DESIGN AND CONSTRUCTION OF AN ELECTRONIC CONTROLLED CIRCUIT BREAKER (ECCB)

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.), DEGREE IN THE DEPARTMENT OF ELECTRICAL/COMPUTER ENGINEERING, SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA
NIGER STATE

NOVEMBER, 2005

DECLARATION

I hereby declare that this project is an original work and has never to my knowledge been submitted elsewhere before.

ETITO ANDREW

30th – 11 – '05

DATE

CERTIFICATION

This is to certify that this project was carried out by Etito Andrew of the Department of Electrical/Computer Engineering of the School of Engineering and Engineering Technology, Federal University of Technology, Minna under the supervision of Mr. Emmanuel Eronu for the award of Bachelor of Engineering (B. Eng.)

5-12-2005

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DATE

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(HEAD OF DEPARTMENT)

DATE

EXTERNAL EXAMINER

DATE

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I acknowledge first and foremost the Almighty God for having granted me the grace, love and mercies and having brought me this far in my academic pursuit and raising people to support me all through. I say thank you Lord.

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Not forgotten are Mrs. Elizabeth Abu, Mrs. Victoria Etito, my nephew Obediah, E. Etito (Jnr), Emmanuel O. Etito and my niece Ms Hilda E. Etito for their support and prayer. God bless you all.

DEDICATION

This Project is dedicated to the entire Etito Family and to the Almighty God .

ABSTRACT

Protection of power system is a very vital aspect of Electrical Engineering, which bring into invention the device called circuit breaker. This is a device that opens or closes an electric power circuit either during normal or abnormal system operation.

This project work attempts the design and construction of an Electronic Controlled Circuit Breaker (ECCB) for a double phase power system (220v, 5A) with the use of solid state devices, which include the comparators, rectifying circuit, current amplifier, thyristors and relay. The project is to be used as a means of protection against abnormal condition.

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

CHAPTER TWO

CHAPTER THREE

THEORETICAL BACKGROUND

CHAPTER FOUR

SYSTEM, DESIGN, SPECIFICATION AND ANALYSIS

CHAPTER FIVE

CONSTRUCTION AND TESTING

CHAPTER SIX

CONSTRAINTS, CONCLUSION AND RECOMMENDATION

CHAPTER ONE

1.0 INTRODUCTION

Faults can be very destructive to power systems. A great deal of study, development of devices and design of protection schemes have resulted in continual improvement in the prevention of damage to transmission lines and equipment, and interruption in power generation following the occurrence of faults such as short circuits or partial short circuits, open circuits, over current, under voltage and over voltage. The occurrence of fault conditions is inevitable because the power system is an engineering artifact, and hence suffers from the effects of aging, human error, external interference e.t.c.

It is in the light of the above that frantic and relentless efforts are being made to ensure the development and design of circuit breakers with high sensitivity and efficient operating ability. It should be noted that the protection system is another engineering system designed not to prevent faults, but to respond to their occurrence and minimize their effect [7].

1.1 CIRCUIT BREAKER DEFINED

A circuit breaker is a mechanical device for making and breaking automatically a circuit both under normal and abnormal conditions. A circuit breaker must fulfill certain conditions as open and close in the shortest possible time under any network condition, conduct rated current, withstand thermally and mechanically any short-circuit current, not create any large over-voltage during opening and closing and be easily maintained.

If not for the fact that circuit breakers are capable of making and breaking a circuit, particularly in abnormal condition, it could be regarded as switch. But switches are not able to make and break automatically a circuit under fault condition and in excess of its rated normal current.

Circuit breakers are used for load control, over-load and fault protection and isolation of equipment to remove it from electrical stress. This is based on its effectiveness in isolating only the faulty part of the system.

1.2 TYPES OF CIRCUIT BREAKER

There are many circuit breakers in use today, however, they may be classified into:

(a) those without arc control, and

(b) those with arc control

The later could be subdivided into self-blast arc-control circuit breakers, and those in which the arc-control is provided by mechanical means external to the circuit breaker

Circuit breaker without a form of arc-control may be either plain air-break or plain oil-break in which the contact separates in air or in oil. In the plain oil-break circuit breakers, some assistance to an arc extinction is achieved by the gas bubble generated around the arc. Long and inconsistent arcing times are obtained with plain oil-break circuit breakers and they are only suitable for low-current voltage operation.

Self-blast circuit breakers are oil circuit breakers in which the pressure of the gas bubble set up in the arc is utilized to force fresh, un-ionised oil into the arc path, thus materially increasing the rate of insulation resistance in the circuit breakers.

The cross-jet oil circuit breakers incorporate the principle of arc control. As the moving contact is withdrawn, the gas generated by arc exert pressure on the oil in the back passage, and as a result, when the moving contact uncovers the arc splitting jets, fresh oil forced across the arc path. These types of circuit breakers are made with rupturing capacities of up to 2500MVA at 66kV. For high voltages and capacities, multiple break units have been developed.

The disadvantage of self-blast oil circuit breakers is that arcing times tends to be long and inconsistent when operating against current- considerably less than rated current because the gas pressure generated is much reduced compared with that generated at rated current. This particular difficulty is overcome in circuit breaker which utilizes a form of arc control in which the blast is provided by external means and thus is independent of the value of fault current to be broken. They may be either impulse-oil circuit breakers on air-blast circuit breakers.

In the impulse oil circuit breakers, oil is force across the arc path, the necessary pressure produced by external mechanical means is independent of the strength of the current to be broken. They are usually multi-break and have capacitance or resistance shunts to control the voltage the cascaded breaks. They are suitable for very high voltage systems of 200kV and above.

All oil circuit breakers have the disadvantage of fire risk due to the inflammability of the oil. This lead to the development of air-blast circuit breakers. The air circuit breakers are similar to impulse oil circuit breakers in that arc-control, which takes the form of an air-blast, which may be across the arc, along the arc, or radial is the arc, is provided by an external air compressor and independent of the current to be interrupted.

Arc control is used basically to remove ionized gas which acts as conductors rather than an insulator, from the arc path. [9]

Increasing use for modern electrical installation is the miniature circuit breakers (MCB). MCB incorporates most of the features of other circuit breakers in a compact form, and increasingly are being fitted in place of fuses in consumer units for the protection of final sub-circuit.

The MCB has the following advantages:

(a) it can be reset or re-closed easily

(b) it gives a close degree of small over-current protection

(c) it will trip an a small sustained over-current, though not on a harmless transient over-current such as switches surges.

