DESIGN AND CONSTRUCTION OF AN AUTOMATIC THREE PHASE CHANGER

BY

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DEDICATION

This project is dedicated to my Lord and personal savior Jesus Christ, my parents, siblings, my friends and all who have in one way or the other contributed to my academic pursuit may the good lord bless you all abundantly.

DECLARATION

I Uchola Omata Wilson, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology Minna.

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To my principled and incorruptible head of Department, Engr.Yunusa Adediran (PhD), you are one in a million, I thank you sir for the discipline and sense of responsibility you have instilled in my colleagues and I. My project supervisor, Mr. J.G. Ambafi. I thank you for your assistance, support and encouragement throughout the course of executing this project. God bless you sir.

To the class of 2008 graduates of Electrical and Computer Engineering; the top is where all of us belong; I will definitely miss you. Lucy, Theodora, Atta, Moses, Samson, Chidi, and Hassan, we remain friends.

ABSTRACT

This project work presents the design and construction of an Automatic Three Phase changer with over voltage and under voltage protection. The circuit operates to select among available phases that has voltage supply whenever there is a power failure or abnormal voltage supply (below 180V and above 250V) in any of the phases. The design incorporates three subsystems namely, power supply unit , which provides operating voltage; over voltage and under voltage detector unit which dictates the permissible voltage levels required; and the phase change over switching unit utilizing relays to actualize the changing over.

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CHAPTER ONE

General Introduction

1.1 Expository Introduction

Energy plays an important role in living creatures on earth. Modern life-style has further increased its immense importance. Since an improved life-style means faster transport, faster communication, and faster manufacturing processes. All these lead to an increase in energy requirement for all those modern systems [1].

At present due to its demands for higher efficiency more usage and better controllability. Electrical energy is the most popularly demanded form of energy. Whether we obtain it in the usable thermal form (heating application), in mechanical form (electrical motors), for lighting purposes (illumination systems), or in transport systems [1].

Electric power is generated at the best locations while load centers (distribution points and load consumers) are generally away from there. Generating units and loads are connected by transmission lines. Thus energy system is divided into two main parts.

a) Utility (including sources and transmission networks).

b) Consumers (who utilize the electrical energy) [1].

This project shall focus on the consumer or utilization.

The three-phase A.C system for transmission and utilization is preferred to any other system because A.C generation is simpler and changing from A.C to D.C is very easy due to the availability of rectifiers [1].

In the present day arrangement (Nigeria as a case of reference), in which mains switch and rewirable fuse (board fuses, black fuses or cut-out fuses) are utilized at the consumer end. The cut-out fuse acts as a means of changing phases and it connects consumer with any one of the available three phases. When a line or phase loses power or supplies abnormal voltage (below 200V and above 240V). The cut-out fuse is then removed and re-inserted into the next appropriate fuse holder of an active line and then mains switch is turned on again. This process has to be repeated every time the active power loses power or supplies abnormal voltage.

This project aids in maximizing efficiency in the three phase utilization system. This is accomplished by selecting and delivering continuous power supply at consumer end provided there is at least one phase supplying a normal voltage.

1.2 Objectives

This project is aimed at the design and construction of an Automatic three phase changer which has the ability to select a phase with normal voltage supply (between 180V and 250V) at a commendable speed and effectively protect the consumer from under voltage and over voltage utilization . The realization of this project eliminates the need for the manual phase change over switch (use of cut-out fuses).

1.3 Methodology

The principle on which the circuit will operate is based on the sensing of abnormal voltages through the switching of transistors, triggering of operational amplifier and the change over from different phases was accomplished using electromechanical devices modular method of approach is used in the implementation of the design. Each section (module) of the design is taken separately and implemented. The modules were then integrated to realize the final circuit.

Three identical sets of circuits, one each for three phases, are designed. The designed circuits were simulated using application software (Multisim software). The implementation of the circuit was tried on base board (bread board). For initial testing then the final layout and soldering of circuit components was done on a Vero board. Another testing was carried out. The Vero board was placed in a casing and a final testing was carried out.

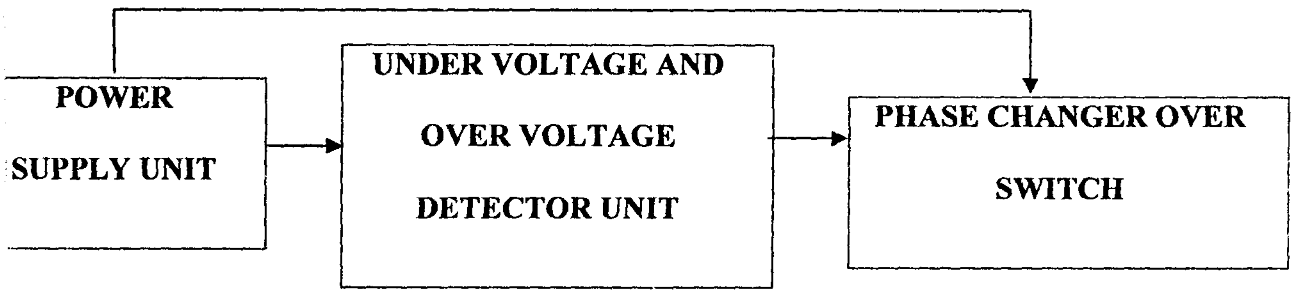

FIG. 1.1 Block diagram showing project modular design

1.4 Scope of project

The project work is described in five chapters. The first chapter comprises of general introduction while second chapter deals with the literature review and theoretical background of components involved in the project design. The design procedure and calculations are presented in the third chapter. The fourth chapter deals with tests, results and discussion of result. The final chapter gives the conclusion, problems encountered, improvements and recommendations.

1.5 Source of materials

All materials were procured locally from various electronic component vendors. The testing of the circuit was done in the Electrical/Computer laboratory at Federal University of Technology Minna on close supervision.

Chapter Two

Literature Review/Theoretical Background

2.1 Historical Background

Electricity was first discovered by Michael (1791 – 1867). Efforts made to convey electricity for utilization was realized by the invention of three phase alternating current electrical generation and distribution by Nikola Tesla, George Westinghouse and others in the 19^{th} century. Thomas Edison was the brainchild of the Direct current generation and distribution in the 19^{th} century [3].

However, electrical power supply has been found to be unstable and unreliable ever since the invention of the system. It has been marred by over voltages, under voltages and most times unavailability.

Different measures have been taken to solve this problem of unreliable electric power supply. One of the first possible solutions was the voltage regulator which came into use soon after Thomas Edison's breakthrough in the late 19^{th} century, due to the damage caused by fluctuating power supply voltage to electrical/electronic equipments. Discoveries were made by scientist on ways to reduce this effect, and this ultimately led to the voltage regulator in the 1920's. Its principle of operation was based on a fixed position field coil and a second field coil that can be rotated on an axis in parallel with the fixed coil [3].

