dark, which is an added advantage in cases where it is placed in a dark place or it needs to be checked at night.

3. This model uses the 89C51 microcontroller as its logical analyzer and coordinator. The advantage this presents include
   a. Compactness of design: the other designs use a combination of three to 9 operational amplifiers and ICs but this model uses only one microcontroller unit
   b. Utilization of new technology
   c. Ease of improvements and upgrades
   d. Low cost of improvements and upgrades
   e. Modularity
   f. Less power consumption
   g. It can be interfaced with peripherals e.g LCD displays, speakers, etc and even a computer and controlled remotely.

2.5. LIMITATIONS

Features excluded include

1. This model does not check if the phases have proper voltage levels. The reason this feature was excluded is that this model was made specifically for Nigerian power supply and from observation in Nigeria if you have a good voltage level, it is fairly constant, but if you have low voltage, the voltage always fluctuates continuously, and

almost immediately you change phase, the same phase goes low and you may have to revert back to the old phase. These frequent changes produce spikes in the circuit and may harm delicate equipment. Until the Nigerian power supply improves, it is impractical to include such a feature.

CHAPTER THREE: DESIGN AND IMPLEMENTATION

3.1. GENERAL DESCRIPTION

The whole project can be divided into four parts

1. The Phase Monitors.
2. Microcontroller unit.
3. Phase switches.
4. Display unit.

3.2. CIRCUIT DIAGRAM

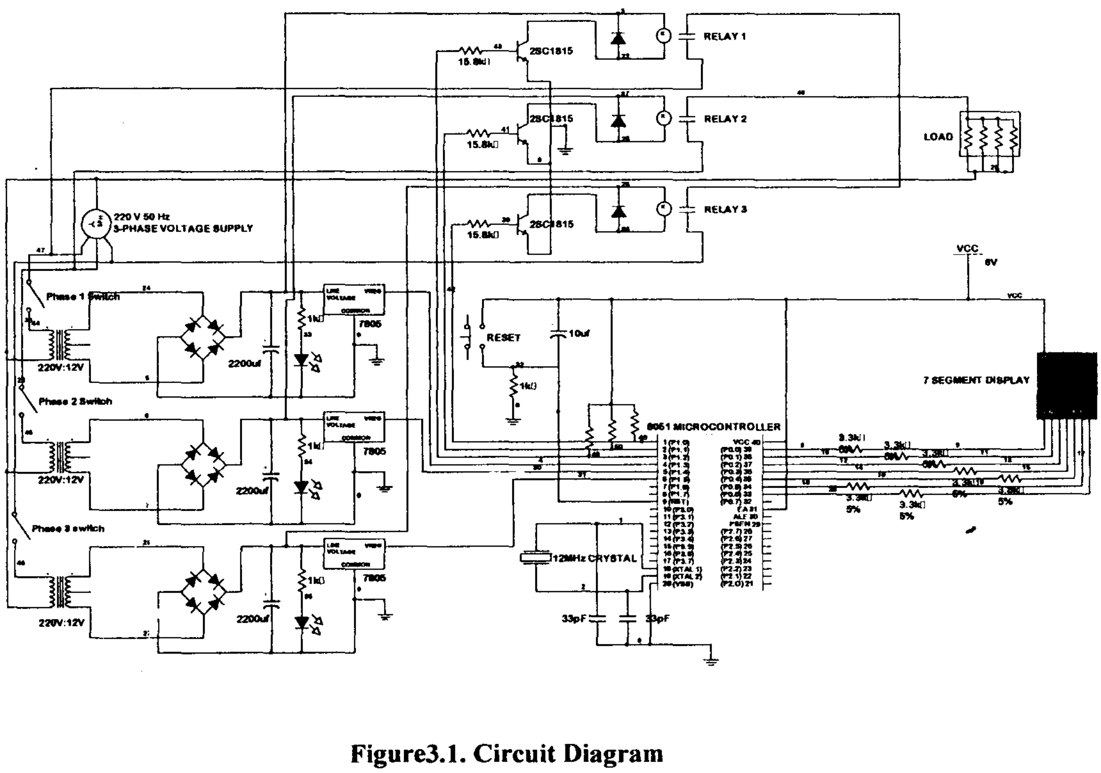

Figure3.1. Circuit Diagram

3.3. THE PHASE MONITOR UNIT

This consist of 3 sets each consisting of a step-down transformer, a bridge rectifier, a 4700uf capacitor and an LM7805 integrated voltage regulator.