(d) It eliminates cost of fuse replacement, and may be used as a switch isolating circuits.

(e) For all applications, the MCB tends to give better overall protection against both fire and shock risk than can be obtained with the use of normal high breaking capacity or re-wireable fuses.

The MCB has the main disadvantage of the initial cost even though it has a long term advantage.

Second, there is a tendency for the tripping mechanism to stick or become sluggish in operation after long periods of inaction. Hence, it is recommended that the MCB be tripped at frequent intervals to ease the springs and so ensure that it performed its prescribed operations without damage to itself or to the circuit it protects.

1.3 RATINGS OF CIRCUIT BREAKERS

It is a normal practice to specify the rupturing capacity of circuit breakers in kilovolts amperes or megavolts-amperes. This practice is well established but has criticism of not being logical, because the breaking capacity in megavolts-ampere is obtained from the product of short-circuit current and recovery voltage.

While the short circuit current is flowing, however, there is only a small voltage across the circuit breaker contacts. Thus the MVA rating is the product of two quantities, which do not exist simultaneously in the circuit breaker.

It will be more logical to have a current rating rather than an MVA rating for circuit breakers. The International Standard method of specifying circuit breakers rating or interrupting capacity is defined as a rated symmetrical current at a rated voltage.

The symmetrical breaking current of a circuit breaker is the current which the circuit breakers will interrupt at a power factor of 0.15 for ratings up to 500MVA and a power factor of 0.3 for ratings of 750MVA or upwards with a recovery voltage of 95 percent normal voltage. [9].

1.4 OPERATING PRINCIPLES OF CIRCUIT BREAKERS

All types of circuit breakers are designed to operate automatically in opening the circuit under fault conditions, or to be opened or closed normally when desired.

Circuit breakers are generally installed at substations on the ends of primary feeders. They may be elsewhere, however, where heavy short circuit currents must be interrupted and cannot be handled by other means such as circuit breakers are usually activated by over-current or fault-sensing relays, which serve to open them. This is done by tripping a compressed spring. Opening may be achieved in from 2 to 60 or more cycles. Relays also control their re-closure, which is accomplished by means of solenoids or electric motors. Circuit breakers may be set for a single operation, or for multiple re-closing operations.

Circuit breakers are used in many installation place of fuses for a number of reasons which may include:

(a) In the event of an overload or fault, all poles of the circuit are positively disconnected;

(b) Circuit breakers are capable of remote control by means of emergency stop buttons.

(c) The overload tripping characteristics are set by manufacturers and cannot be altered.

(d) It can open a circuit if the supply fails, thus avoiding unexpected reintroduction of the supply causing apparatus to become live; and

(e) Supply can be quickly and easily restored when the fau8lt has been cleared.

1.5 SELECTION OF CIRCUIT BREAKERS

A circuit breaker is selected for a particular operation, taking into consideration the following:

(a) the normal current it will have carry

(b) the amount of current which the supply will feed into the circuit fault, which current the breaker will have to interrupt without damage to itself.

CHAPTER TWO

LITERATURE REVIEW

A circuit breaker is a piece of equipment which designed to protect an electrical apparatus from damage caused by overload or short circuit. Unlike a fuse which operates once and then has to be replaced. A circuit breaker can be reset either manually or automatically to resume normal operation.

The history of circuit breakers is the history of electricity. Circuit breakers appeared at about the same time as electrical power for industrial use, which is the end of the 1800s and the beginning of the 20th century. Until very recently, electrical circuit breakers were basic devices. If the current through the circuit breaker exceeded a certain level (rating), the circuit breaker would eventually "trip" open. It is suppressing to know that circuit breakers do not trip immediately when the current exceed their overload rating. In some cases, the time delay can be several minutes, depending on how much the current exceeds the circuit breaker rating.

Circuit breakers are often implemented with a solenoid (electromagnet) whose strength increases as the current increases and eventually trips the circuit breaker. Alternatively, a bimetallic strip may be used which heats and bends with increase currents. some circuit breakers incorporates both techniques. This allow the properties of the circuit breaker to be tailored to suit the application, with the electromagnet generally responding to short, large surges in current (short circuit) and the bimetallic strip responding to smaller but longer-term (overload) over current conditions. Circuit breakers for larger currents are usually arranged with pilot devices to sense a fault current and to operate the trip opening mechanism.

Thermal-magnetic trip units are economic and compact. They have been used effectively and efficiently for many years. Their function can also be performed by electronic trip units. The first use of electronics, in the 1960s, was associated with protective relays for medium voltage circuit breakers. Since the early 1970s, electronic trip units have been increasingly applied to power circuit breaker and the larger frame sizes of industrial/commercial molded case circuit breakers. The advantage of electronic trip units is that tome-current curves can be readily adjusted; both for phase current settings and for the setting of integrated grand fault units. This flexibility permits coordination between series connected over-current protective devices such that under fault conditions, only the devices immediately upstream from the fault will clear the circuit. A further advantage is that the trip characteristic is independent of ambient temperature.

The electronic circuits on circuit breakers may also incorporate communications capability. At first this was limited to application such as zone-selective-interlocking. Here an upstream power circuit breaker is set to trip with no intention delay, but a trip restraint signal from a downstream circuit breaker can cause the power breaker to remain closed for setting up to 0.5 seconds, the maximum short-time duration. When a fault occur on the load side of a selectively coordinated downstream circuit breaker, this downstream breaker communicates that a fault has been detected and the upstream power breaker then permits the downstream breaker to interrupt the fault. However, if the fault occurs between the power circuit breaker and the downstream circuit breaker, no restraint signal is received from the downstream circuit breaker, and the power circuit breaker will clear the fault without any intention delay.

Electronic advances have also increased the safety protection of residential circuit breakers. Ground-fault circuit interrupters (GFCI) have been available for many years and these circuit breakers, in addition to protecting the branch circuit wiring against over-current provide personnel protection against electrical shock in cords and equipment connected to the outlets.

In summary, circuit breakers protect the conductors against over-current. This is accomplished by first detecting the over-current and then interrupting the over-current with subsequent isolation. Thermal-magnetic trip units or electronic trip units detect the over-current. Interruption and isolation is accomplished by drawing an arc between separating contacts, with subsequent arc extinction. Circuit breakers, low voltage industrial/commercial molded-case circuit breakers, low-voltage power circuit breakers and medium-voltage circuit breakers. An overall electrical distribution system can be expected to incorporate all classes of circuit breakers. Electronic has increased the sophistication of trip units, including communication capability, and has permitted additional safety features such as shock-protection through GFCIs.