Rotating the coil in one direction or the other away from the center position will increase or decrease voltage in the secondary movable coil. Hence when there is an over voltage in the power supplied, the voltage can be decreased by this regulator and if there is under voltage it will be consequently increased to the nominal supply voltage. This device however, was bulky and its accuracy in regulation was limited [3].

In the 1940's and 50's the Autotransformer was popular. In that period capacitors were more expensive than transformers so the autotransformer was used in the alternating current (A.C) voltage stabilizers. This device maintains an A.C output that is as close to the standard or normal mains voltage as possible, under conditions of fluctuation. The disadvantages were that it was bulky, costly and the mechanical parts easily wear out resulting in the lack of proper contacts between the charger and the taps of the autotransformer [2].

The present technological dispensation has experienced a change in voltage stabilization. The approach used is the Regulated Direct Current inversion approach. This uses the principle of switch mode power supplies. The regulated D.C output from the power supply is inverted using transformer. The output of the system is a square wave A.C voltage, which could be converted to obtain a pure sinusoid. This method produces good regulation. The system is not heavy but it is expensive and complex compared to previous systems. The major disadvantage is that it requires D.C power supply which is not utilized in most countries [2].

Phase controlled automatic voltage regulator (AVR) is one other attempt to realizing a good voltage regulation. In this system the load is connected in series with the voltage controlling device, which is usually a silicon controlled rectifier (SCR) and a transistor.

Voltage control is achieved by triggering the SCR at a voltage control circuit in such a way that the voltage across the load connected to the output terminals is regulated to the desired level.

The method is very fast in response to voltage fluctuation at the input. The system is not heavy and is inexpensive. Its disadvantage however, is that the output wave form is distorted.

Automation plays a predominant role in the modern scientific world. The automatic three phase changer gives a different kind of voltage supply regulation which is effective. This approach utilizes voltage sensing device and switching relays to ensure that the consumer makes use of supply which operates on a normal voltage level (between 200 and 240 volts). This system is relatively cheaper, light weight, and has a faster response. It ensures that the load is protected from over voltages and under voltages.

2.2 Theory of Operation

Switching apparatus can be defined as a device for opening and closing or for changing the connections of a circuit. There is a need to switch from a faulty phase supply to another phase supply operating on a normal voltage (between 200 and 240 volts). The present arrangement which utilizes the services of a semi rewirable fuse (cut-out) at the mains distribution board. The cut-out is removed manually from faulty phase terminal and connected in phase terminal operating on a normal voltage [5].

However, the focus is on automatic switching since it applies to this project.

2.3 Categories of Switching Circuits

The types of switches normally applied in power circuit includes:-

I. Disconnectors

II. Load interrupters

III. Safety switches

IV. Transfer switches for emergency power

i. Disconnection switches:-

They are used for changing the connection in a circuit or for isolating a circuit or equipment from the source of power all voltage classes. Interlocking is generally provided to prevent operation when the switch is carrying current. Latches may be required to prevent the switch from being opened by magnetic forces under heavy fault currents.

ii. An Interrupter or Load-Break switch:-

This is generally associated with unit substation supplied from the primary distribution system. It is a switch tasked with the functions of disconnection switch and load interrupter for isolating, at a rated voltage with current not exceeding the continuous current rating f the switch.

iii. Safety Switches:-

These kinds of switches may be fused or infused. They are operated by a handle from outside the enclosure and is so interlocked that the enclosure cannot be opened unless the switch is open or the interlock thereafter is operated. The application of fused enclosed switches is limited to a current not in excess of 80% of the current rating of the same switch without fuses.

iv. Automatic Transfer Switches:-

This is used for emergency and standby power systems. These switches provide protection against failure of the utility service.

This project utilizes the automatic transfer form of switching. The circuit is built around a transformer, comparator, transistor and relay. Three identical sets of the circuit, one for each phase are used. The power supply provides to the transformer is stepped down, which is then rectified by diodes and filtered by a capacitor to produce unregulated operating voltage. This voltage is then regulated. The 555 timer, which is configured to act as a Schmitt trigger, depending on the voltage it senses it would energize or de-energize the relay and hence any phase can be selected [9].

2.4 Power supply of switching circuit

The block diagram shown below is a typical D.C power supply system and it incorporates the transformer, rectifier, filter and regulator.

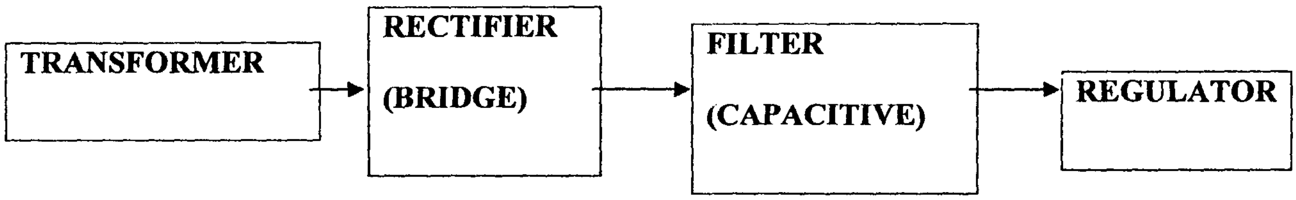

Fig: 2.1 Block diagram of power supply unit

2.4.1 Transformation

A transformer is a static or stationary electrical device by means of which electrical power in one circuit is transformed into electrical power of the same frequency in another circuit through the principle of electromagnetic induction. It can raise or lower the voltage in a circuit but with a corresponding decrease or increase in current [1].

A transformer consist of two or more coils of wire placed near each other so that most of the magnetic field generated by one coil passes through the other coil.

In practice a transformer always has a finite winding which cause the efficiency to be less than 100% for a sinusoidal input voltage, the flux, Φ varies alternately i.e. $\Phi = \Phi max \times sinwt$ and the instantaneous voltage in primary is to FARADAY'S LAW and it is stated mathematically as:

$E = -d\Phi/dt = wN\Phi_{max} \times \text{Cos}(wt)$

$= 2\pi fN\Phi_{max} \times \text{Cos}(wt)$

Where $W = 2\pi f$ and $\pi = 3.14$

The R.M.S value of E is given as:

$$E_{rms} = \frac{2 \times 3.14 \times F \times N \times \Phi max}{\sqrt{2}} = 4.44FN\Phi max$$

Since the flux is the same for the primary and secondary coils. The ratio of the secondary voltage and current can be derived from

$$V2/V1 = E2/E1 = \frac{4.44 \times F \times N2 \times \Phi_{max}}{4.44 \times F \times N1 \times \Phi_{max}}$$

$V2/V1 = N2/N1$.................................. 2.1

Where

V1 = Primary input voltage

V2 = Secondary output voltage

N1 = Number of primary turns

N2 = Number of secondary turns

When a transformer circuit is closed magneto to motive force (mmf) of I_1N_1 ampere-turn develops and the ratio of primary current and secondary current is attained