It's function is to send a regulated 5v DC to the respective pins of the 8051 micro controller if there is a voltage in the phase it is monitoring.

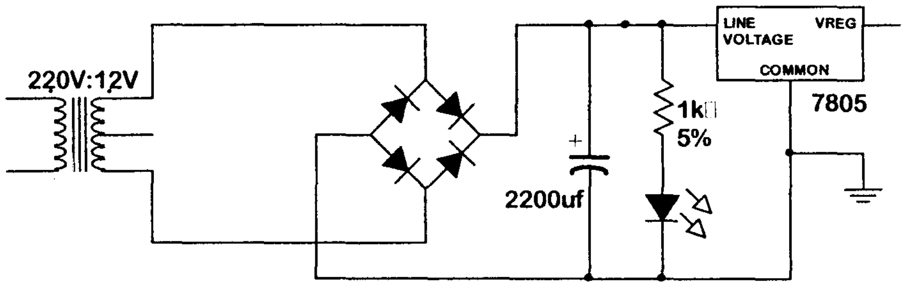

Figure 3.2: Phase Monitoring Unit

3.3.1 THE STEPDOWN TRANSFORMER

The step-down transformers (3 units) in the phase monitoring unit have the following specifications

Input voltage=220volts (RMS)

Output voltage=12volts (RMS).

Current rating =300mA

3.3.2 THE BRIDGE RECTIFIER

Traditional bridge rectifiers are made up of four diodes interconnected as shown in the circuit diagram above. However there are newer integrated modules that are produced with all the four diodes integrated into one package. This makes for ease in design and actual implementation and helps reduce space requirements on the board. The integrated module used in this project is the RS307L (A91)

Its power rating is 10watts sufficient for the purpose at hand.

3.3.3 THE POLARIZED CAPACITOR

To calculate the required capacitance of the polarized capacitor

$$Q = CV$$

$$Q = IT$$

$$CV = IT$$

$$C = IT/V$$

$$T = 1/2F$$

$$F = 50HZ$$

$$T = 1/(100) = 0.01$$

$$Q = 0.3X0.01 = 0.003$$

Ripple Voltage (dv) = 15% x (peak voltage-voltage drop across rectifier)

$$Peak\ voltage = \sqrt{2}\ Vrms$$

$$= \sqrt{2}\ 12V$$

$$= 16.9706$$

Voltage drop across rectifier IC = (0.7 X 2)=1.4v

$$dV = \frac{15}{100}X\ (16.9706 - 1.4) = 2.3356V$$

$$C = \frac{0.003}{2.3356}$$

$$C = 1304X10^{-3}F$$

The closest standard capacitor to this value in the market is the 2200uF capacitor.

The temperature rating for the capacitor chosen is 105°C, because the unit may be exposed outside the house, in the sun or anywhere

3.3.4 THE LED AND ITS CURRENT LIMITING RESISTOR

The LEDs cannot be connected directly to the 12volts Direct current(D.C.) line because of its current rating which is usually very low hence a current limiting resistor is placed in series with it .

To calculate the value of the required resistor,

$$Vdrop = 2v$$

$$I\ of\ led = 10mA$$

$$R = (Vin - Vled)/(I\ led)$$

$$R = \frac{12 - 2}{10mA}$$

$$R = 1000\Omega$$

3.3.5 THE LM 7805 VOLTAGE REGULATOR

This is a 3-pin integrated circuit that supplies a regulated 5V dc from an input ranging from 7v to 20v

The choice of this voltage regulator is because of its availability, and suitability (input voltage from bridge rectifier is 12v and input to pins of microcontroller is 5V)

3.4. THE MICRO-CONTROLLER UNIT

This is the control and coordination point for the project. It is the most important part *of the project and regulates all other units together to act as a single unit.*

The unit consists of two parts a hardware and soft ware

3.4.1. HARDWARE: This consists of an 8051 microcontroller, and a12MHz crystal with its biasing capacitors and resistors, a reset button. These hardware enable the microcontroller operate effectively and are from the manufacturer's data sheet [10]. It also contain an independent 6Volts power supply.