CHAPTER THREE

THEORETICAL BACKGROUND

History has shown that electrical appliances have had their life spans shortened by fluctuations in the supply voltage. Practically, no power system can maintain voltage at rated value at the consumer terminals at all times. Over voltage or under voltage may arise causes of these abnormalities include switching surges, physical contact between conductors of an electrical circuit e.t.c.

A malfunction due to these conditions may be either reversible or irreversible. In the second case, the properties will have changed sufficiently for normal operation to be impossible. This may range from an unacceptable change in a particular component to total destruction of the device[9]. For example, over voltage on fluorescent lamps causes the choke to pass more current to the lamp. This lowers the resistance of the arc column, resulting in a lower voltage drop in the lamp voltage. The input watts to the lamp slightly increased and therefore the lumen output decreases over a certain range. On induction motors, over-voltage leads to increased torque, increased starting current and decrease power factor. But compressors which form the life line of refrigerators and air conditioners, are more sensitive to under-voltages. This is because at under-voltage, more current is produced in the winding to form power loss (I^2R) which eventually heats up the winding. The result is burnt and or degradation of its performance thus leading to the malfunctioning of these expensive appliances.[5]

This project seeks, therefore, to present a simple and effective form of protection against system abnormal conditions of over-voltage and under-voltage so as to prolong the life span of electrical and electronic equipment connected to it. This device is the

"Electronic Controlled Circuit Breakers". The block diagram to achieve thus aim is shown in fig 3.1 which consists of four main units viz: power supply, network of comparators, triggering circuit and the relay.

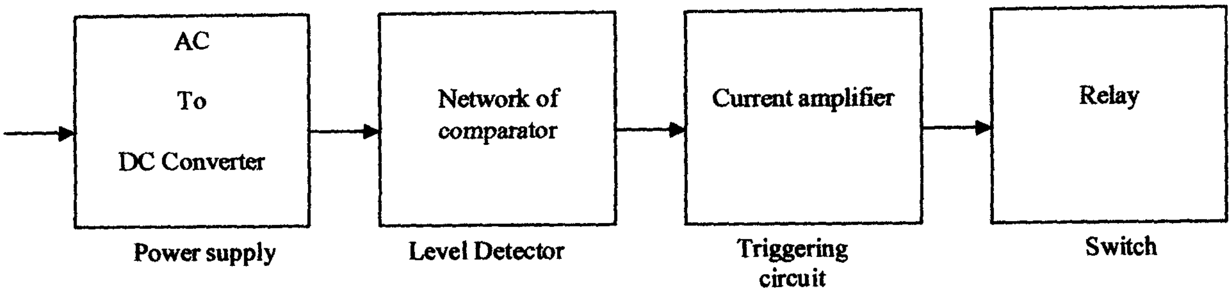


Fig. 3.1 Block Diagram of an Electronic Controlled Circuit Breaker (ECCB) for a double-phase power system

3.1 THE POWER SUPPLY

The power supply is a basic necessity in any system, be it electrical or electronic. A power supply converts the a.c. input of 50Hz power line (main) to dc output voltage. This positive voltage supply is needed for the amplifiers in electronic equipment. Transistors require dc collector voltage and dc bias for the base. Vacuum-tube amplifiers need the dc supply for plate and screen voltages.

The main component in the power supply is the rectifier which generally is a silicon diode. The diode conducts only when forward polarity of voltage is applied. An a.c input that has positive and negative half-cycles is converted to a d.c with constant polarity. Other additional components are then added to improve the d.c output.

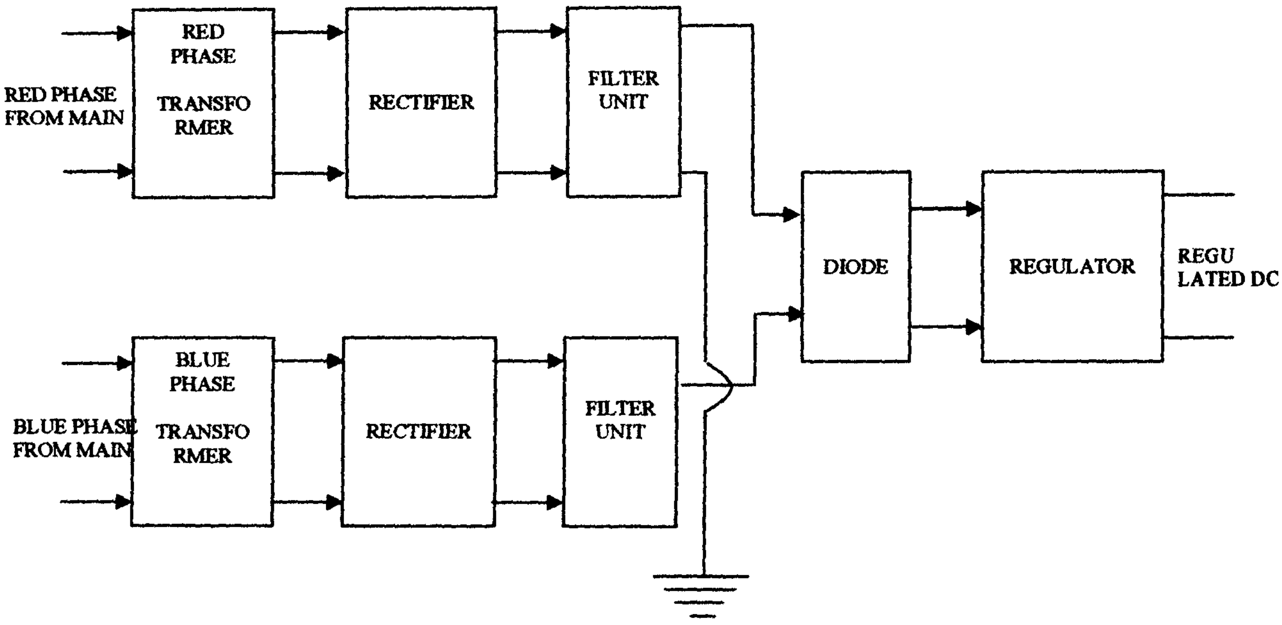


Fig. 3.2: Block diagram for a double-phase power supply system

3.1.1 THE TRANSFORMATION UNIT

The system begins with a transformation unit rated at 220/15V AC, 50Hz. The transformer which is a step-down type not only steps down the line voltage but isolates the rectifying and filtering unit.