$N_1I_1 = N_2I_2$

$N_1/N_2 = I_2/I_1$

Combining 2.1 and 2.2 gives

$V_2/V_1 = N_2/N_1 = I_1/I_2$

Where,

I_1 = Primary current

I_2 = Secondary current

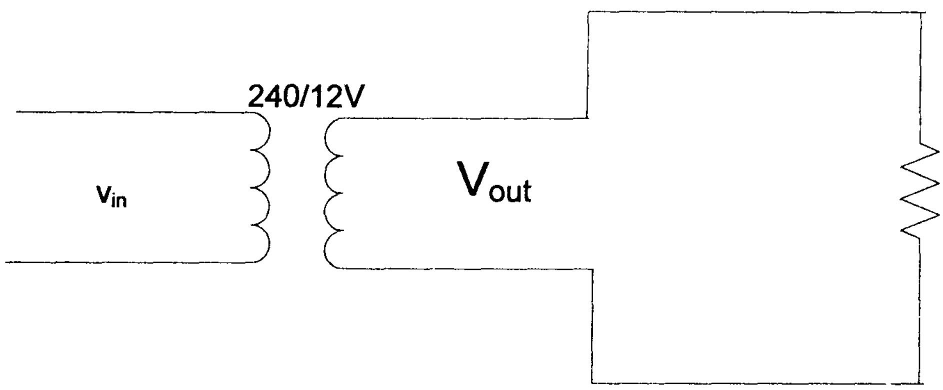

Fig: 2.2 Transformation Circuit

2.4.2 RECTIFICATION

Rectification is the conversion from A.C (alternating current) to D.C (direct current) voltage through the use of a rectifier. A rectifier circuit which employs one or more diodes to convert A.C into pulsating D.C voltage.

A rectifier may be used to carry out half or fill rectification depending on the application. This project is concerned with full wave bridge rectifier. The common type of bridge rectifier makes use of four discrete diodes arranged in a bridge network. They are connected as shown in figure 2.3(a).

Diodes D1 and D2 conduct an alteration as illustrated in figure 3.2(a) while D3 and D4 conduct negative half cycle on alternation. Both conducting paths deliver current to the load in the same direction [1].

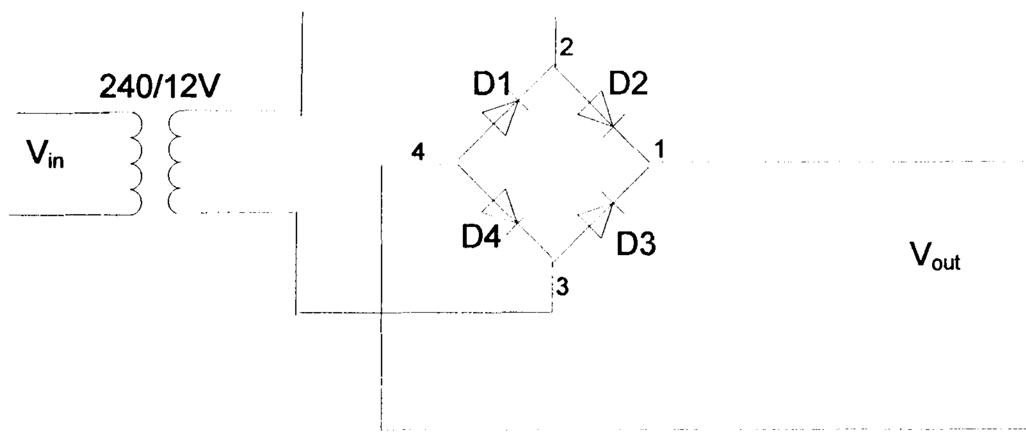

Fig 2.3 (a) Bridge rectifier

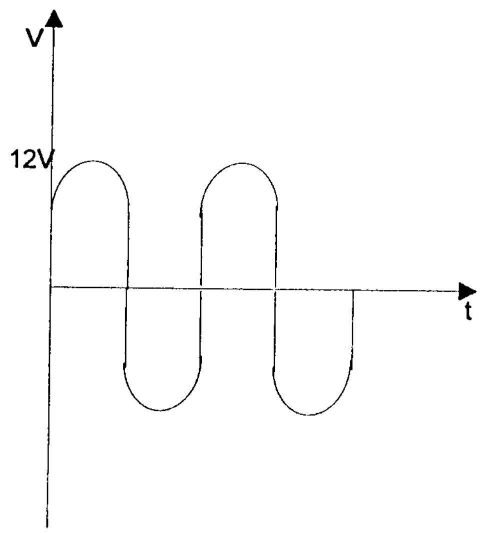

fig: 2.3(b) Input to a bridge rectifier

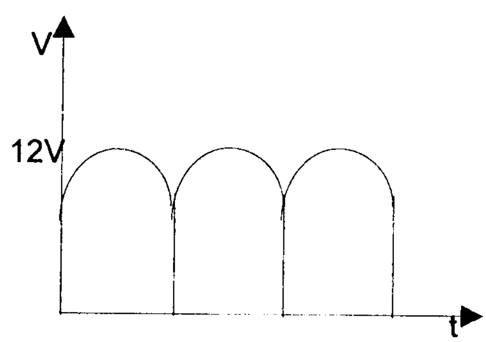

Fig:2.3 (c) output from bridge rectifier

2.4.3 FILTERING

A filter is required to smooth the pulsating D.C output voltage from the rectifier. Various types of filter are built using a combination of inductors and capacitor or each single one in combination with a resistor. However a single capacitor in parallel with the output from the rectifier performs the required filtering action.

Capacitor are used as shorts to the A.C source particularly one of very high frequency hence capacitor would remove any A.C component still contained in the output voltage from the rectifier. The capacitor stores energy during the conduction process and deliver it to the load during the non-conducting period, hence the time of flow through the load is prolonged.

The filter capacitor must be large enough to store sufficient amount of energy to provide a steady supply of current to the load, otherwise the output will drop as the load demands more up to date [1].

2.4.4 REGULATION

Unregulated power supply suffers from the drawbacks that their D.C output volt changes with changes in load or input voltage. A regulated power supply can be obtained by using a voltage regulator circuit.

A regulator is an electronic control circuit which is capable of providing a nearly constant D.C output voltage even when there are variations in load or input voltage.

The change in voltage from no-load to full-load condition is called voltage regulation. The aim of this voltage regulator circuit is to reduce these variations to zero or at least to the minimum possible value.

$$\% \text{ regulation} = \frac{V_{max} - V_{min}}{V_{max}} \times 100 \text{..................} 2.4$$

Where V_{max} = maximum D.C output; V_{min} = minimum D.C output voltage [1].

2.5 Over voltage and under voltage Detector Unit

The 555 timer operational amplifier (OPAMP) was in connection with other external components to define the system switching thresholds which will be able to sense overvoltage and under voltage conditions.