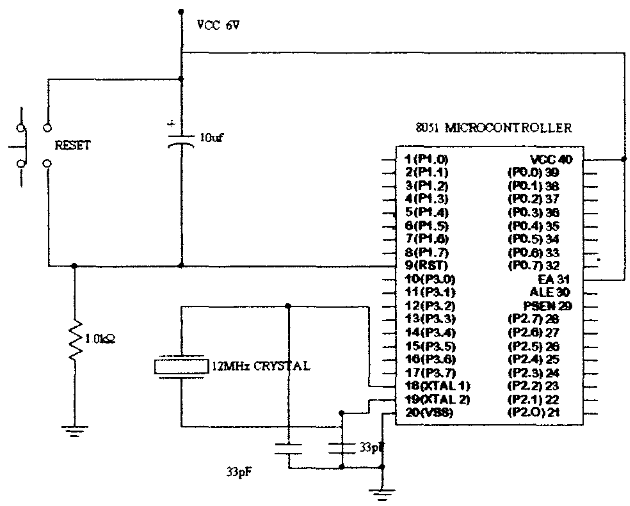

Figure 3.3 The Micro Controller Unit

3.4.2. SOFTWARE: the software is a simple looping program. It monitors 3 ports- P0.3, P0.4, P0.5 and sets P0.0, P0.1, or P0.2 high respectively if the corresponding port is high, then it outputs the binary equivalent of the seven segment display for "1" if P0.3 is high(corresponding to the red phase), "2" if P0.4 is high(corresponding to the yellow phase) and "3" if P0.5 is high(corresponding to the blue phase or a "0" if none of them is high.

The ports are partially prioritized with P0.3 having the highest priority, and P0.5 the lowest.

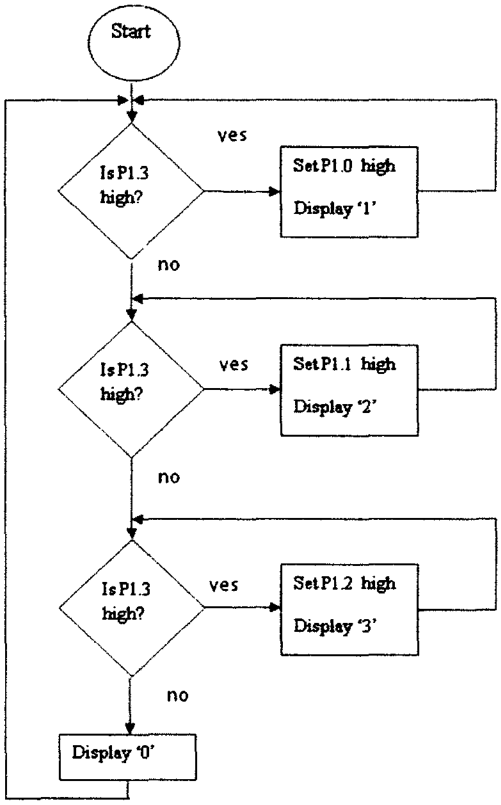

Figure 3.4 flow chart

3.5. THE SWITCHING UNIT

The Switching Unit consist of 3 sets of transistor and relays . Their function is simply to latch the load resistance to an active line following a trigger from the microcontroller unit

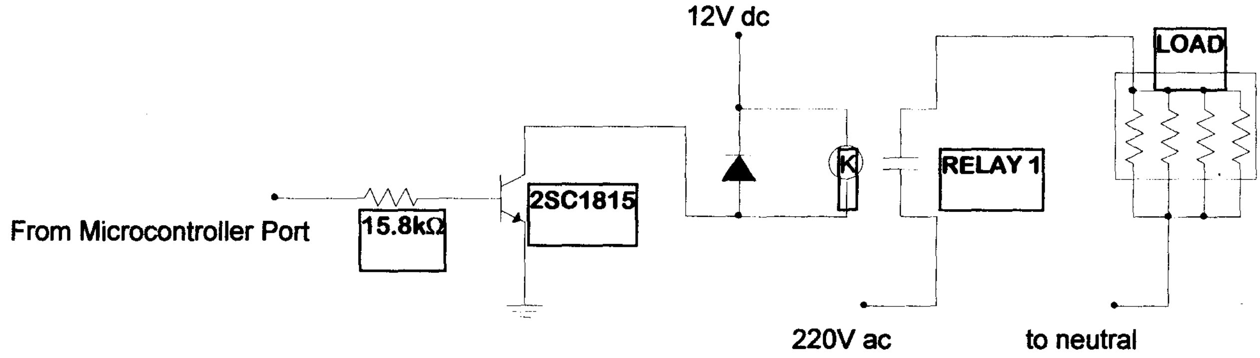

Figure 3.5 The Switching Unit

The transistor used is the 2SC 1815 it has the following specifications

$$Hfe = Ic \div Ib[6]$$

$$Minimum\ hfe = 70$$

$$Load\ current = 100mA$$

$$Minimum\ base\ current = 100mA \div 70$$

$$= 1.4286mA$$

To guarantee the transistor switch is always saturated, we use 130% of calculated base current[]