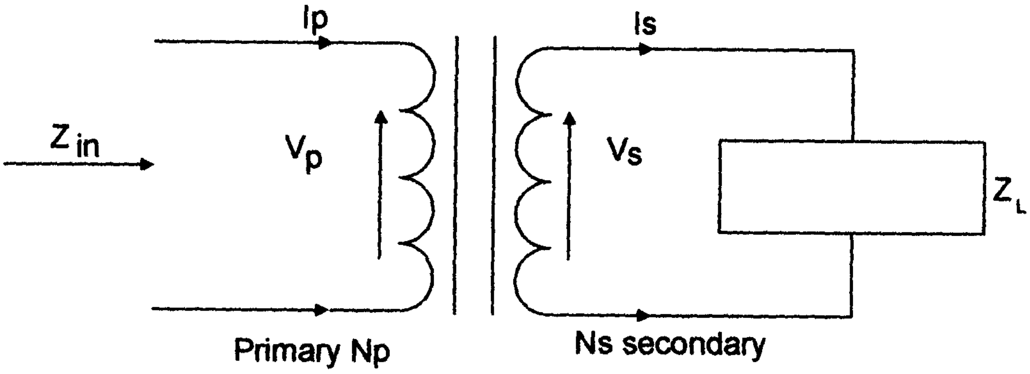


Fig. 3.3: The Transformer Action

The power on both primary and secondary sides are equal.

$$V_pI_p = V_sI_s \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad (3.1)$$

or

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad (3.2)$$

Load impedance is

$$Z_L = \frac{V_s}{I_s} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad (3.3)$$

Input impedance is

$$Z_{in} = \frac{V_p}{I_p} = \frac{V_s.N_p/N_s}{I_s.N_s/N_p} \quad - \quad - \quad - \qquad (3.4)$$

$$= \frac{V_s}{I_s}\left(\frac{N_p}{N_s}\right)^2$$

$$= Z_L\left(\frac{N_p}{N_s}\right)^2 \quad - \quad - \quad - \quad - \qquad (3.5)$$

Step down transformers are used to reduce high voltages to the lower voltages. The transformer equation is given by:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p},$$

Assumes that the power produced in the output is equal to the power introduced in the primary input. The efficiency of such ideal transformer is:

$$\eta = \frac{P_2}{P_1} \times 100\% \quad - \quad - \quad - \quad - \quad - \quad - \qquad (3.6)$$

$$= \frac{V_2 I_s \text{Cos}\phi_s}{V_1 I_p \text{Cos}\phi_p} \times 100\% \quad - \quad - \quad - \quad - \quad - \quad - \qquad (3.7)$$

In practice though, the transformer efficiency is normally less than 100%. [6] This is accounted for by some losses in power. There are about four losses encountered. These are:

(a) The energy losses dues to leakage of magnetic flux.

(b) The energy lost in the form of heat ($=I^2R$) in the coils

(c) Energy lost in the form of eddy current formed in the soft-iron core.

(d) Energy lost due to hysteresis in the iron.

3.1.2 THE RECTIFIER

A rectifier circuit is one which links an a.c supply to a d.c load, that is, it converts an alternating voltage supply to a direct voltage. Rectifier circuits divide broadly into two groups, namely the half-wave and full-wave connections.

The half-wave circuits are those having a rectifying device in each line of the a.c. supply, all cathodes of the varying devices being connected to a common connection to feed the d.c. load, the return from the load being the a.c. supply neutral. The expression half-wave describes the fact that the current in each a.c. supply line is unidirectional.

The full-wave (bridge or double-way) circuits are those which are in effect two half-wave circuits in series, one feeding into the load, other returning load current directly to the a.c lines, eliminating the need to employ the a.c. supply neutral. The expression full-wave is used because the current in each a.c supply line, although not necessarily symmetrical, is in fact alternating.

The control characteristic of the various circuits may be placed broadly into one of three categories: namely, uncontrolled, fully-controlled, and half-controlled. The uncontrolled rectifier circuits contain only diodes, giving supply voltage fixed in magnitude relative to the a.c. supply voltage magnitude. In fully-controlled circuits, all the rectifying elements are thyristors. This is often described as a bi-directional converter, as it permits power flow in either direction between supply and load.

The half-controlled rectifier circuits contain a mixture of thyristors and diodes which prevent a reversal of the load voltage but do allow adjustment of the direct (mean) voltage level. The half-controlled and uncontrolled (diode only) circuits are often described as unidirectional converters, as they permit power down from the supply to the d.c. load.

For the case in review, the stepped down voltage from the secondary output of the transfer undergoes rectification via a full-wave rectifier circuit. This will give a voltage which changes polarity during each cycle of the a.c. waveform, that is, it is positive in one half cycle and negative in the other half giving an average of zero over the cycle.

The full-wave rectifier which provides a d.c. output during both cycles of the input voltage, shall be used for the purposes of our study.

The bridge (full-wave or double-way) connection is arranged to be uncontrolled as shown in fig. 3.4 below:

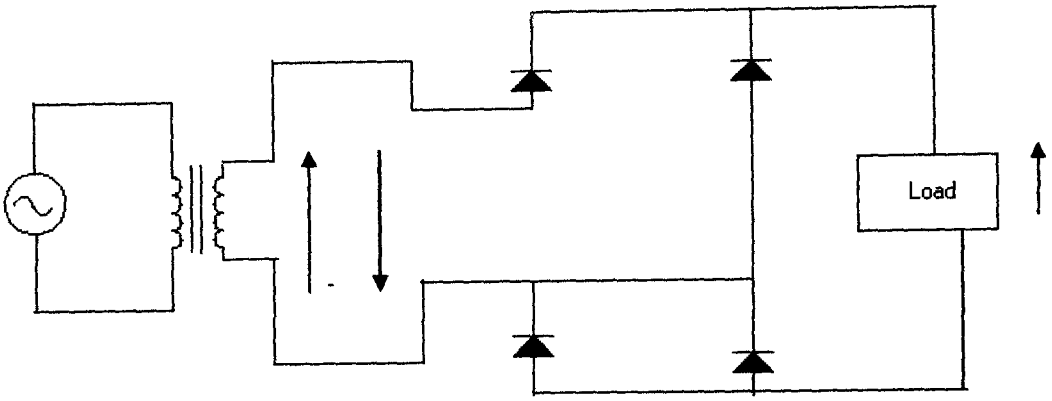


Fig. 3.4: Single-Phase Bridge Circuit Connection

The circuit in fig. 3.4 clearly shows the concept of two half-wave circuits in series making the full-wave connection, two diodes with common cathodes feeding into the load, two diodes with common anodes returning the load current to the other supply line.

