DESIGN AND IMPLEMENTATION OF AN AUTOMATIC ACTIVE THREE PHASE SELECTOR FOR SINGLE PHASE LOAD

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EEE/12/0936

A PROJECT REPORT SUBMITTED TO DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING FEDERAL UNIVERSITY OYE-EKITI.

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN ELECTRICAL AND ELECTRONICS ENGINEERING.

NOVEMBER, 2017.

DEDICATION

This project work is dedicated to the glory of God, and to the memory of late Prince Augustine Adedapo Aina.

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CERTIFICATION

This project work titled "Design and implementation of an automatic active phase selector for single phase load" by Adeniyi Joshua Sunday, meets the requirements for the award of Bachelor of Engineering (B.Eng.) degree in Electrical and Electronics Engineering Department, Federal University Oye-Ekiti.

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ABSTRACT

This project presents a system which is a power based auto select technology which automatically selects an active phase from a three phase supply, for single phase load. This eliminate the use of conventional manual changeover using rewireable fuses. This design was implemented using a combination of Op-Amps 555 timer and relay (switch) circuit to achieve the set aim. Testing results showed that the load will continue to receive power even when failure occurs in any of the three phase supply. Areas of application includes homes and small business premises.

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SYMBOLS	MEANNING
V_p	voltage in primary winding
V_s	voltage in secondary winding (supply voltage)
I_p	current in primary winding
I_s	current in secondary winding
$V_{a.c}$	alternating current voltage
$V_{d.c}$	direct current voltage
I_{LED}	light emitting diode current
V_{LED}	light emitting diode voltage
V_{max}	maximum instantaneous voltage
V_{rms}	root mean square voltage
$I_{d.c}$	current flowing in direct current system
R_L	load resistance
V_r	ripple voltage
T_r	ripple periodic delay
F_r	ripple frequency
I_B	base current
I_C	collector current
V_{BE}	base emitter voltage
V_{CC}	common collector voltage

ACKNOWLEDGEMENT

I wish to acknowledge the mercies, blessings, and grace of Almighty God for giving me the wisdom, knowledge, strength and good health in accomplishing these tasks because without his will, none of these would have been possible.

I wish to acknowledge the support from my supervisors, Dr. Engr. J.Y Oricha and Engr. S. Sanni for their advice, support and intelligence in helping me to accomplish this project work. May God Almighty protect and guide you through your pursuits in life.

I would not forget to heartily appreciation the Head of Department Engr. O. Akinsanmi, the project coordinator Engr. G. K Ijemaru, and the entire lecturers in Electrical and Electronics Engineering Department who had impacted in me knowledge at one stages and the others.

My profound gratitude goes to Rev., Fr. A. A. Aina, Mr. & Mrs. Adebukola A. Aina, Mr. & Mrs. Graham A. Aina, and all the Prince A. A. Aina family for their care, and their strife towards ensuring that they provide financial and parental assistance throughout my course of studies in the university.

The efforts of my entire family members Adeniyis most especially Mrs Janet T. (Nee Adeniyi) cannot be overlooked. I thank and appreciate you all.

I'm indeed indebted to all the people, who by one way or the other have contributed to the successful completion of my university education.

Equally appreciated my fellow colleagues Babatunde, Ayodele, etc and my brothers Alademomi Adeyeye and Ogunniyi Seyi etc also, my special thank goes to Mrs Adeyinka Oluwatoyin (Iya Jummy) for her support and cares.

Lastly, my sincere and loving appreciation goes to Ayilola, Olabisi Felicia for her support, love, care and financial concerned during the course of the studies. Thanks for always being there.

CHAPTER ONE

1.0 INTRODUCTION

In Nigeria today, the problems of power outage across phases is rampant thus leading to some sensitive equipment and appliances being kept without power. Sometimes these equipment get damage as a result of constant power outage resulting from the failure of one phase or the other.
The power generation and supply in the country insufficient to meet the demand of the consumers. The power lines are frequently overloaded resulting to a trip by the action of switch gears or the load shedding processes undertaken by the distribution authorities known as Electricity Distribution Company, EDC (Nweke F. U. et. al 2012).
Power supply in Nigeria and in most developing and under-developing countries of the world is nothing to write home about. This has an adverse effect on the consumers of the electricity and the equipment that are operated from the main sources of supply. Electricity plays a major role in economic development of any nation but the supply keeps dwindling and sometimes not enoughin Nigeria. The increase in urbanization, development and offshoot of industries and companies keeps adding to the power instability and collapse (Nweke F. U. et. al 2012).

The project is designed to provide uninterrupted AC mains supply i.e., between 220 to 240 volt to a single phase load. This is achieved by automatic phase selector mechanism of the load from the missing phase to the next available phase in a three phase system. It is often noticed that power interruption in distribution system is about 70% for single phase faults while other two phases are in normal condition (Nirbhay S. et. al. 2017). Thus, in any commercial or domestic power supply system where three phase is available, it is advisable to have an automatic changeover system for uninterrupted power to critical loads in the event of missing phase. In this system auto selection is achieved by using a set of relays interconnected in such a way that if one of the relay feeding to the load remains energized always. Under the phase failure condition the corresponding step down transformer secondary delivers zero voltage which is duly rectified to DC and then fed to the logic gates comprising of AND & OR to switch on the next relay that delivers the power to the load. It also has a provision of connecting to an inverter source which delivers uninterrupted power to the load incase all the three phases are missing. The project is supplied with three transformers connected to the three phases supply. In most cases, domestic homes and offices, which employ single phase equipment for its operation sometimes experience challenges during unbalance voltages, overloads and under-voltages, in power supply, much time would be required in the process of manual change over. This means that time and the process needed for the phase change may cause serious damages to electronics equipment, hence, there is need for automatic phase switching system. (Adewale et.al. 2011). In a case where a single phase public utility prepaid meter is operated with a single phase power supply unit and there is phase failure from the public utility power supply, the prepaid meter will stop reading. At this point if the phase is not manually changed, the single phase prepaid meter will stop reading. That is to say someone needs to be present always to make the changes at any point in time. But to overcome these protocols, automatic systems need to be used (Oduobuk, E. J. et.al 2014).

1.1 BACKGROUND OF THE PROJECT

The intelligent phase selector is a system that is capable of comparing three phases and switching automatically to any of the three phases for a given single phase load. The system consists of three main parts namely; the transformer, comparators (which is the brain of the system) and electrical switching device (relay).The transformer used here is the step down type of transformer (it step down 240v to 12v) and these transformer is fed in with different phase voltage and rectified. Then fed in to a voltage regulator that has positive output.

The regulator outputs were connected to comparators. The comparators is the brain of the system because these comparators are connected in a way that each of them will give out an output. The relay in the system is where the output voltage is connected before it then supply the load.

1.2 STATEMENT OF THE PROBLEM

This project were carried out because of the under-listed problems which includes;

1. There has been usual manual changing of cut-out fuses when there is phase failure in homes and the offices which is tedious and prone to human error.
2. In the process of continual manual changing from one available phase to the other, prone to human error their might be loss of live and properties.
3. There might be fire outbreak in the process of manual changing from one phase to others.

1.3 MOTIVATION

The need to design and implement this project was due to the problem homes and offices are facing in trying to switch to the next active power phases, even with no technical skilled of people doing these at times.

1.4 AIM/OBJECTIVES OF THE PROJECT

The aim of this project is to design and implement an automatic phase switch for single phase load to overcome power fluctuation/phase interruption by selecting next most active available phase to feed the equipment without any notice of power outage.

OBJECTIVES OF THE PROJECT

1. To develop a simple low cost device aimed at easing the prevalent burden faced by delicate offices and homes who need very low but uninterrupted power supply.
2. To build a system that can be able to choose any voltage that appear to be high potential among other voltage.
3. Avoidance of risk in doing manual changeover or switching.
4. To avoid stress and inconveniences in selecting of phase voltage
5. Reliable power supply.

This work was achieved using many design approach, which include all the step used in designing the project such as soldering, connection of components, testing for continuity of the various components. The designing of the circuit was accomplished by a constant and detailed study of the constituent components. This involved the study of their characteristics in isolation, and when connected together with some other components.

CHAPTER TWO

2.0 LITERATURE REVIEW

This chapter going to looking into the definition of "Automatic three phase selector", and what brought about the automatic phase selector. Also, will look at way of effecting the design and it construction and the survey of previous projects topic.