2.5.1 555 TIMER DEVICE

The 555 timer devices were configured to act as Schmitt triggers. A Schmitt trigger is a computer circuit that incorporates positive feedback. It is a comparator application which switches the output negative when the input passes upward through a positive feed back to prevent switching back to the other stat until the input passes through a layer threshold voltage thus stabilizing the switching against rapid triggering by noise as it passes the trigger point. The Schmitt trigger action uses a comparator to stable level crossing switches in contrast to the action of a straight reference comparison [8].

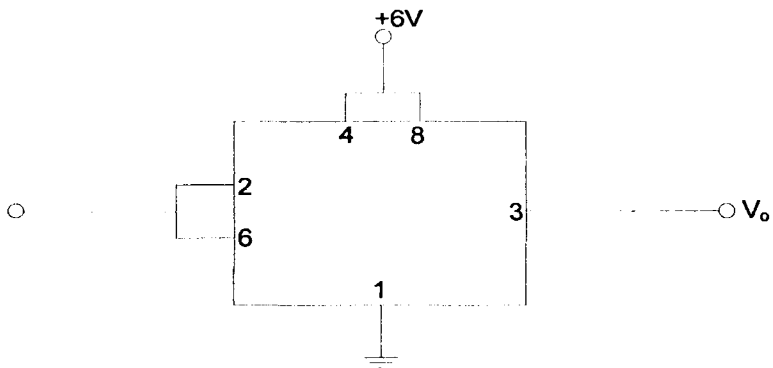

Fig: 2.4 555 timer configured as Schmitt trigger

2.5.2 ZENER DIODE

They are used to maintain a fixed voltage. They are designed to breakdown in a reliable and non-destructive way so that they can be used in reverse to maintain a fixed voltage across their terminals. This characteristics means that the zener diode can be used for the following applications

- Over voltage protection(our main concern)
- Limiting the clipping circuit
- Voltage stabilizer.

The figure 2.6 shows how Zener diodes are connected with a resistor in series to limit the current flowing through it [1].

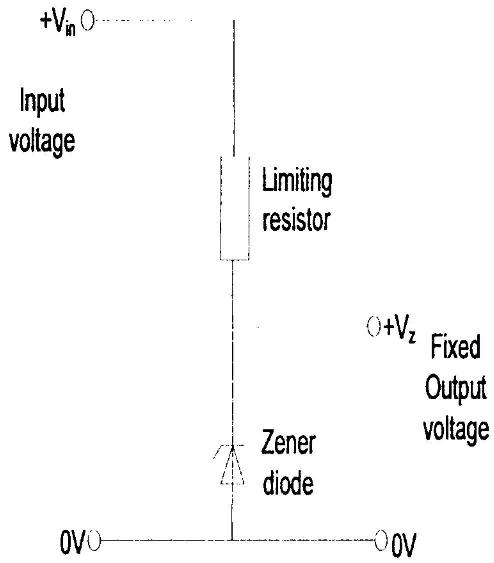

Fig: 2.5 Zener diode

2.5.3 BIPOLAR TRANSISTOR AS SWITCH

When a transistor is used as a switch it must be either off or fully on. The bipolar transistor can be used in such a way that its collector voltage swings between two extremes. This is exactly equivalent to a conventional switch. To implement an NPN transistor as a switch. Figure 2.6(a) and 2.6(b) below shows a typical example.

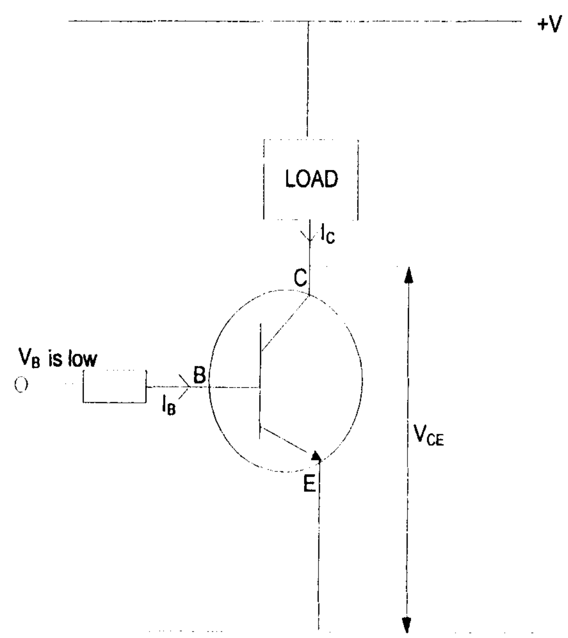

Fig: 2.6 (a) BJT with base emitter junction reversed biased

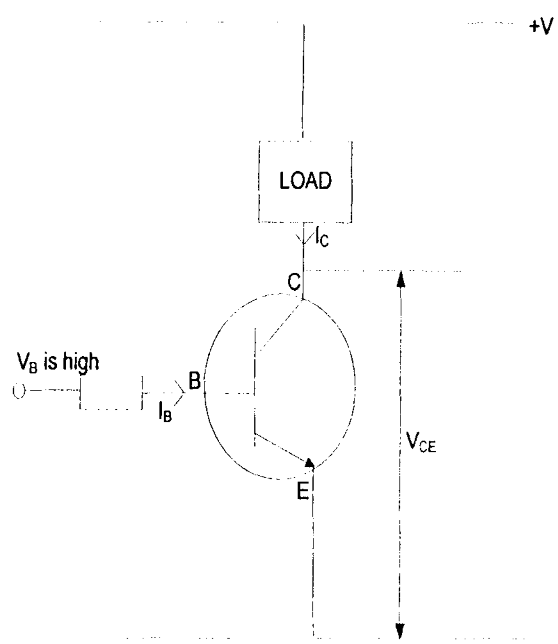

Fig: 2.6 (b)BJT with base-emitter junction forward biased

In figure 2.6(a), the base emitter junction is reversed biased by holding the base voltage at a suitable low voltage with respect to emitter. This prevents the transistor from conducting with the result that the output voltage will raise to the value close to Vcc. The transistor can only switch off completely if the impedance between the collector an emitter is infinite. At impendence less than infinite, a current will flow from supply through the load resistor and transistor to ground. With the saturation illustrated in figure 3.2.3(a), the transistor is regarded as being off but with small leakage current Iceo will flow, causing a potential drop across the load resistance equal to Iceo x Rc. Output voltage Vout= Vcc-Iceo. In the figure 2.6(b), the base emitter junction is forward biased by holding the base voltage at a suitably high potential with respect to the emitter. The transistor will conduct heavily and will saturate at a maximum value of collecting current Ic max. The output voltage can only be exactly equal to zero if the impedance between the collector and emitter becomes zero; this would cause the entire supply voltage to be dropped across he resistance RL. If this happens, then the currents is given by

$$I_c = V_{cc}/R_L.$$

As the transistor is not a perfect switch, Ic(max) will be less than Vcc/RL and small voltage Vce(max) will remain across the collector-emitter of the transistor [1].

2.6 PHASE CHANGER SWITCH

This unit comprise of relay as the change over switch which is connected with a free wheeling diode to protect the relay from spiking voltage and an LED (light emitting diode) is present in this sub-system to indicate if the relay is de-energized or energized.