3.1.3 THE SMOOTHING (FILTERING) CIRCUIT

The output of the rectifier is not a pure d.c. voltage but a pulsating d.c. containing a ripple component. To reduce the ripple voltage to a tolerable level, it is generally necessary to include some kinds of filter circuit between the rectifier and the load. Filtering circuits can be accomplished by using capacitors and either inductors or resistors. Inductors when used for this purpose, are often referred to as chokes once they chock off any variations of the current and for easy conduction of only d.c. The filtering capacitor is connected in shunt with load.

Ripple factor

This is a measure of how effective the filter is reducing the a.c. ripple in the d.c. output voltage.

$$\text{Ripple factor} = \frac{V_{ripple}}{V_{d.c}} \times 100\% = \frac{I_{ripple}}{I_{d.c}} \times 100\% \qquad - \quad - \quad - \qquad (3.8)$$

3.1.4 VOLTAGE REGULATOR

It is desirable for a power supply output voltage to remain constant regardless of load variations. Voltage regulation improves the filtering. Some common voltage regulator circuits include:

(a) Zener based circuit

(b) Feedback regulator-shunt and series.

For zener based circuit, at forward bias, this diode behaves like the ordinary diode. However, in reverse bias, a zener diode can be used to simply produce a fixed reference voltage.

Regulation is accomplished by the zener diode with the series regulation resistor Rs. The limiting resistor Rs has the function of providing a voltage drop that varies with the amount of load current. However, the diode must have enough voltage to operate in its breakdown mode to provide enough reverse current. When the unregulated voltage tends to increase because of less load current, the diode passes more current and higher voltage drop across Rs (fig. 3.5). When there is a decrease in the regulated voltage, Rs has a lower voltage drop. The net result is a constant d.c. output voltage across zener diode and R_L.

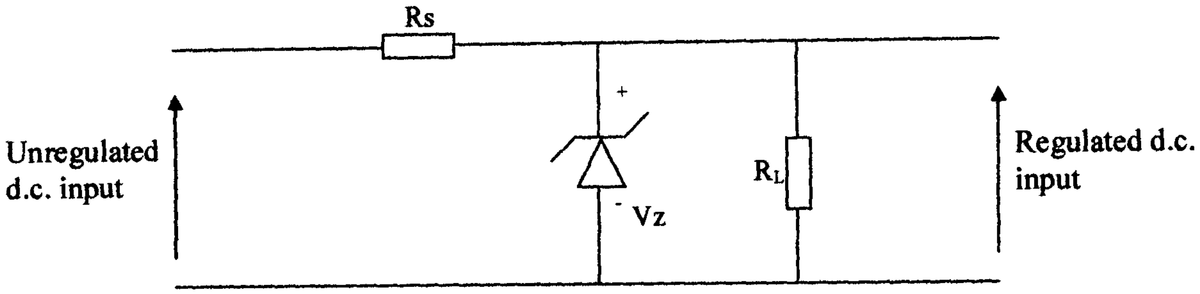


Fig 3.5: Zener Diode Rectification

3.2 COMPARATORS

The function of a comparator is to compare two voltages A and B. If A is greater than B, the comparator will remain at one voltage level; if B is greater than A, then the output will be at a second value. Thus, if B is changing relative to A starting at a lower value and increasing, as the level of B passes that of A, the output will switch. The relationship is shown in the transfer characteristic in fig. 3.6

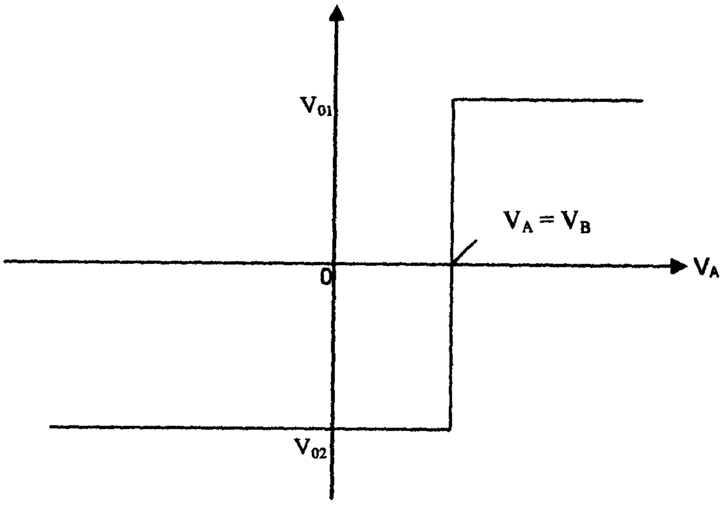


Fig. 3.6: The transfer characteristic of a comparator

General purposes operational amplifier (op-amps) can be used as comparators with considerable flexibility in design. Alternatively, special purpose comparator op-amps may be used. In either case, negative feedback is not used and the basic configuration is an open-loop arrangement. The absence of negative feedback means that stability problems do not arise and faster op-amps may be used to provide more rapid switching of the output.

The op-amps is used in the open-loop mode, so that a very small input signal drives the output into saturation. Therefore, the output exists in either of two modes:

$+V_{out}$ sat or $-V_{out}$ sat. It stays at a high level ($+V_{out}$ sat.) when the non-inverting input voltage goes below the inverting voltage. For this study, the reference voltage was tied to the non-inverting (+) input, while the inverting input was used as the variable (V_{var}) input as shown in fig. 3.7 below, so that as long as the voltage in the non-inverting input (V_{var}), the output voltage, V_{out} will be at a high state (near +V). At a point where the variable input voltage, V_{var} becomes greater than the fixed reference voltage V_{ref}, the output voltage V_{out} will switch to low voltage level (near –V).