2.1 REVIEW OF RELATED PROJECT

Oduobuk, E. J. et.al. (2014). described that the system was designed and simulated using (Multisim). The circuit components were mounted on a Vero board. LM324 integrated circuit (comparator) and 2N2222 transistors were used as active components alongside other passive components. Result shows that, when the three phase a.c inputs: Red phase, yellow phase and blue phase from public utility supply was fed to the system, the system compared the inputs with regard to phase imbalances, and the input with the highest voltage appears across the output. It also changes over from one phase to another immediately the circuit senses further phase imbalance.

Ayan Ghosh et.al. (2016). described that the power failure is a common problem which hampers the production of industry, construction work of new plants and buildings. It can be overcome by using a backup power supply such as a generator. The main aim of the work is to present the real idea of an automatic phase switch for 220V to

240V alternating current. Although, there are many designs that can perform almost similar functions like, single phase change-over switches, two phase automatic transfer switch and three phase automatic change-over switch, but this model is about an automatic phase switchover (phase selector) which is designed for only three phase A.C input power to single phase output applications.

Mbaocha Christian. (2012). described it as a designed to check the availability of any active phase, and the load will be connected to the active phase only. This feat is achieved with AT89C52 MCU. This controller continuously checks for active condition of all the phases connected to it, and the controller connects the load the load to the active phase Relay, controller. rectifier. using a relay. The relay is driven with a transistor. If two or three phases are active, the phase will be connected to the phase that is ON only and automatically transferred to the phase that is ON in the event of a main outage or from generator back to main when restored. An LCD is provided to display the status of the phase condition.

Nweke F. U. et.al. (2015). Explained that the device automatically switches over to the alternative phase that has current when there is power outage or extremely low voltage in the phase which the load is connected without the power being off. The selector links the load and the other phases and relay switches allowing the usage of the remaining phases where there is outage on the mains source without disturbing or interrupting the load. It maintains constant power supply to the load by automatically activating the phases when the need arises. This safeguards the electronics system from being damaged and burnout as a result of voltage instability. collapse. insistent outages which are paramount in under developed and developing countries.

Ahmed. M.S. et.al. (2006). Phase selector is a mechanism used in alternating or switching between power phases with respect to the availability of power on any of the phases. That over the decades, there has been frequent phase failure in the power phases resulting to manual switching of the fuse from one phase to the other. However, the focuses on the design of a phase selector using automatic switching mechanism. This during its operation, transfers the consumer's loads to the available power source in the case of power failure in the power supply from the national grid and automatically detects when power is restored to the failed phase and returns the loads to this source.

Jerry C. Whitaker (2005). The automatic phase selection to drive single phase load from the available three phase supply is already done by making use of microcontroller and opto-coupler ICs where microcontroller senses the incoming voltage levels from the three phases if voltage in any one of the phase namely R, Y and B, a signal is transferred to the relay mechanism through opto-coupler to perform the switching to Y phase if R phase goes down and finally to the B phase if both of the phases (R and Y) falls below the standard voltage of 200 Volts generally. The function of opto-coupler is just to provide the electrical isolation of low voltage circuit from that of the high voltage.

2.2 REVIEW OF FUNDAMENTAL CONCEPTS

The automatic phase selector switch, (single-phase automatic throw-over breaker) is designed to supply an industrial/ appliance single phase 220V/50Hz load from three phase four wire in order to maintain uninterrupted power supply of essential single-phase loads and protect them against unallowable voltage variations in the mains. For this purpose, a single-phase load is switched into a three phase circuit. Depending on voltage presence and voltage quality on phases will automatically select the optimum phase and promptly switch the single phase load supply to this phase. A phase prioritization is foreseen, i.e. the device restores the supply circuit to the user-selected priority phase after switching to reserve phases and regenerating the voltage on the priority phase.

2.2.1 POWER SUPPLY SYSTEM

Three-phase power is a method of electrical power that makes use of three wires to deliver three independent alternating electrical currents. The current in each wire is set off from the others by one-third of a complete cycle, with each current representing one phase. This means that a device operating off this type of power source receives a more stable flow of electricity than it would from single-phase supply system. Some three-phase power systems actually have four wires; the fourth is a neutral wire that allows the system to use a higher voltage Keljik and Jeffrey (2008). In a three phase power system there are three voltage phasor, separated by 120 electrical degrees.

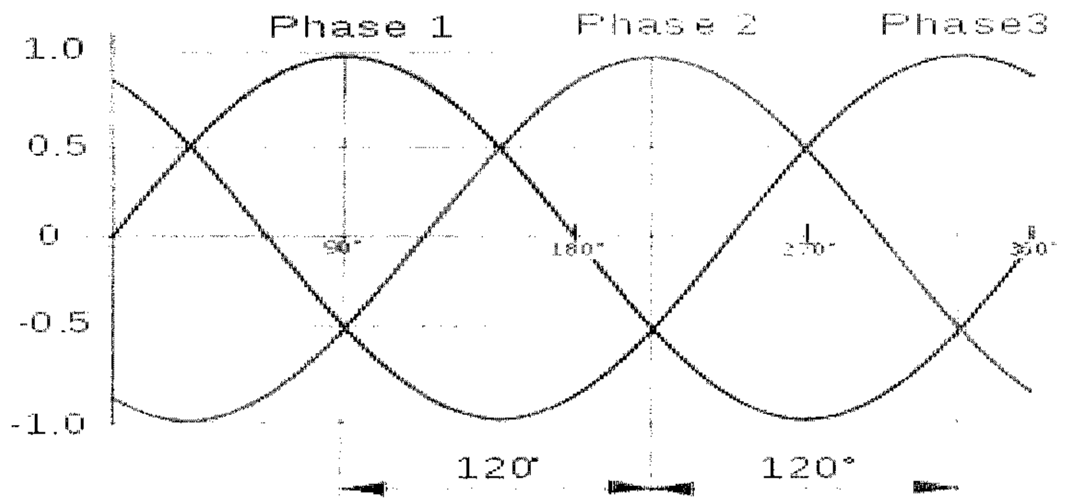


Figure2.1 Three voltage phasor

The three voltages may be written in time notation as:

is it is hazardous to human health, and many lives have been lost as a result of carbon-monoxide emission from generating sets.

The impact of power failure can be measured on the household, firms and the economy in general. These impact varies from the experience of dark night to a lot of damages being caused to household requirements. Many households have their appliances and equipment damaged due to frequent power failure (Joseph and Adebayo, 2012).

2.2.4 SYSTEM INTERACTIONS AND SOLUTIONS

In a typical manufacturing plant, the incoming power is distributed such that while there are several types of equipment and tools that are directly connected to the incoming three phase power, there is an even larger number of different controller. sensors and power supplies that are connected to a single phase source derived from the incoming line-line or line neutral three phase voltage. As such, a normal manufacturing plant will have a mix of single and three phase power supplies as front-ends for the equipment in the plant. Based on the sensitivity of typical equipment, many of the 40-50 power quality events that occur will cause process interruptions (Nagrath and Kothari 2000). Failure of specific equipment will depend on the input stage designs, distribution of symmetrical and asymmetrical sags, and the random nature of the point on wave at end of sag. This makes it very difficult for any single manufacturer to systematically track equipment failure within the facility, and to correlate it with a specific power disturbance. Positive correlation can be obtained by tracking equipment failures as recorded by the equipment manufacturer. For some specific products that have been investigated(including PLCs, robots, drives and medical equipment), it seems to be clear that input stage failures, in particular diode failures and burnt out traces/fuses/wires, seem to represent the most significant reliability problem. Two approaches are

At phase 1

$$V_{A(t)} = V_p \cos(\omega t) \quad (2.2)$$

At phase 2

$$V_{B(t)} = V_p \cos(\omega t - {}^{2\pi}/_{3}) \quad (2.3)$$

At phase 3

$$V_{C(t)} = V_p \cos(\omega t - {}^{4\pi}/_{3}) \quad (2.4)$$

Where:

v_p is the peak voltage

$\omega = 2\pi ft$, is the phase angle in radians

t, is the time in seconds

f, is the frequency in cycles per seconds.

2.2.2 CAUSES OF POWER FAILURES

A power outage (also called a power cut, a power blackout, power failure or a blackout) is a short-term or a long-term loss of the power to a particular area. There are many causes of power failures in an electricity network. Examples of these causes include faults at . damage to electric transmission lines, substations or other parts of the distribution system, a short circuit, or the overloading of electricity mains. Power outages are categorized into three different phenomena, relating to the duration and effect of the outage:

1. Faults at power stations

2. Damage to electric transmission lines. substations or other parts of the distribution system.

3. A short circuit, or the overloading of electricity mains.

- A permanent fault is a massive loss of power typically caused by a fault on a power line. Power is automatically restored once the fault is cleared.