2.6.1 RELAY

A relay is an electrical device which opens and closes under the control of another electrical circuit. It could be referred to as an electromechanical device because when a current flow through its coil, the resulting magnetic field attracts an armature hat is mechanically linked to a moving contact. The object of many electromechanical systems is to control a simple and right, buzzer, electric motor or solenoid. A relay is an excellent method of isolating a logic device from a high voltage circuit [6].

There various kinds of relay applied for different functions. The relay made use of in this project is a latching relay because it has two relaxed states (bi table)

2.7 REVIEWS ON PREVIOUS WORKS

There have been various approaches to realize the automatic three phase changer. The sensing device used by those works involved the 741 operational amplifier. The disadvantages of this are that this kind of operational amplifier only offers a single input threshold. Hence input signal near that of the threshold could cause the output to switch rapidly back and forth. This leads to instability of the switching relay [4].

This project makes use of a Schmitt trigger. When the input is higher than a certain threshold, the output is high, then the input is below another chosen threshold, the output is law; when the input is between the two, the output retains its value and turns and thus relay maintains its state. This implies that the Schmitt trigger has some memory.

This project also offers over voltage protection with the implementation of Zener diode and C9014 transistor.

CHAPTER THREE

DESIGN AND IMPLEMENTATION

3.0 SYSTEM DESIGN AND PROCEDURE.

The design of the automobile three phase changer involves or incorporates the following sub-systems.

- A suitable power supply
- An overvoltage and under voltage sensor.
- The phase change over switch

3.1 DESIGN OF THE POWER SUPPLY

3.1.1 THE SELECTION OF THE TRANSFORMER

The power supply was derived from three phases via three separate transformers as shown in figure 3.1. The three 12V, 0.5A step-down transformer were used to provide low A.C voltage from 240V A.C mains.

The ratings of the transformers were also chosen because the 12V is sufficient, if rectified and regulated to operate the D.C components such as transistors, 555 timer and relays in the circuit.

3.1.2 SELECTION OF RECTIFIER

The transformers were connected to full wave bridge rectifiers to produce D.C output voltage of amplitude given by the expression

$$V_{dc} = [(V_{r.m.s}\sqrt{2} - 1.4)]$$

Where, Vr.m.s = root mean square input voltage

$\sqrt{2}$ = r.m.s to peak scaling factor.

1.4 = the combined forward voltage drop of two adjacent conducting diodes in a rectifier.

For a 12V r.m.s input voltage, the peak output was deduced as

$$V_{dc}\,(peak) = [\ 12\sqrt{2} - 1.4] = 15.56V$$

3.1.3 SELECTION OF FILTER

This D.C voltage through Rectifier Bridge was smoothened by a capacitor of capacitance value deduced from the expression

$$C = I\,T/\,V$$

Where, I = maximum load current

T = 1/F

F = supply frequency

V = maximum A.C ripple voltage.

From a regulated 6V output, the minimum input voltage into regulator was 8V (from manufacturer's data). The load current was computed from the summation of the current drawn by the different subsystems.

Relay current = relay voltage/ coil resistance

The relay coil resistance has measured at 400Ω and the relay voltage has rated at 6V.

I relay = 6/400 = 15mA

The maximum load current is drawn when the three 555 timer devices are switched to energize the relays and three indicators LED's are turned on for the three relays.

I relay (total) = I relay x 3 = 15mA x 3 = 45mA

With the three LED's on

I_{led} (total) = I_{led} x 3

This project makes of LED rating 10mA. Hence, I_{led} (total) = 10mA x 3 = 30mA

$\Sigma I = I_{relay} + I_{led}$ (total)

= 45mA + 30mA = 75mA

For a regulated 6V output on a 15.56V peak, the maximum A.C ripple voltage of

(15.5 - 8) was calculated for

V = 15.5 – 8 = 7.5 V

Using the expression

C = I T / V

I = 75mA

T = 0.02s

$$C = 0.075 \times 0.02 / 7.5 = 200\mu F$$

The above capacitance was thus given as the minimum needed on the protected system. However, it was increased to 2200μF to improve system specification at lower A.C line voltages the accompanied voltage rating of capacitor chosen was 25V. For efficiency the capacitor voltage to should be 1.5 times higher than maximum D.C voltage. This is deduced as

$$1.6 X\ 12V = 18V$$

To ensure efficiency and compensation for losses a 25V, 2200μF smoothing capacitor was utilized.

3.1.4 SELECTION OF VOLTAGE REGULATOR

A three terminal voltage regulator I.C 7806 was chosen to regulate the rectified unregulated D.C voltage. The pins definitions are as follows

Pin 1 – unregulated input D.C voltage

Pin 2 – ground

Pin 3 – the regulated output.

The I.C 7806 was chosen for this design because a +6V regulated voltage was required to drive the relay and 555 timer. For maximum voltage regulation, adding a capacitor parallel between common leg and the output is usually recommended. This eliminates any high frequency A.C voltage that could otherwise combine with the output voltage. A 4.7μF, 16V capacitor is used for this design.

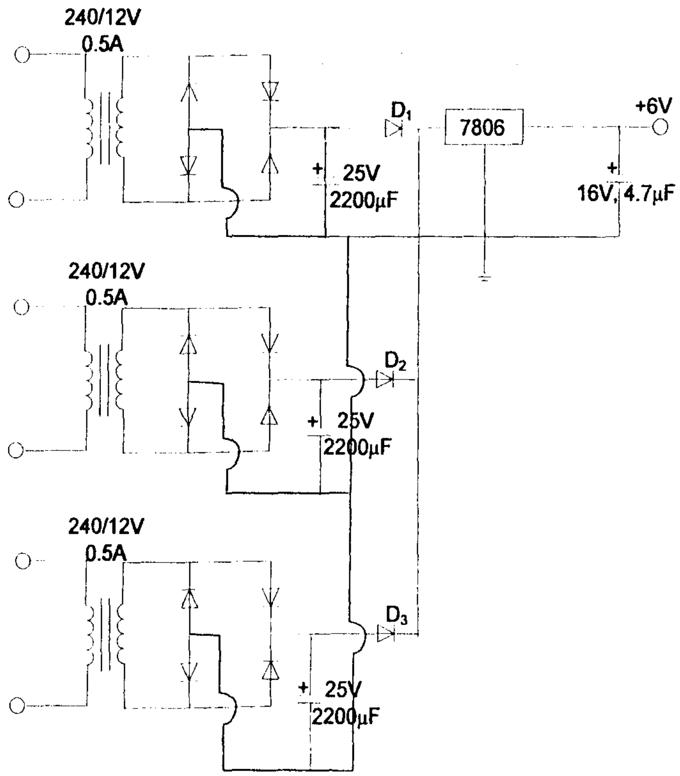

Fig 3.1: Power supply unit

3.2 DESIGN OF THE OVERVOLTAGE AND UNDERVOLTAGE SENSOR.

3.2.1 SELECTION OF 555 TIMER

The 555 devices were configured as Schmitt triggers. This implies that they are operating at zero frequency, hence the 555 timer are not oscillating. In the Schmitt trigger mode, a 555 device switches ON/OFF at two different input voltage levels.