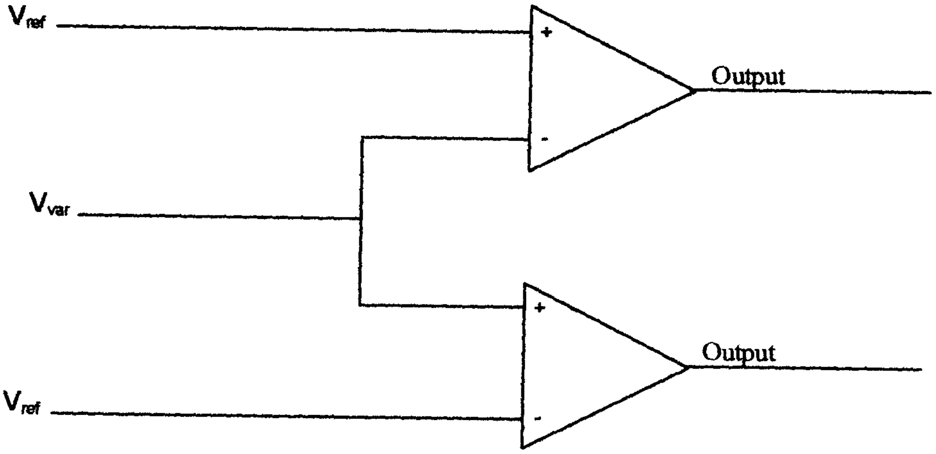


Fig. 3.7: The Comparator

3.3 THE CURRENT AMPLIFIER

This consists of four transistors with two each in both phases. When the output of the comparator (IC_2) is high (normal supply), the relay (RL_1) is then trigger. On occurrence of an abnormal condition (over-voltage), the 24v zener diode allow only 24v to the variable resistor Rv_1 and the excess voltage then flow to Q_1 which then ground Q_2 and such no voltage flow to the relay RL_1 making it to remain at no connection (NC). But when the voltage is low (under-voltage), the comparator IC_2 will go low, and such there will be no connection. The second phase which is the blue-phase is identical to the first-phase (Red-phase), as such follow the same principle of operation as that of the red-phase.

3.4 SWITCHING CIRCUITS

A switching circuit is one which there exist two stable states, the ON state and the OFF state. Many differential devices operate the two state conditions and can be used as switching devices. These include the relay and the electronic switches like the semi-conductor diodes, transistors, thyristors (or Silicon-Controlled Rectifier SCR) and the triac.

In this project, switching circuit is required to turn ON or OFF the power supplied to the output of the circuit breakers so that when the voltage is normal the output of the circuit breaker will be in the ON state and OFF when abnormal. The relay is used as the switching device.

3.4.1 THE RELAY

A relay is a device which is capable of existing in two position when controlled electricity to effect the operation of other devices in the same or another electric circuit.

The two modes or positions of all protective relays when it is not energized, i.e., when no current flows through it, the normally open (NO) with their contacts open and normally closed (NC) with their contacts closed.

3.4.2 THE ELECTROMAGNETIC RELAY

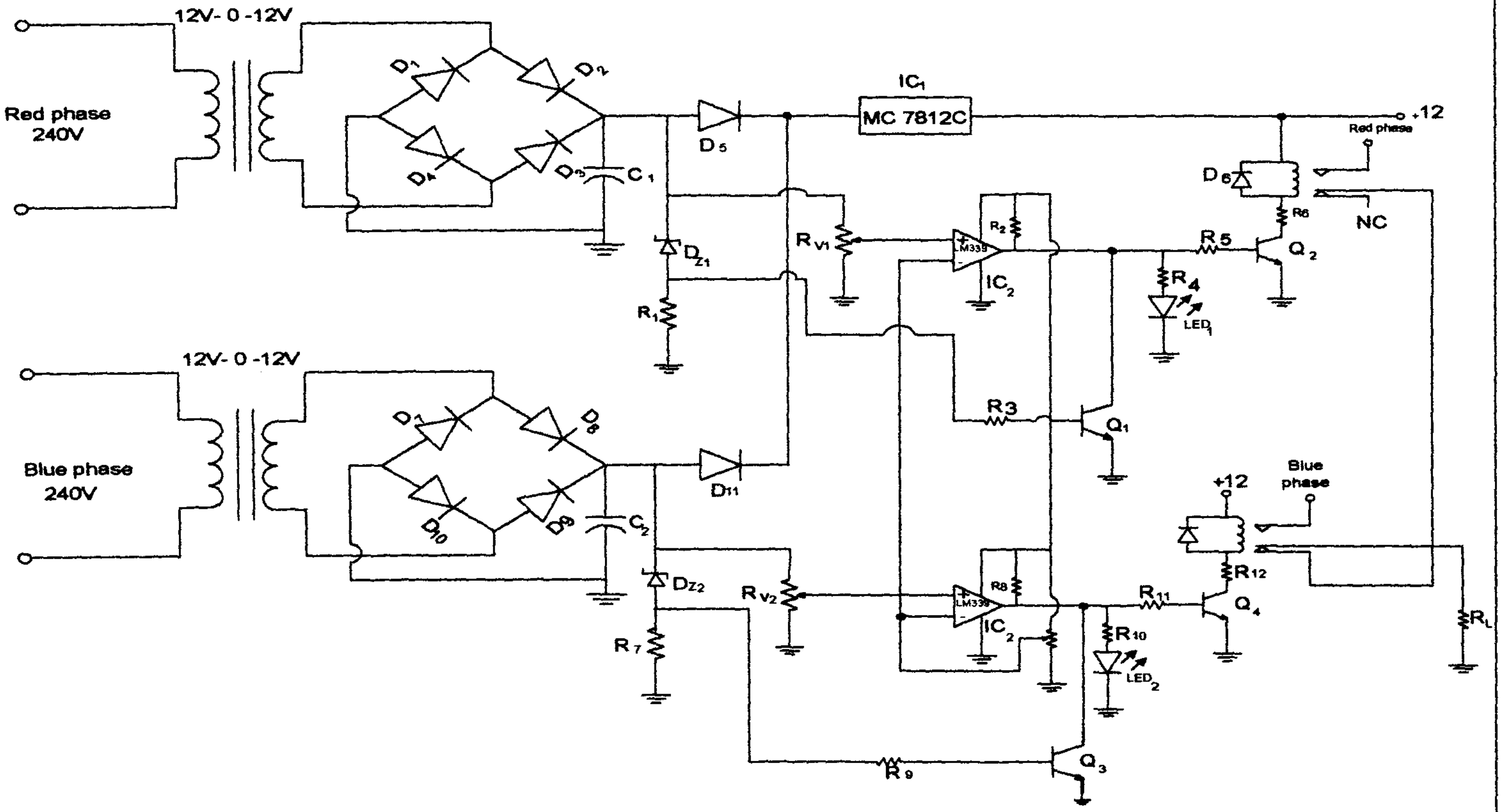
The most commonly used of all types of relay is the electromagnetic relay. Two main purposes for the use of this relay in this project are:

(1) To enable a large current to be controlled by a small current. It is therefore a sensitive switch, so that a small current change can control devices which use heavier currents such as lamps etc.