A brownout is a drop in voltage in an electrical power supply. The term brownout comes from the dimming experienced by lighting when the voltage sags. Brownouts can cause poor performance of equipment or even incorrect operation.

A blackout is the total loss of power to an area and is the most severe form of power outage that can occur. Blackouts which result from or result in power stations tripping are particularly difficult to recover from quickly. (Carreras et.al. 2003).

2.2.3 EFFECT OF POWER FAILURE

Power as the one if not the greatest leading factor that drive any economy to substantial growth and development. Power is the indispensable (Gbadebo and Chinedu 2009). The force driving all economic activity in the nation and as a result a greater economy emerges.

However, power failures can also serve as a deterrent to economic growth of any nation. This stem from the fact that power outage cause a lot of damages to the household and the industries whose activities will be limited due to non-availability of regular power for equipment and machine used in the process of production (Gbadebo and Chinedu 2009). It is interesting to note that, due to erratic power supply in Nigeria many firms have shut down their plants due to high cost resulting from the use of generator to power their plants and offices. The resultant effect of this power failure possible to fix the problem. The first is based on designing the equipment to survive voltage sags. This may be distinct from the issue of having the equipment ride through voltage sag. As equipment specifications today do not include voltage sag recovery characteristics, it is no surprise that equipment remains unprotected. Power supply in Nigeria is anything but stable. This has adverse effects on the consumers of the electricity and the equipment that are operated from the mains sources of electricity supply in these parts of the world. This project provide an automatic switching mechanism that transfers the consumer loads to another phase in the case of power failure in the other phases. It automatically detects when power has been restored to the phases. It an important key in the provision of a continuous power supply for domestics use through a near seamless switching between the mains supply and the three phases.

The Automatic phase selector is a device that links the load and the three single phases supply and relay switches. This enables the use of either of the remaining phases when there is outage on the mains source. This device maintains constant power supply to the load by automatically activating the phases when there is need. Since the user might not always be in need of the generator. provision has been made to prevent the generator from starting should an outage occur. Sequel to the rate at which more sophisticated electrical/electronic gadgets are being procured and installed in our homes, hospitals and business premises, there is a justifiable need for a faster and more reliable change-over system in an event of power outage. Because of the study of the problems cause by phases this lead to the invention of a switching device called the "automatic phase selector.

CHAPTER THREE

3.0 DESIGN METHODOLOGY

This chapter gives full detail design of the comprehensive project. The designing of this circuit will be accomplished by a constant and detailed study of the constituent components. This involved the study of their characteristics in isolation, and when connected together with some other components. A rough design was always made with some theoretical backup. Those designs were implemented and tested using project boards to first construct the prototype circuit.

3.1 COMPONENTS USED IN THE DESIGN AND CONSTRUCTION OF THE AUTOMATIC THREE PHASE SELECTOR

Some important components of the automatic three phase selector are included below;

1. Transformer (step down transformer)

2. Diodes –IN4007

3. Zener diode -5.1V

4. Capacitor-1000microF, 35V-470microF, 12V

5. Operational amplifier (LM 393)

6. Resistors-3.3k, 10k

7. Potentiometer (variable resistor)-10k

8. Relay switches 12V, 400Ω

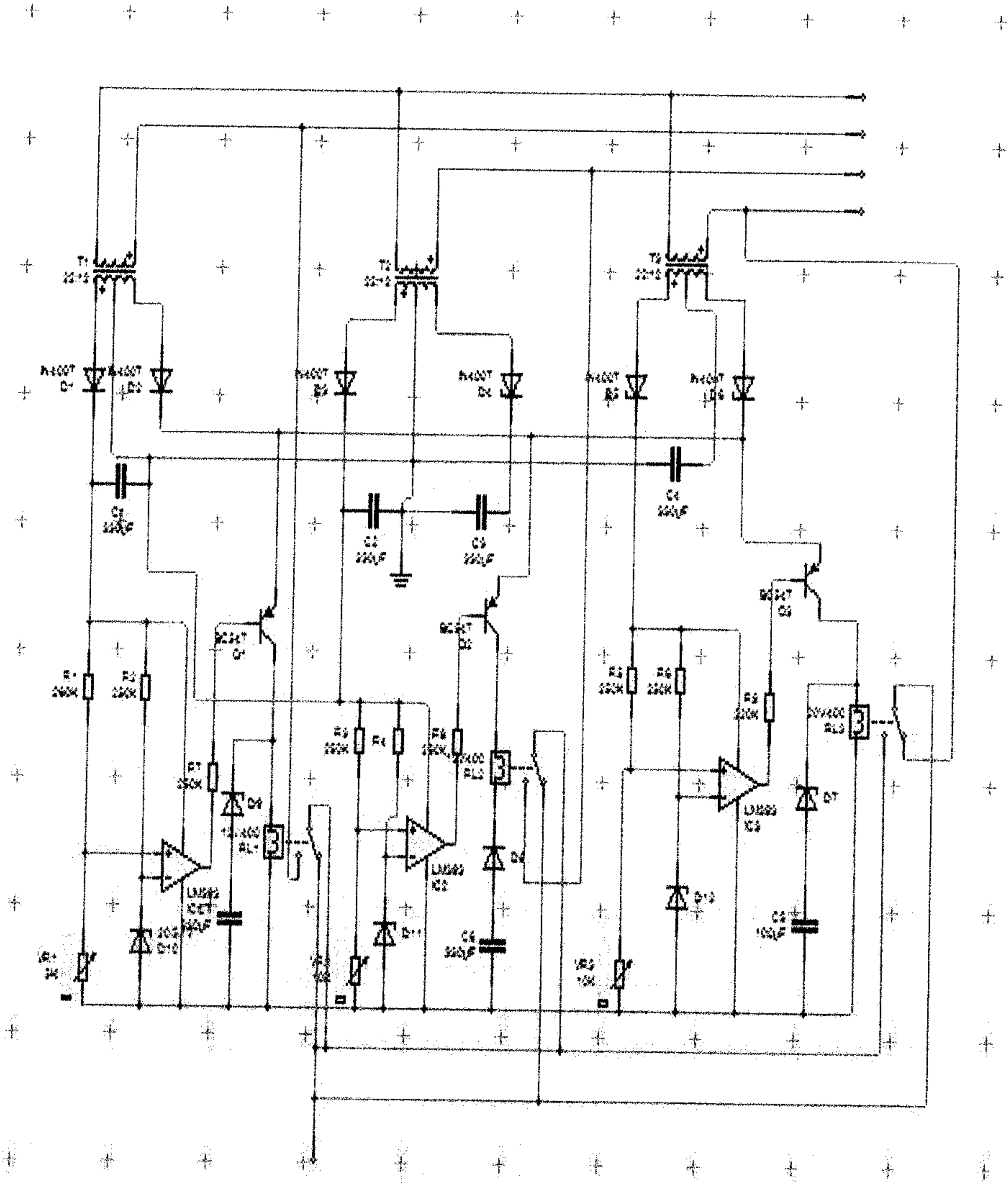


Figure3.1 Circuit diagram of an automatic phase selector.

3.2 THE DESIGN AND IMPLEMENTATION

The design procedure in this work is sub-divided into two sub-sections as theory and system analysis. The automatic three phase supply selector for a single phase load design was implemented in three units.

- Power supply Unit
- Voltage sensing unit
- Switching Unit

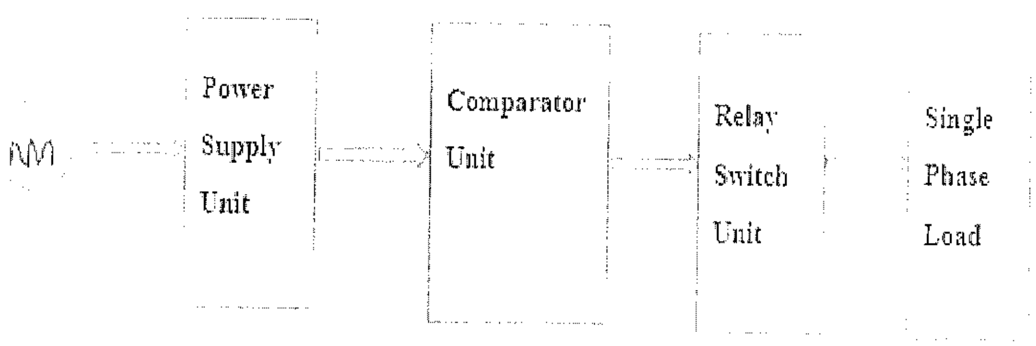


Figure3.2 Block diagram showing three main stages of the automatic phase selector.