The 555 timer device maintains a high output level until V_{in} rises above 2/3 Vcc, at this point output switches low were Vcc = 6V

Therefore threshold 1 = 2/3 x 6 = 4V

The output remains low until the input voltage applied to pins 6 and 2 drops below 1/3 Vcc. The output then switches high. Threshold 2 = 1/3 Vcc = 1/3 x 6 = 2V

The output transitions were used to energize and de-energize the relay switches. The input voltage into pins 6 and 2 of the Schmitt gates were taken from a potential divider connected across the output as shown in figure 3.3.

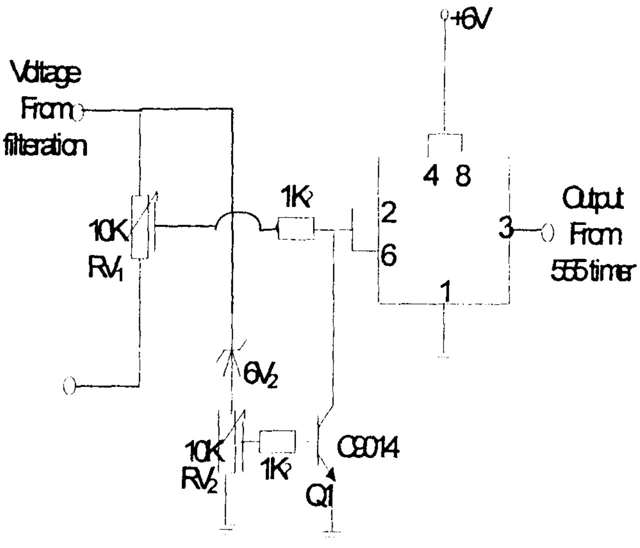

Fig 3.2 Schmitt trigger with potential divider network connected across

Two voltage take-off points were provided on the D.C supply. The overvoltage and under voltage sense output. V_{R1} was adjusted to provide the desired minimum A.C input voltage below which load connection cannot occur this was about 180V. V_{R2} was adjusted to yield the maximum allowable A.C input voltage of about 270V.

The voltage from RV1 has fed into pins 6 and 2 of the Schmitt trigger device via the 1kΩ resistance as shown in figure 3.3 above. This prevented loading on the D.C supply.

3.2.2 SELECTION OF THE DRIVER

In the design of the project a C9014 (NPN) transistor employed together with a zener diode and potential divider network was the driver of the circuit. This network is shown below in figure 3.4.

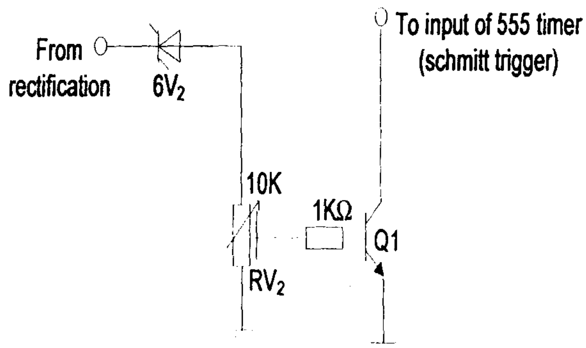

Fig: 3.3 Transistor and Zener diode network

On a supply of +6V the 555 timer gates had switching threshold of 1/3(6V) and 2/3(6V) . However, these voltages were increased in magnitude by the input attenuators.

The overvoltage section of the system works as follows:

If the voltage drop across the potential divider V_{R2} rises above V_{BE}, Q_1 is turned on, pulling pin 6 and 2 of the Schmitt gate to ground and forcing the output pin 3 high hence disconnecting the relay associated with the overload phase. At normal A.C line voltage, (below 270) Q is OFF.

The characteristic properties of C9014 NPN transistor is as follows:

$V_{IN} = 12V$

$V_{CE} = 10V$

$H_{fe} = 0.1769$

$I_C = 20mA$

Therefore R_C would be calculated as:

$R_C = V_{IN} - V_{CE} / I_C$

$= (12 - 10) / 0.002 = 2 / 0.002 = 1000\Omega = 1k\Omega$

Also,

$V_{IN} = I_B R_B = V_{BE}$... 3.1

Where, $I_B = H_{fe} \times I_C$.. 3.2

$= 0.1769 \times 0.002 = 0.0113A$

Hence,

$R_B = V_{IN} - V_{BE} / I_B$

$= (12 - 0.7) / 0.0113 = 1000\Omega = 1K\Omega$

The characteristic of the Zener diodes chosen are as follows,

Maximum Zener current I_2 (max)

I_Z (max) = P_Z (max) / V_2

The rating chosen were P_Z (max) = 0.5W and V2 = 6V2 (i.e. 6.2 volts)

Therefore, I_Z (max) = P_Z (max) / V_2 = 0.5 / 6.2 = 80.6mA

3.3 DESIGN OF PHASE CHANGE OVER SWITCH.

3.3.1 SELECTION OF RELAYS

The circuit utilizes three relays of rating 6V, 400Ω can resistance. These relay specifications were selected since the project work is a prototype and minimal D.C voltage supply is required for a light testing load. This relay rating is therefore appropriate for this design. The three phase switching relays were given the outputs of the 555 timer devices.

If the input voltage on any 555 timer falls below the minimum switching threshold, the corresponding relay driven by the device is de-energized, transferring the connected load to the next energized relay contacts.

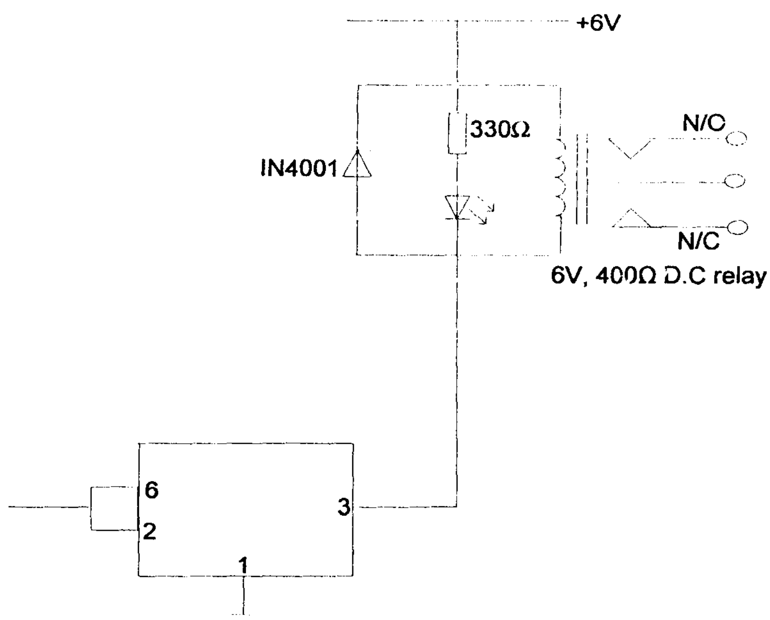

Fig: 3.4 (a) Relay switch

The load is connected to the relays as shown below:

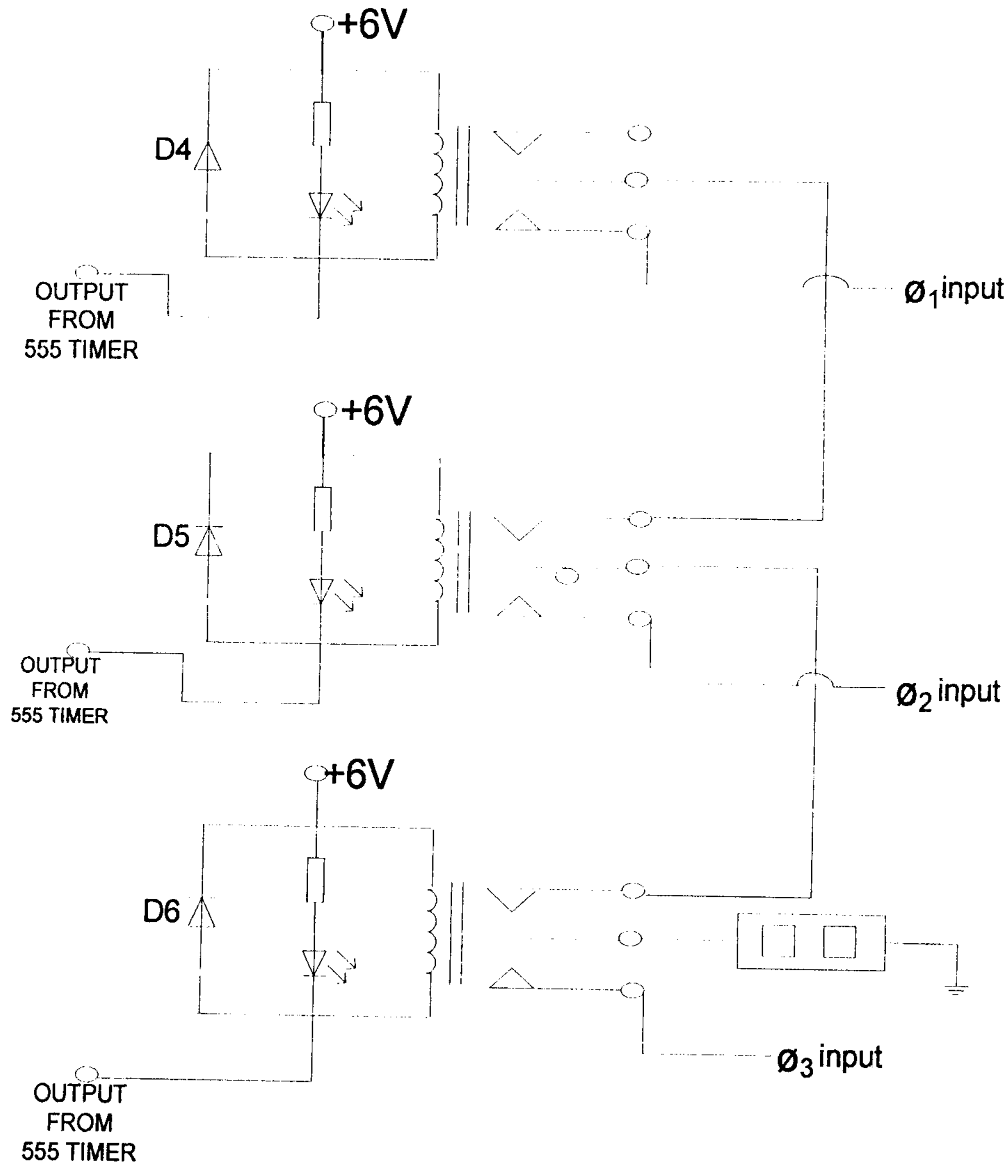

Fig: 3.4(b) Relay switch connected to respective loads

3.3.2 SELECTION OF DIODES, LED AND RESISTOR

From figure 3.5(b) $D_1 - D_3$ are commutating diodes (de-spiking diodes). The LED's 1-3 here used as system status indicators to indicate the selected phase and also to show if errors exist on any phase.

LED of 10mA was used as they were readily available and they can take load of 3.3 volts. Hence, a resistor with resistance

$$R_l = V_{led} / I_{led} = 3.3 / 10 \times 10^{-3} = 330\Omega$$

is placed in series with each LED in other limit excess current of over 10mA flowing through each LED.

3.3.3 PHASE STATUS INDICATORS

Phase 1, $\emptyset_1$, as shown in figure 3.5 (b) is allotted the highest priority in that if phase 1 input lies between the minimum and the maximum threshold, V_{MIN} and V_{MAX} respectively. It powers the load. However, if phase 1, $\emptyset_1$ is deselected, the load is then powered by either $\emptyset_2$ or $\emptyset_3$, depending on which one meets the system specification.

The LED's give an indication of phase selection or de-selection. The LED when lit shows the order in which load is provided.