(2) To enable the control circuit to be isolated from the controlled circuit.

In the operation of an electromagnetic relay, controlling current flows though the coil and magnetizes the soft iron armature which is attracted towards the core when the magnetic pull overcomes the tension in the spring. The movement of the armature opens, closes or changes over the electrical contacts which are in the circuit being controlled. Owing to the large number of turns on the coil, a very small current through it produces a magnetic field strong enough to operate the relay. There is no electrical connection between the contacts of the control circuit and the controlling circuit.

COMPLETE CIRCUIT DIAGRAM OF AN ELECTRONIC CONTROLLED CIRCUIT BREAKER [ECCB]



CHAPTER FOUR

SYSTEM DESIGN, SPECIFICATION AND ANALYSIS

The electronic controlled circuit breaker (ECCB) of this project work is designed to work within the limit of the specification outlined below. Also, in the analysis only one-phase is used since the two-phase are identical. It is also important to mention here that the choice of the digital family used in this work is based on their fast response, moderate power consumption, good noise immunity and the cost.

4.1 DESIGN SPECIFICATION

1. Voltage profile 240 a.c supply
2. Double-phase system
3. Over-voltage
4. Under-voltage
5. Automatic switching

4.2 DESIGN ANALYSIS

Input rated voltage 240V a.c

Output rated voltage 15V a.c (r.m.s)

4.2.1 THE BRIDGE CIRCUIT

$$V_s = V_{max} \sin wt \quad - \quad -- \quad - \quad - \quad - \quad - \quad - \qquad (4.1)$$

$$V_{mean} = \frac{1}{\pi}\int_0^{\pi} V_s \, d(wt) \quad - \quad - \quad - \quad - \quad - \quad - \qquad (4.2)$$

$$= \frac{1}{\pi}\int_0^{\pi} V_{max} \sin wt \, d(wt)$$

$$V_{mean} = \frac{V_{max}}{\pi}\left[-\text{Cos } wt\right]_0^{\pi}$$

$$= \frac{V_{max}}{\pi}(-\text{Cos } \pi + \text{Cos } 0)$$

$$= \frac{V_{max}}{\pi}(1 + 1)$$

$$= \frac{2V_{max}}{\pi}$$

but $V_{max} = 27.5V$

$$\therefore V_{mean} = \frac{2 \times 27.5}{\pi}$$

$$= 17.5V$$

Voltage dropped across the bridge rectifier, V_d for maximum of 1v,

$$V_{mean} = \frac{2}{\pi} = 0.6v$$

$$V_d = V_{mean} \times 2$$

$$= 0.6 \times 2$$

$$= 1.2v$$

Transformer output peak voltage

$$\frac{15 \times 2}{\sqrt{2}} = 21.2V_{ac}$$

DC output voltage from the rectifier

$21.21 \times 1.2 = 25.45V_{dc}$

4.2.2 REGULATED DC OUTPUT

Voltage regulator MC 7812C

Ratings: input voltage 15-25V dc

output voltage 12V dc (1A)

Regulated dc output voltage = 12Vdc

4.2.3 FILTERING (SMOOTHING) CIRCUIT

Filtering capacitor:

Voltage, rated voltage 50V

Capacitance 2200µf

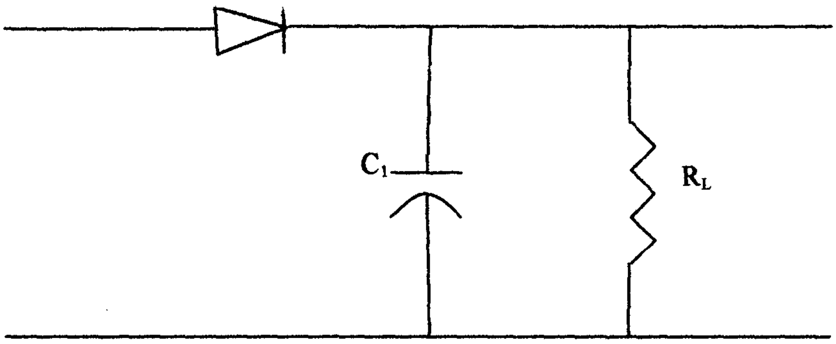


Fig. 4.2: Smoothing Circuit

$$\text{Ripple factor } R_F = \frac{\text{effective value of a.c component}}{\text{Average (or dc) component}}$$

$$= \frac{1}{2FC_1R_L} \quad - \quad - \quad - \quad - \quad - \qquad (4.3)$$

where f = supply frequency = 50Hz

R_L = load resistance = $\frac{V_{max}}{I_{rated}}$

$$V_{mean} = \frac{2V_{max}}{\pi}$$

$$V_{max} = \frac{V_{mean} \times \pi}{2}$$

$$= \frac{3.142 \times 17.5}{2}$$

$$= 27.49$$

$$\simeq 27.5V$$

It is important to note here that for a good smoothing, the ripple factor should be low enough. Let assume a ripple factor of 0.5%.