3.2.1 THE TRANSFORMER (STEP DOWN)

In power supply sections, 240V/12V transformers and 1A fuses rating were chosen because it's met the requirement of the circuit.

In step down transformer, the parameter is selected to be capable of meeting the load current sees a major load of the relay excitation coil, they are capable of supplying up to the corking voltage of the relay as well as the relay current.

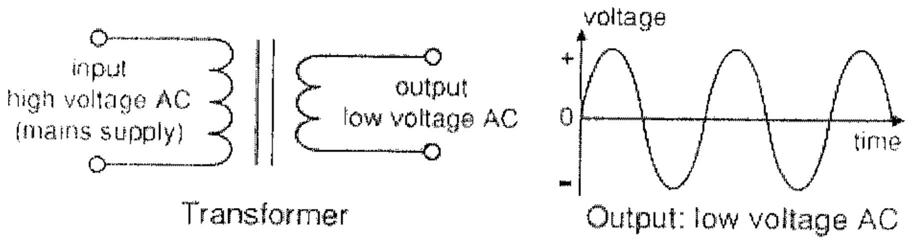


Figure3.3 Transformer and its output voltage waveform.

THE TRANSFORMER SPECIFICATIONS

In this project step-down of the 220Va c to 12V_{dc} was used.

CALCULATION

Transform input voltage (voltage in the primary winding), Vp = 220Vac

Transformer output voltage (voltage in the secondary winding), Vs = 12V

Transformer primary current (current in the primary winding), Ip = 200mA = 0.2A.

Transformer secondary current (current in the secondary winding), I_s = unknown.

From the expression given below,

$$\frac{Voltage\ in\ primary\ winding, Vp}{Voltage\ in\ secondary\ winding, Vs} = \frac{Current\ in\ secondary\ winding, Is}{Current\ in\ primay\ winding, Ip}$$

Where:

V_P = 220V

V_s = 12V

I_p = 0.2A

I_s =?

Therefore,

$I_s = \frac{Vp \times Ip}{Vs} = \frac{220 \times 0.2}{12} = \frac{44}{12} = 3.667A$

Therefore, the current of the transformer secondary current, $I_s = 3.667A$.

The limiting resistor (R_1, R_2 and R_3) were also calculated in order to determine the values of LED drawn currents (I_{LED}).

V_S = 12v (supply voltage), $V_{LED} = 2.2v, I_{LED} = 35mA$ (maximum allowable current across the LED) (Shepherd, J. et. al 2003).

$R_1 = \frac{V_S - V_{LED}}{I_{LED}}$

$= \frac{(12-2.2)v}{35mA} = \frac{9.8v}{0.035A} = 280\Omega$

Therefore, current drawn by Red LED,

$I_{LED} = \frac{V_1}{R_1} = \frac{12}{280} = 0.043A$

$\because I_{LED} = 43mA$

To determine R_2, $V_{LED} = 3.2v$, $V_s = 12v$ (supply voltage) and $I_{LED} = 35mA$ (maximum allowable current across the LED)

$R_2 = \frac{V_S - V_{LED}}{I_{LED}}$

$= \frac{(12-3.2)v}{35mA} = \frac{8.8v}{0.035A} = 251\Omega$

Therefore, current drawn by Yellow LED,

$I_{LED} = \frac{V_1}{R_2} = \frac{12}{251} = 0.048A$

$\because I_{LED} = 48mA$

To determine R_3, V_{LED} = 3.8v, V_s = 12v (supply voltage) and I_{LED} = 35mA (maximum allowable current across the LED)

$$R_3 = \frac{V_S - V_{LED}}{I_{LED}} = \frac{(12-3.8)v}{35mA}$$

$$= \frac{8.2v}{0.035A} = 234\Omega$$

Since 234Ω resistor is not standard, 250Ω resistor was used as the closest value in the design.

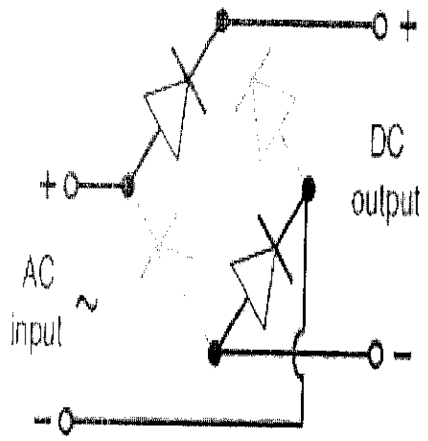
Therefore, current drawn by Blue LED;

$$I_{LED} = \frac{V_1}{R_2} = \frac{12}{250} = 0.048A$$

$\because I_{LED}$ = 48mA

3.2.2 THE RECTIFIER CIRCUIT

The rectifier circuit is a bridge rectifier circuit, which uses four IN4001 diode. The bridge rectifier circuit is a full wave rectifier circuit that converts alternating current to direct current since almost all user electronic garget uses direct current. In this project design the Full-wave bridge circuit was used because of its ability to produce a different reference voltage from the ac reference voltage.



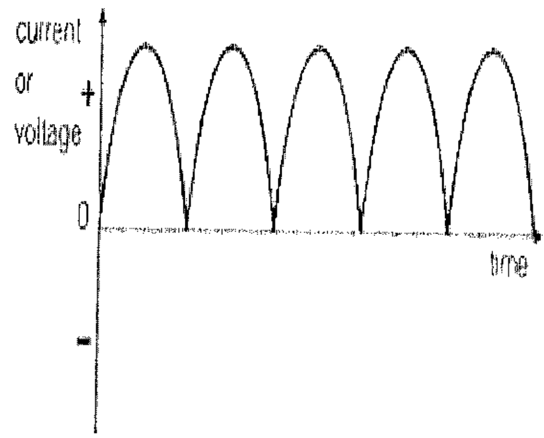


Figure3.4a Circuit symbol for bridge rectifier. Figure3.4b Output full wave varying dc

The maximum instantaneous voltage between the terminals of the rectifier circuit is

$$v_{max} = v_{rms} \times \sqrt{2}$$

$$v_{max} = 12 \times 1.4142 = 16.97v$$

This is desired circuit voltage which will swing from $-16.97v$ to $16.97v$

Peak Inverse Voltage

Peak Inverse voltage is twice the maximum voltage across the half wave (Mehta, V. K and Mehta, R. 2008).

i.e

PIV $= 2V_{max} = 2V_s$

therefore, PIV $= 2 \times 12v = 24v$

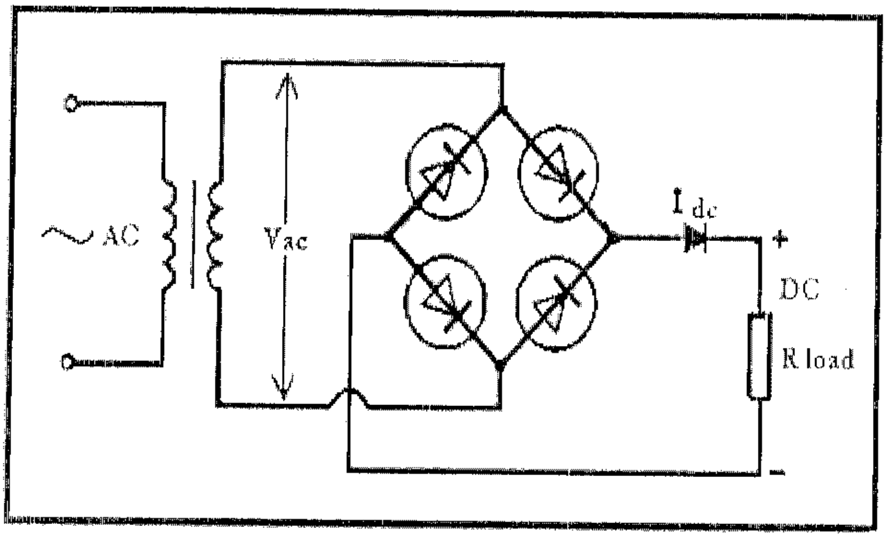


Figure3.5 The full wave bridge rectifier

From the figure3.5 d.c output voltage, above

$$V_{d.c} = I_{d.c} \times R_L$$

Where

$$I_{dc} = dc\ output\ current\ and\ R_L = load\ resistance$$

In full wave bridge rectifier,

$I_{dc} = \frac{2V_{max}}{\pi R_L}$ (Theraja, B. L 2009).