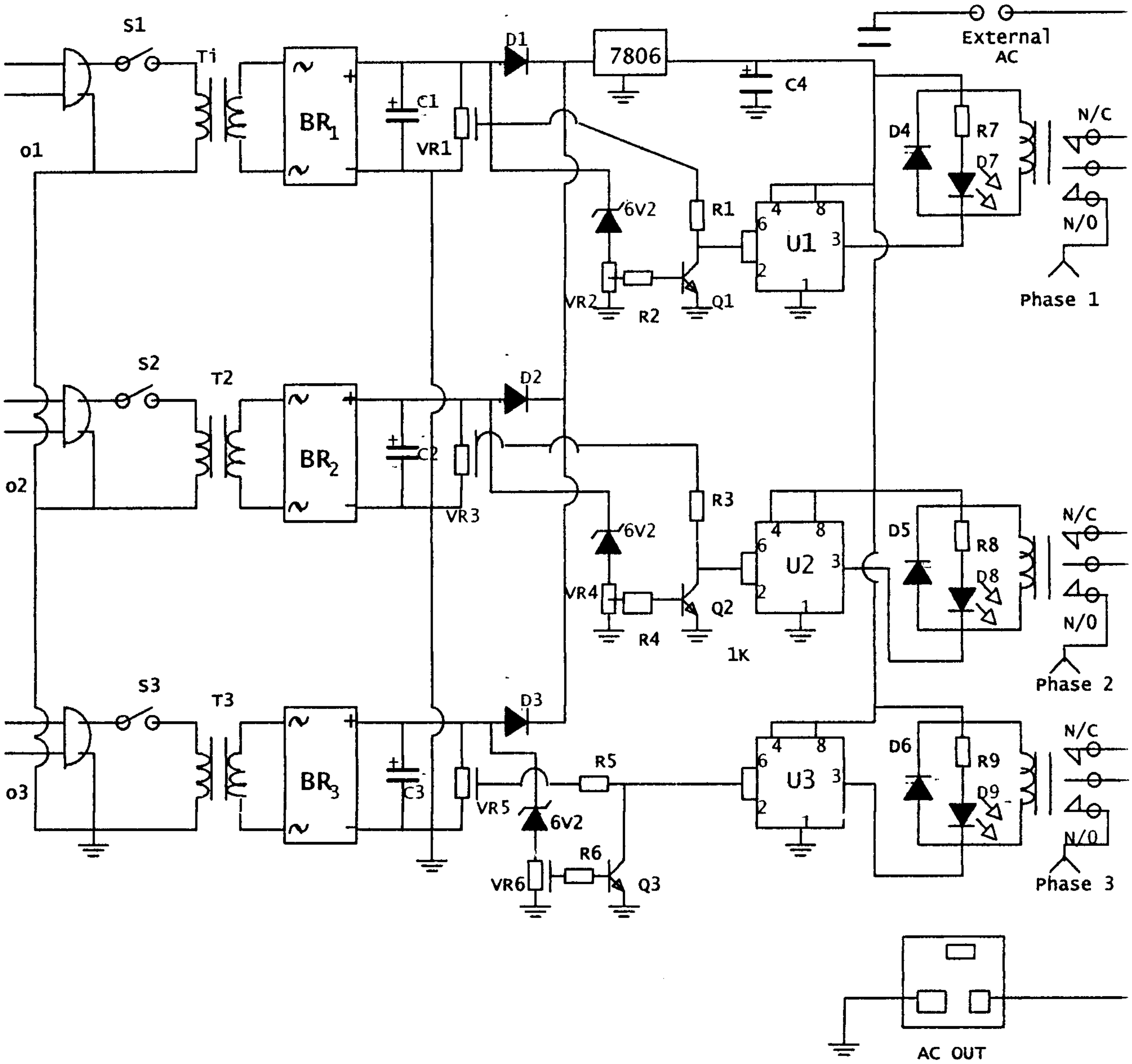

Fig 3.5: Automatic Three phase changer

Chapter Four

Test, Result and Discussions

4.1 Tests

4.1.1 Precautionary Measures

The following precautions were observed before the actual testing of circuit:

- Individual components were tested for continuity before use, to ensure that were all in good working order.
- Polarities of the components (where applicable) were considered before connecting to circuit. This was done to ensure proper sequence of operation.
- Normally open and Normally closed contacts of the relays utilized were identified with aid of digital meter or visual identification so as to avoid wrong connection of relay contacts.
- Necessary portions of the electronic board (vero board) were isolated to avoid continuity which may result in short circuit.
- A little soldering lead was used on joints in the circuit connection to avoid badly soldered joints.
- Moisture was prevented from contacting the circuit.

4.1.2 Testing of Modules

The circuit components are connected on base board (bread board). The power supply was tested using Digital multi-meter and values were recorded. Variable resistors RV1 and RV2 were adjusted to provide desired minimum and maximum allowable A.C input voltages respectively. A 60W filament bulb was used as load for testing. The work was then transferred to the vero board and soldered. Another test was carried out before the work was placed in a casing.

4.2 Results

Table 4.1 Truth table

LED	STATUS	FILAMENT BULB CONDITION	INTERPRETATION
1	ON 2, 3 = X	BULB LIGHTS	Load power supplied by phase 1, $ø_1$
2	ON 1 = OFF, 3 = X	BULB LIGHTS	Load power supplied by phase 2, $ø_2$
3	ON 1 = OFF, 2 = OFF	BULB LIGHTS	Load power supplied by phase 3, $ø_3$
	1, 2, 3 = OFF	BULB DOES NOT LIGHT	Load not powered

4.3 Discussion of Result

4.3.1 Problems encountered

While testing with bread board it was discovered that the voltage across the regulator was not up to 6V. This was probably due to the fact that the connections on the bread board did not make perfect contact as a soldered joint would.

In powering the circuit after its construction some of the legs of the relays were not making enough contact and this resulted in the burning of coil of the relay when the circuit was powered.

When phase 1, $Ø_1$ was connected the three LED's came ON instead of just the red one. This was because there was a common positive connection across the three phases.

4.4 Project Casing

Transparent PVC (poly vinyl Chloride) was used to protect the prototype work on the vero board. The dimension of 28cm × 9cm × 6cm was used and the joints of the casing were joined using Araldite adhesive.

Chapter Five

Conclusions

5.1 Summary

The design and construction of an Automatic three phase changer was realized. It however, calls for precision and carefulness especially in the designing and construction of the control or sensor part of the circuit, as this was the determining factor for establishing the threshold voltage in which the circuits switched.

5.2 Recommendation

This prototype should be improved upon as this is a necessary electrical device that eliminates the need for manual phase changing, thereby limiting the contact of the consumer with the electrical distribution board.

References

[1] R. L. Theraja and A.K. Theraja, a Textbook of Electrical Technology, 23rd edition, S. Chand and company Ltd, New Delhi, India, 2002, pp 224; pp1035-1036; pp1490; pp1907-1908; pp1957-1958; pp1922-1923; pp 1992-1993; pp2197-2198.

[2] www.national.com/voltageregulation.

[3] C. L. Wadhwa, Electrical power systems 6th edition, Japer Ltd, New Delhi 2004, pp185-189

[4] www.efymag.com/automaticthreephasechanger.

[5] Engr.S.O. Uwaifor, Electric Power Distribution, Planning and development, 2nd edition, Evans Ltd, Lagos, Nigeria, 2001, pp34-42.

[6] Kelvin R. Sullivan, Understanding Relays, 3rd edition, Automotive Technology Skyline college, Boston, 2004, pp7-12.

[7] www.eidusa.com/voltageregulators

[8] www.rapidelectronics.com/schmitttriggeraction.

[9] http://en.wikipedia.org/wiki/distribution_board.

Appendix

T_1-T_2	240/12V, 0.5A Transistors
S_1-S_2	One pole switch
BR_1-BR_3	Rectifier Bridge I.C
C_1-C_3	2200µf, 35V Capacitors
C_4	4.7µf, 16V Capacitor
D_1-D_3	IN5392, Diodes
D_4-D_6	IN4001, Diodes
D_7-D_9	10mA, Light Emitting Diodes (LED)
V_{R1}-V_{R6}	10kΩ, Variable Resistors
6V2	6.2V Zener Diode
IC 7806	Voltage Regulator IC with +6V Output
Q_1-Q_3	C9014 NPN Transistors
U_1-U_3	555 Timers Operational Amplifiers
R_1-R_6	1KΩ, Resistors
R_7-R_9	330Ω, Resistors
O_1-O_3	Plugs