$$R_F = \frac{1}{2FC_1R_L}$$

$$C_1 = \frac{1}{2FR_fR_L}$$

$$= \frac{1}{2 \times 50 \times 0.5 \times 27.5}$$

$$= \frac{1}{1375} = 0.00072727\mu f$$

$$= 727.27\mu f$$

Preferred value = 1000μf

Capacitor working voltage

$V_{C1} > 1.2 \times Vd$

$V_{C1} > 1.2 \times 20$

$V_{C1} > 24v$

:. Preferred value of $V_{C1} = 50V$

4.2.4 INDICATORS (LED)

Power supply: Red-phase = red

Blue-phase = Green

Voltage requirement, $V_D = 2.2V$

Current requirement, $I_D = 1.5mA$

Output voltage, Vcc = 12V

Dropping resistor value = $\dfrac{Vcc - V_D}{I_D}$

$$= \frac{12 - 2.2}{15 \times 10^{-3}}$$

$$= 653.33$$

Indicator for working equipment

Red-phase = Red
Blue-phase = Green

$V_D = 5V$

$V_{cc} = 12V$

$I_D = 15mA$

Dropping resistor $R_D = (V_{cc} - V_D)/I_D$

$$= \frac{12 - 5}{15 \times 10^{-3}}$$

$$= \frac{7}{15 \times 10^{-3}}$$

$= 466.7\Omega$

4.2.5 CURRENT AMPLIFIER STAGE

$Q_1 = D400$

$IC_1 = 15mA$

$V_{CC} = 12V$

$IC_1R_6 = V_{CC}$

$$R_6 = \frac{V_{CC}}{IC_1} = \frac{12}{15x10\text{-}3}$$

Power rating $PC_1 = I^2C_1R_6$

$= (15 \times 10\text{-}3)^2 \times 800$

$= 0.18W$

$I_{E1} = I_{B1} + I_{C1}$

$h_{fe} \times I_{B1} = I_{C1}$

$40I_{B1} = 15 \times 10^{-3}A$

$$I_{B1} = \frac{15 \times 10^{-3}}{40} = 3.75 \times 10^{-4}$$

$I_{E1} = 3.75 \times 10^{-4} + 15 \times 10^{-3}$

$= 15.375mA$

$Q_4 = D400$

$I_{C2} = 16mA$

$V_{cc} = 12v$

$IC_2R_{12} = V_{cc}$

$$R_{12} = \frac{12}{16 \times 10^{-3}}$$

$= 750\Omega$

Power rating $P_{C2} = I^2C_2R_{12}$

$= (16 \times 10^{-3})^2 \times 750$

$= 0.192W$

4.2.6 RELAY PARAMETERS

Input impedance = 185Ω

Voltage requirement = 12v

a.c. of relay $I_r = \frac{12}{185} = 65mA$

Power consumed by the relays

$P_r = I^2_rR_r$

$= (65 \times 10^{-3})^2 \times 185$

$= 0.78W$

CHAPTER FIVE

CONSTRUCTION AND TESTING

5.1 CONSTRUCTION

The circuit for the electronic controlled circuit breaker using double-phase power supply is shown in fig. 3.8. In construction of this project for testing purpose, a unit-by-unit construction method was adopted. Each unit of the circuit was laid out on the vero board after being 'test-run' on the breadboard.

The transformer supplies 24v (center-tap) AC to the rectifier bridge. The output of the rectifier was test and the output observed on the oscilloscope. The signal waveform seen was that of a DC with some ripples. With the smoothing capacitor in place, its output was measured and was observed to have increased more than what it was before the capacitor. The waveform obtained was found to eliminate much of the ripples so that an almost pure DC waveform was observed. The output of the voltage regulator was also measured. This output connected to the oscilloscope almost remained constant indicating good stabilization.

Special care was taken during the construction of the comparator unit. This is because the slightest short circuit can lead to the damage of the ICs. IC sockets were used in other to prevent the ICs from being damage by exercise heat during the soldering which was carried out with care in consideration of the numbering of the legs.

In construction the relay circuit, a free-wheeling diode was connected in parallel with the relay to protect the relay from damage by preventing reverse current that will try to flow through it.

5.2 TEST RESULT

The variac and voltmeter were later used to test the working of the complete system. Using different input AC voltages, the table below shows various test result carried out.

Table 5.0: Test result on the system

AC input voltage	Output voltage
0	0
35	0
70	0
100	0
135	0
155	0
175	175
185	185
200	200
215	215
230	230
245	245
260	260
275	0

5.3 PACKAGING

Packaging is the encasement of the complete circuit. It provides:

(i) Physical protection for the sensitive components

(ii) It reduces the risk of electrical shock which may result from contact with exposed live parts of the circuitry.

Ply-wood was used for the packaging because of it good insulating property. Also, adequate provision was made to allow proper air circulation thereby preventing excessive heating up of the components.

5.4 COMPONENTS LIST

Diodes

$D_1 = D_2 = D_3 = D_4 = D_5$

$D_6 = D_7 = D_8 = D_9 = D_{10}$

D_{11} = IN4001

Resistors

Capacitors

$C_1 = C_2 = 100\mu f$

Resistors

$R_1 = R_3 = R_4 = R_5 = R_7 = R_9 = R_{10} = R_{11} = 1K$

$R_2 = R_8 = 10K$

$RV_1 = RV_2 = RV_3 = 50K$

Integrated Circuits

IC_1 = MC 7812C

IC_2 = LM 339N (Comparator)

IC_3 = LM 339N (Comparator)

Transistors

$Q_1 = Q_2 = Q_3 = Q_4$ = D400

Others

TF = Transformer (240/24V)

RE = Relay

CHAPTER SIX

CONSTRAINTS, CONCLUSION AND RECOMMENDATIONS

6.1 CONSTRAINTS

During the realization of this work, a lot of constrains were experienced, which include:

One major problem or limitation was that the values of components for this design were scarcely available in the market at all. This led to the redesigning of the work and those components not readily available were substituted with their equivalents or closest values.

After configuring the components on a breadboard, it did not give a perfect output when tested as desired. In the process of making adjustments, many components were damaged thus retarding the progress of the project. However, solving some of the problems led to a better understanding of the work.

Mention must be made of the incessant power failure, which resulted in the delay in the completion of the project.

Also, inadequate funds was a major concern to the completion of the project.

6.2 CONCLUSION

The design of the electronic controlled circuit breaker has been shown as one of the efficient ways pf curbing the effect of frequent occurrence of electrical faults and the stabilization of power supply. While some existing power supply equipment (or voltage regulators) are costly, bulky and complex, this design is easy to implement, portable, cheap, convenient and reliable.

It should be noted that this design is unique in the sense that the over-voltage and under-voltage fixed points can be readily changed by simply adjusting the three variable resistors at the comparator input to the desired threshold setting.

6.3 RECOMMENDATIONS

To ensure high performance and durability:

(1) The system should be kept in a well ventilated area where the ambient temperature of the system should not be more than the normal room temperature, otherwise the system will suffer great loss of heat which might damage it.

(2) The system should not be overloaded by connecting it to many equipment simultaneously.

(3) No object should be kept on top of the equipment and as much as possible, shock and vibrations should be avoided as this might result in a short circuit or open circuit in the internal circuitry.

And for further study:

(1) The design and construction of an electronic controlled circuit breaker which will incorporate not only under-voltage and over-voltage but also over-current should be given to succeeding set of project students.

(2) Since this work was done using double-phase power supply, it is recommended that a design involving a three-phase supply should be attempted.

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