$I_{dc} = \frac{2 \times 12v}{3.142 \times 200\Omega} = \frac{34}{628.4}$

$= 0.054A$

$I_{dc} = 54mA$

Therefore,

$V_{dc} = I_{dc} \times R_L = \frac{2V_{max}}{\pi R_L} \times R_L = \frac{2V_{max}}{\pi}$ (For a 2 – pulse, full wave, bridge ac to dc converter).

Where

$\pi = 3.142$

V_{max} Were calculated to be 17V

$\therefore \quad V_{dc} = \frac{2V_{max}}{\pi} = \frac{2 \times 17V}{3.142}$

$= 10.82V$

However, the values of dc voltages (V_{dc1}, V_{dc2} and V_{dc3}) and currents (I_{dc1}, I_{dc2} and I_{dc3}) across the three phases were equally 10.8Volts and 54mA respectively.

3.2.2 THE SMOOOTHENING BLOCK

The smoothening block is also called the filter block or the filter circuit. The main function of the filter circuit is to minimize the ripple content of the bridge rectifier output. A low-pass filter that preserves the dc component of the rectified voltage while filtering out components at frequencies or above choice to remove the ripple component from the rectified voltage. In this case of rectifier circuit, the signal wave form to be rectified is 50Hz, 220v rms voltage.

The ripple frequency is therefore;

$f_{ripple} = 2 \times 50 = 100Hz.$

The relationship above is equivocal to ensuring small ripple through making the time constant for discharge much longer than the time between recharge. The diagram given below shows the original rectifier output and the out of ripple filter.

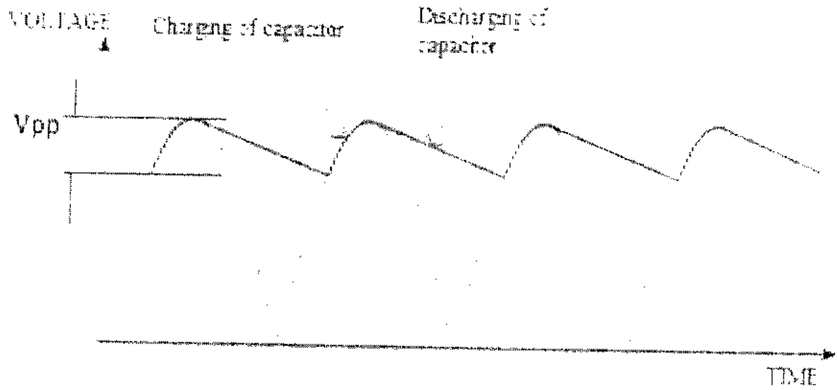


Figure3.6 Voltage variation across capacitor

Filter Capacitors (C_1 C_2 and C_3)

The ripple voltage can be approximated by the triangular wave form depicted below which has a peak to peak of V_r (p-p) and a period T_r.

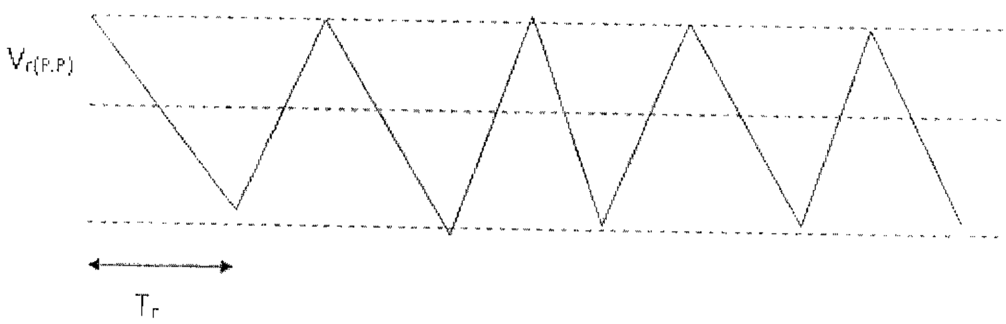


Figure3.7 Output signal wave form.

Considering the charge lost during the discharge of the shunt capacitor as d_q in a time T and is given as:

$$d_q = I_{dc} \times T_r \qquad (3.1)$$

Thus: $$V_{r\,(p-p)} = \frac{d_q}{C} = \frac{I_{dc} \times T_r}{C} \qquad (3.2)$$

But

$$I_{dc} = \frac{v_{dc}}{R_L}$$

Therefore,

$$v_{r(p-p)} = \frac{\frac{V_{dc}}{R_L} \times T_r}{C}$$

$$v_{r(p-p)} = \frac{V_{dc} \times T_r}{R_L\,C}$$

But the ripple delay (Period) $T_r = \frac{1}{F_r}$

Therefore,

$$V_{r(p-p)} = \frac{V_{dc}}{R_L\,C\,F_r} \qquad (3.3)$$

Where RL is the worst case load resistance, i.e the maximum circuit resistance

= 100Ω

$$V_{rms} = \frac{v_{r(p-p)}}{2\sqrt{3}} = \frac{V_{dc}}{2\sqrt{3}R_L\,C\,F_r} \qquad (3.4)$$

From equation 4 above; taking the ratio of V_{rms} to V_{dc} to get a constant known as ripple factor r_f

Given that,

$$r_f = \frac{V_{rms}}{V_{dc}} = \frac{1}{2\sqrt{3}R_L\, C\, F_r} \text{ (Theraja, B. L 2009).} \qquad (3.5)$$

But ripple frequency f_r = 100Hz, because it's a full wave rectifier bridge

$$r_f = \frac{12}{17} = 0.7$$

For the worst case resistance of the circuit, R_L = 100 and assuming a maximum ref 0.7%

Recalling that V_{rms} = 12v, V_{max} = 17V

Also note that $V_{max} = I_{dc}R_L$, therefore $R_L = \frac{V_{max}}{I_{dc}}$

Substituting $R_L = \frac{V_{max}}{I_{dc}}$ in equation (3.5) above

$$r_f = \frac{V_{rms}}{V_{dc}} = \frac{1}{2\sqrt{3}\, F_r (\frac{V_{max}}{I_{dc}}) C} \qquad (3.6)$$

Rearranging the above equation; it becomes;

$$r_f = \frac{I_{dc}}{2\sqrt{3}F_r V_{max} C} \qquad (3.7)$$

$$C = \frac{I_{dc}}{2\sqrt{3}F_r V_{max} r_f} \qquad (3.8)$$

Given parameters are

C=?

Vmax = 17v

f_r = 100Hz

r_f = 0.7% = 0.007

Find I_{dc}

$$I_{dc} = \frac{v_{dc}}{R_L} = \frac{0.636V_{max}}{R_L} \quad (3.9)$$

But

V_{max} = 17v

$$I_{dc} = \frac{v_{dc}}{R_L} = \frac{0.636V_{max}}{R_L} = \frac{0.636 \times 17}{100} = \frac{10.812}{100} = 0.108A$$

Therefore to find the capacitor C;

$$C = \frac{I_{dc}}{2\sqrt{3}F_r V_{max} r_f}$$

$$c = \frac{0.1082}{2\sqrt{3}\times100\times17\times0.007} = \frac{0.1082}{2\times1.732\times100\times17\times0.007} = \frac{0.1082}{41.222}$$

= 0.002625F

$c = 262.5 \times 10^{-6}F \ or \ C = 263\mu F$

Since 263μF capacitor is not standard, 330μF capacitors were used as (C_1 C_2 and C_3) in the standard value in the design.

SWITCHING UNIT

a. **Collector current (I_C)**

From the below expression collector current were calculated;

$$I_C = \frac{V_{CC}}{R_l} = \frac{12v}{400\Omega}$$

$\because I_C = 0.03A$ or 30mA

Base current (I_B)

$$I_B = \frac{I_C}{\beta} \qquad (3.10)$$

Where: supply voltage $(V_{CC}) = 12v$

Base emitter voltage (V_{BE}) $= 0.7v$ (Mehta, V. L and Mehta, R. 2008).

Gain (H_{FE}) = 25

Recall that coil resistance $R_L = 400\Omega$.

$\because I_B = \frac{0.03}{25} = 0.0012A$

But to ensure sufficient base current to drive the transistor into saturation, the quantity of the base current is doubled.

i.e

$I_B = 2 \times 0.0012$

$I_B = 0.002A$

$I_B = 2mA$

Base resistance (R_{10} and R_{11})

$$R_{10} = \frac{V_{CC} - V_{BE}}{I_B} \qquad (3.11)$$

$$= \frac{(12 - 0.7)v}{0.002A} = \frac{11.3v}{0.002A}$$

$R_{10} = 4708\Omega$

$\because R_{10} = 4.71k\Omega$

In this case, since the resistor R_{11} is also for the same purpose, the value of $R_{10\ used}$ in the design was 4.7KΩ.