$$1.3 \times 1.4286 = 1.85718mA$$

$$Rb = Supply\ Voltage \div \frac{Maximum\ Current\ Required}{Minimum\ HFE * 1.3}$$

$$Rb = 12 \div \frac{0.1}{70 \times 1.85718}$$

$$Rb = 15{,}599.64\Omega$$

The closest standard resistor is 15.8kΩ

3.6. THE DISPLAY UNIT

This consists of a seven segment display and its biasing resistors [2]. Its function is to accept inputs to its 7 pins from the 8051 and display the integer that corresponds to the active phase or to display a 0 if there isn't any active phase.

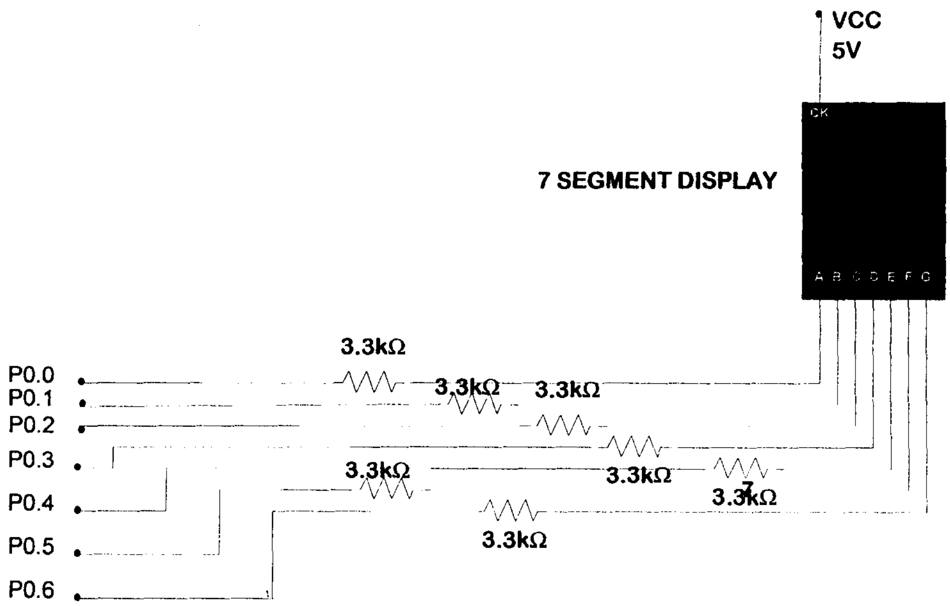

Figure 3.6: The Display Unit

To calculate the value of the current limiting resistors

$$Vdrop = 2v$$

$$I\ of\ led = 10mA$$

$$R = (Vin - Vled)/(I\ led)$$

$$R = \frac{6-2}{10mA}$$

$$R = 400\Omega$$

In this project 330Ω resistors are used because the power supply does not give the rated 6V but around 5.7V-5.9V.

CHAPTER FOUR: TESTS, RESULTS AND DISCUSSIONS

4.1 GENERAL CONSTRUCTION

The construction of the project was in four stages

a. Simulation: a virtual simulation was constructed using the multisim circuit design software.

b. Bread boarding: separate modules of the circuit were constructed on breadboards.

c. Vero boarding: the circuit was finally laid out on a Vero board and soldered.

d. Casing: the whole project was finally encased in transparent plastic to ease conveyance and demonstration.