3.2.4 THE RELAYS SWITCHES

Relays switches, are used for switching operations. The relays have contact point which form the normally open (NO) and the normally closed (NC) switches. It has an energizing coil through which the switching contacts can be pulled together or drawn apart to accomplish the NO and NC effects. When a current passes through the coil of the relay, the metal core becomes magnetized and attracts a strip of metal which closes the contacts that form the normally open switch. At this point the normally closed terminal opens.

Removing the energizing voltage demagnetize the metal core which then releases the metal strip to open the NO terminal and close the NC terminal again. Thus, the relay contacts can be opened or closed by simply applying or removing the energizing voltage as required.

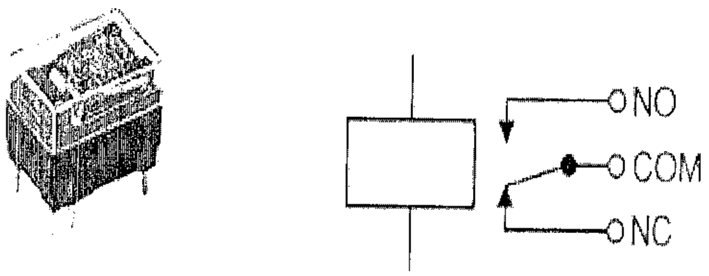


Figure3.8 Relay switch

The relay's switch connections are usually labeled COM, NC and NO:

- COM = Common, always connect to this; it is the moving part of the switch.
- NC = Normally Closed, COM is connected to this when the relay coil is off.
- NO = Normally Open, COM is connected to this when the relay coil is on.
- Connect to COM and NO if you want the switched circuit to be on when the relay coil is on.
- Connect to COM and NC if you want the switched circuit to be on when the relay coil is off.

In the design, of this project the rating used is 12V, 10A relay switches.

3.2.5 GENERAL CIRCUIT WORKING OPERATIONS.

The circuit is built around with a transformer, comparator, transistor and relay. Three identical set of circuit, one each for the three phases are used. Let us now consider the working of the circuit connecting red phase. The main power supply phase R is stepped down by transformer X1 to deliver 12V, 300mA, which is rectified by diode D_1 and filtered by capacitor C_1 to produce the operating voltage for the operational amplifier (IC_1). The voltage at inverting pin 2 of op-amp IC_1 is taken from the voltage divider circuit of resistor R_1 and preset resistor VR_1

is used to set the reference voltage according to the requirement. The reference voltage at non-inverting pin3 is fixed to 5.1V through Zener-diode ZD_1. Till the supply voltage available in phase R is in the range of 200V-230V, the voltage at inverting pin 2 of IC1 remain high, i.e. more than reference voltage of 5.1V, and its output pin 6 also remain high. As a result, transistor T_1 does not conduct, relay RL_1 remains de-energized and phase R supplies power to load L_1 via normally closed (N/C) contact of relay RL_1. As soon as phase R voltage goes below 200V. The voltage at inverting pin 2 of IC_1 goes below reference voltage of 5.1V, and its output goes low. As a result, transistors T_1 conducts and relay RL_1 energizes and load L_1 is disconnected from phase R and connected to phase Y through relay RL_2. Similarly, the automatic phase changing of the remaining two phases, via phase Y and phase B can be explained. Switch S_1 is main power on/off switch.

CHAPTER FOUR

4.0 RESULT, ANALYSIS AND DISCUSSION

IMPLEMENTATION

The implemented circuit is a close reflection of the objective of this work. It simulates an automatic switch with an intrinsic ability of searching for a suitable active phase to hook on to whenever any of the previously supply phase among the three goes off. The additional feature supported by the voltage programmable current sink internally incorporated into the circuit to skip some very low voltage as it seeks a suitable phase.

4.1 TESTING

The system is tested with three phase supply system. When the three phase terminal is connected to the pin input terminals of the system, the indicator light emitting diode (LED) comes ON indicating power supply to the system. Just immediately after the powering of the system, one of the LED indicating any of the phases comes ON indicating that one of the lines has being selected and gives an output. It's also applies to the other phases.

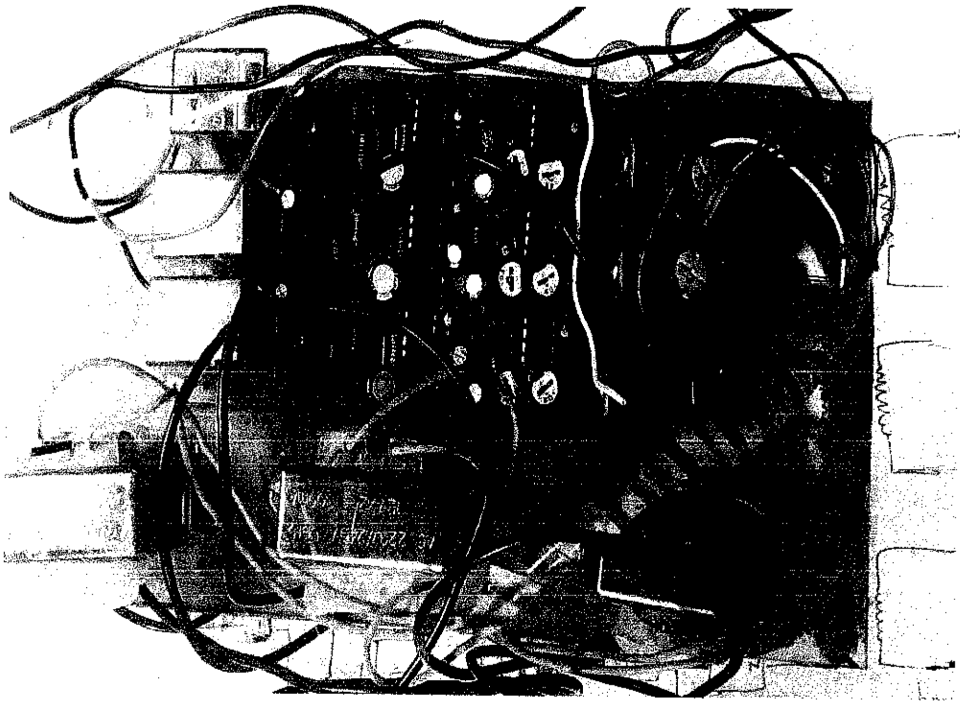


Figure4.1 the circuit arrangement of components

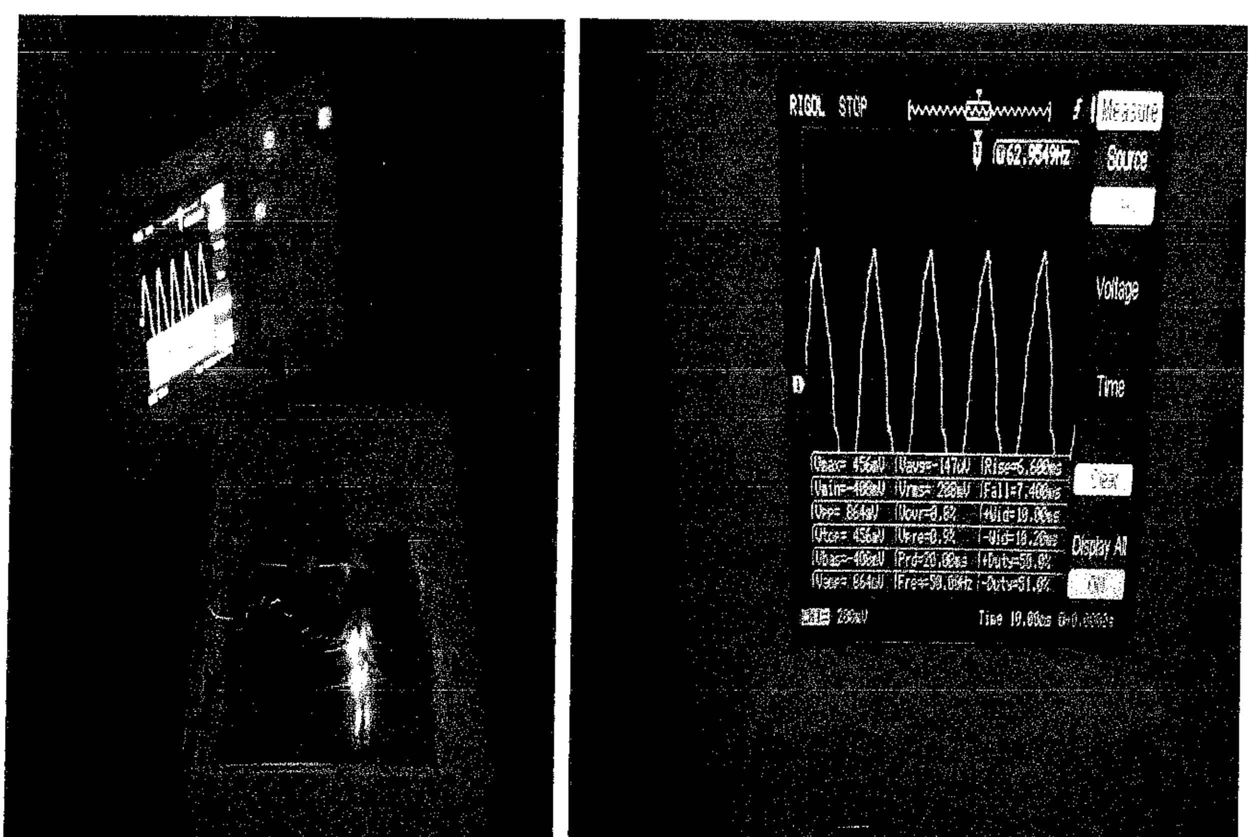


Figure4.2 Output measurement of the Oscilloscope.

4.1.1 TRUTH TABLE FOR PHASE SELECTION

Input – R	Input – Y	Input – B	Output
0	0	0	No supply
1	0	0	R – phase
0	1	0	Y – phase
0	0	1	B – phase
0	1	1	B – phase
1	0	1	B – phase
1	1	0	R – phase
1	1	1	R – phase

4.1.2 TRUT TABLE SUMMARY OF RESULT

Comparator 1 (C_{m1})		Comparator 2 (C_{m2})		Output Q	Output phase interpretation
Inverting input (V−)	Non-inverting input (V+)	Inverting input (V−)	non-inverting input (V+)		
0	0	0	0	0	Shutdown
0	1	0	1	1	Red phase
0	0	0	1	1	Yellow phase
0	0	1	0	1	Blue phase
1	1	1	1	0	No response

Note: High (1) > 5v and Low (0) ≤ 5v

4.2 ANALYSIS

Analysis of the circuit operation can be described base on block diagram below

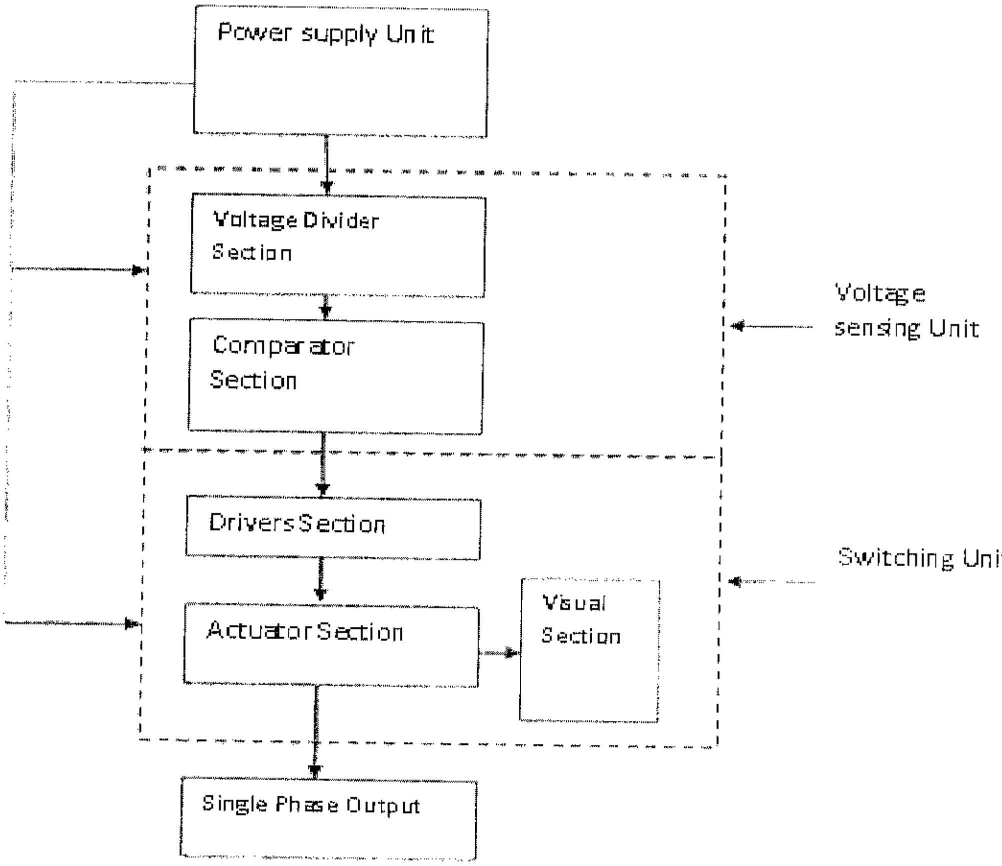


Figure4.3 Block diagram shows the interconnection of the phase selector unit.

4.2.1 Power Supply Unit:

This serves as input unit to the system because AC mains enter the circuit through this point. In this unit, power is converted from A.C to D.C and filtered as shown in figure below

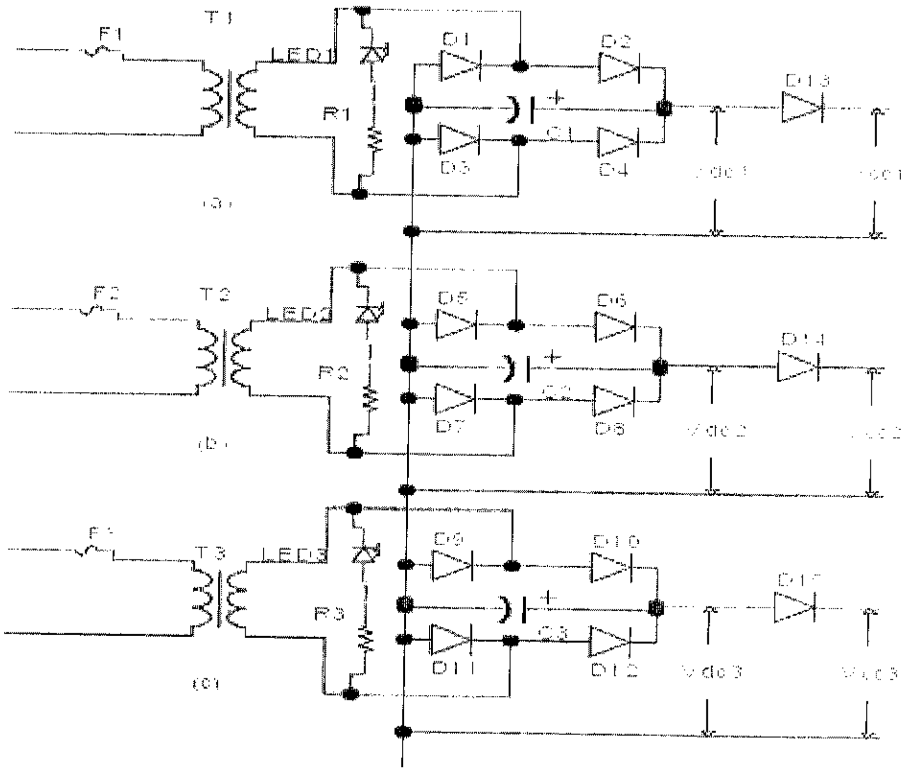


Figure4.4 Circuit diagram of three power supply Unit

The circuit diagram of three phase power supply consist of step-down transformers (T_1, T_2, T_3,), diodes (D_1, to D_2), Fuses (F_1, F_2, F_3), capacitors (C_1, C_2, C_3), Resistors (R_1, R_2, R_3) and Light emitting diodes (LED_1, LED_2, LED_3). The operation of the power supply unit occurs in three stages; the transformer stage, rectifier stage and filter stage.

a. Transformer Stage: This section consists of three Step-down transformers (240V/12V), three fuses (1 ampere), and light emitting diodes (Red, Yellow, and Blue).The rating of transformers was chosen because of the conversion of 240V to 12V AC which was the circuit requirement. Fuses were also used to protect excess current coupled with resistors as current limiters for Light emitting diodes. The light emitting diodes serve as indicators for presence of the mains supply.

b. Rectifier Stage: In rectifier section, diodes were configured in a full wave bridge rectifier so as to boast the circuit efficiency. The rectifier convert 12V AC voltage from the Supply from the transformer output to 12V pulsating DC. During circuit operation, diode and conducts and produce a positive cycle, that is forward biased, while diodes and becomes reverse biased. In negative cycle, diodes and conduct and becomes forward biased. But since load current is in the same direction in both half cycles, full wave rectifier appears across the output terminals (Theraja, B. L. 2009).

c. Filter Stage: An electrolytic capacitor is used to filter the pulsating D.C voltage that comes out from the rectifier section. During operation, the capacitor charges up (i.e store energy) during conduction of half cycle thereby opposing any changes in voltage. Hence, filter out voltage pulsations.