4.2 TOOLS AND EQUIPMENT

Tools used for the project include

a. A Microcomputer unit

b. National instrument's circuit design suite (Multisim) 10^{th} edition

c. Digital multimeter

d. Analog Multimeter

e. Soldering iron and stand

f. Soft solder

g. Sucker

h. Wire Cutter

i. Pliers

j. Breadboard

k. Screwdriver

l. utility Knife

m. metal file

n. Heat source

o. piercing tools

4.3 TEST AND MEASUREMENT METHODS

Tests on the project were carried out in stages

1. conceptualization test: during conceptualization, tests were carried out on the design using the principles learned throughout the 5years of study in school to ensure the working principles of the project were sound
2. Simulation test: the Multisim software was used to create a virtual working prototype of the design and it was tested and tweaked to various levels to see if the actualization of the circuit was feasible
3. Bread board tests: each module was built on a bread board and tested
4. Vero board tests: after the final Vero boarding and soldering the project was tested
5. Final tests: after casing it, the project was tested as a finished prototype

4.4 RESULTS

Each module worked and the overall circuit functioned as expected

Table 4.4.1 Table of results

Active phases	display output	voltage output at terminal(volts)
Nil	0	0
1	1	230
2	2	230
3	3	230
1 and 2	1 or 2(*)	230
1 and 3	1 or 3(*)	230
2 and 3	2 or 3(*)	230
1, 2 and 3	1, 2 or 3(*)	230

* The active phase is determined by the last phase that was active before the current state (refer to the Appendix- assembly program algorithm).

4.5 DISCUSSION OF RESULTS

The results recorded were satisfactorily.

4.6 SHORTCOMINGS OR LIMITATIONS

a. Analog system of research in the library

b. Problem with materials on the net-no standard name,

c. The project is relatively new causing restriction on materials available)

d. Component used in the project are not manufactured in Nigeria hence are not tropicalised this causes them to overheat

e. The Nigerian Electrical power supply is characterized by occasional spikes and dips which might cause strange or faulty behavior of the project

4.7 PRECAUTIONS AND POSSIBLE SOURCES OF ERROR

a. The project should utilize a central ground not separate grounds for the 6V power supply and for the microcontroller and the phase monitors

4.8 TROUBLESHOOTING

a. The relays should have a very fast switching speed to firstly avoid possible line to line faults while switching

b. The neutral was decentralized to avoid frequent short circuits which occurred when the neutral was centralized.

CHAPTER FIVE: CONCLUSION

5.1. WORK SUMMARY

The aim of this project is to create a back up supply of electric power by utilizing a three phase hot redundant system.

The results obtained were satisfactory

5.2. RECOMMENDATIONS

Based on the experience I got from executing this project I recommend these ideas for future attempts at this same project

1. The cost of the whole project can be considerably reduced by using Personal integrated Computers (PICs) or custom made controllers which are considerably cheaper.
2. The microcontroller can be interfaced to a computer for remote monitoring.
3. A sound device could be incorporated to indicate a change in phase
4. A voltage level determining circuit can be incorporated in the design so that the device also switches to the phase with the best voltage level between the three phases.
5. The indicators can be installed before the service fuses or board fuses so that when a fuse fails it will be easy to detect.
6. The phase changer can be made a 4 phase to include an automatic generator switch.

REFERENCE

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[2] ECE511 Assignment 2007/2008 session Engr Eronu lecturer Electrical/ Computer Engineering Department School of Engineering and Engineering Technology Federal University of Technology Minna Niger State Nigeria

[3] http://en.wikipedia.org/wiki/History_of_electric_power_transmission

[4] http://en.wikipedia.org/wiki/Flyback_diode

[5] Electronic industries association of Japan, Transistor manual

[6] http://www.rason.org/index.html Using Bipolar Transistors as switches

[7] Albert Paul Malvino PhD, Electronic Principles. 3rd edition, McGraw-Hill Inc, New York, United states of America, 1984, pp 22-32

[8] B.L. Theraja and A.K. Theraja, A Textbook of Electrical Technology ,Twenty Third Revised Edition, S. Chand and Company Ltd Ram Nagar, New Delhi, 2003, pp 279-285

[9] WWW.EFYMAG.COM

[10] Atmel Corporation , 89C51 data sheet.

APPENDIX 1: PROGRAM

```
ORG 00h
 START:
      MOV P1,#0H
      JB P1.3, PHASE1
 START2:
      JB P1.4, PHASE2
 START3:
      JB P1.5, PHASE3
      MOV P0,#0C0H
      SJMP START
 PHASE1:
      SETB P1.0
      MOV P0,#079H
      SJMP START
 PHASE2:
      SETB P1.1
      MOV P0,#024H
      SJMP START2
 PHASE3:
      SETB P1.2
      MOV P0,#030H
      SJMP START3
    END
```

APPENDIX 2: CIRCUIT DIAGRAM