4.2.2 Voltage Sensing Unit.

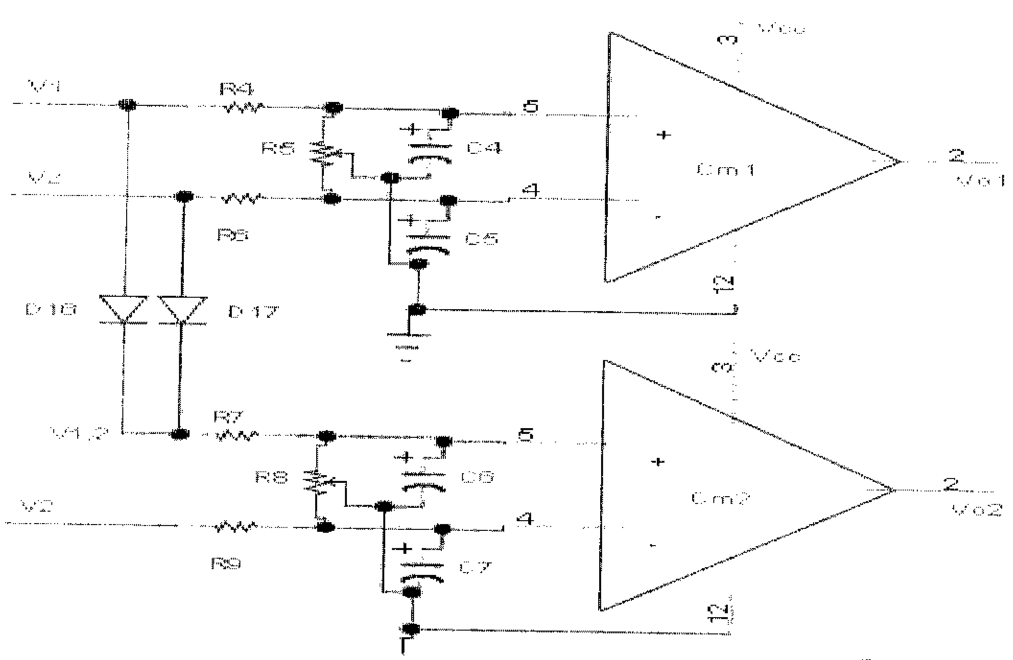


Figure4.5 Circuit diagram of Voltage Sensing Unit

The voltage sensing Unit consists of Comparator (C_{m1} and C_{m2}), diodes (D_6 and D_2), resistor (R_4, R_5, R_6, R_7, R_8 and R_9) and capacitors (C_4, C_5, C_6 and C_7). These circuit operates by reducing the rectified voltages (V_1, V_2 and V_3) to half with the help of voltage divider. The resistors used to form the voltage dividers includes (R_4, R_5, R_6, R_7, R_8, and R_9). The reduced voltages are compared through the inverting and the non-inverting inputs of the comparators. During the process, when the voltage in the non-inverting input is greater than the inverting, input the output of the comparator (V_1, or V_2) becomes "high" (1). But in a situation where the voltage in the inverting inputs is greater or equal to the non-inverting inputs, the output (V_1, or V_2) will become "low" (0) (Oduobuk, E. J. et. al 2014).

4.2.3 Switching Unit.

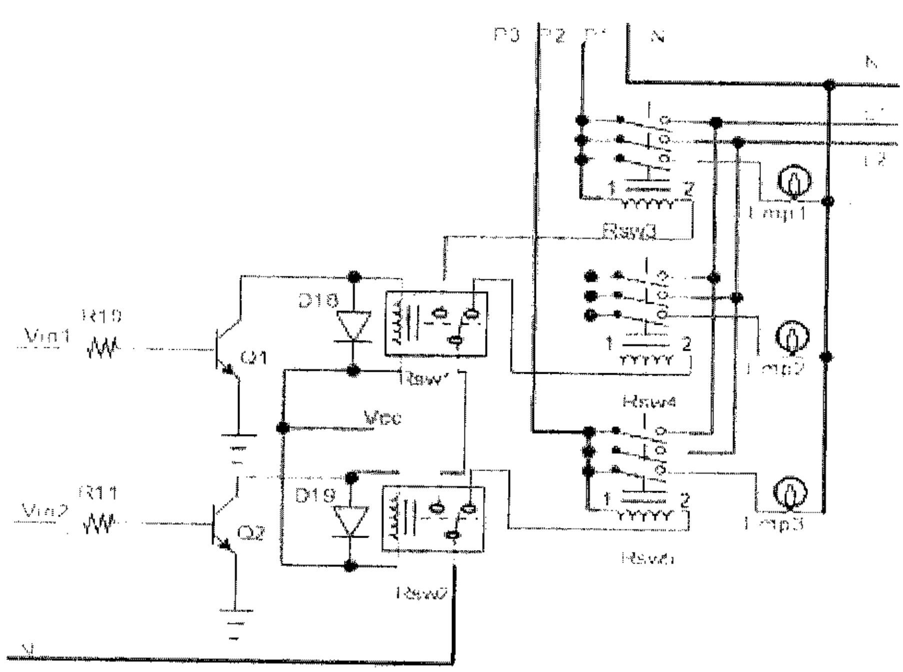


Figure4.6 Circuit diagram of Switching Unit.

The switching unit is responsible for making and breaking electrical contacts. It is subdivided into drivers, actuators and display sections. The devices involved were resistor (R_{10}, and R_{11}), relays (R_{sw1} and R_{sw2}) and contactors (R_{sw3}, R_{sw4}, and R_{sw5}).

a. Drivers Section

Transistors are used to drive the relays in this unit. The unit consists of two NPN transistors (Q_1, Q_2) and resistors (R_{10}, R_{11}). Transistors (Q_1, Q_2) conducts when its base senses voltage and from the outputs of the comparators. This transistor were used to swings the collector current to the quantity required by the coils of the relays.

b. Actuator Section

The actuator section consist of relays and contactors switches. The relays (R_{sw1}, and R_{SW2}) are used to actuate the contactors (R_{sw3}, R_{SW4}, and R_{sw5}). This is because the contactors coils used operate with A.C voltage.

c. Visual Section

The visual unit was design with three indicator lamps (L_{mp1}, L_{mp2}, L_{mp3},). This section displays the nature of the output system. In other words, the phase that appear across the system output is indicated with the colour of the Lamp weather Red Lamp (L_{mp1}), Yellow Lamp (L_{mp2}), or Blue Lamp (L_{mp3}) (Oduobuk, E. J. et.al 2014).

4.3 DISCUSSION OF THE CIRCUIT

The circuit is built around with a transformer, comparator, transistor and relay.

Three identical sets of this circuit, one each for three phases, used. Here the use of a step down transformer and we used LM393 working as comparator is used here is surrounded by all other components. Transistor BC547 acting as a switch.

Relay is the electromagnetic type. The processes under here are divided into five namely;

- Step down the main supply
- Rectification
- smoothing
- Comparing
- Switching

Main supply Red, Yellow and Blue phases is stepped down to desired voltage and current. Each transformer is individually connected to the phases R, Y, B respectively. In this case, only one phase work at a time. The diodes (IN4007) are used to rectify the AC to DC. The capacitor for removing the noises/ripples in the DC. The resistors and the potentiometer of the circuit give the specified voltage input to the comparator. Based on the comparator output, the transistor goes to on and off position. Thus we can say that transistor work as a switch. The components were mounted on the bread and were wired up. A 12V dc supply was generated. The main circuit consist comparator, transformer, transistor and relay. Three identical set of this circuit connected on the breadboard. Then the output is verified by connecting a load (bulb) at the output and got the desired output.

4.3.1 WORK OF LM393 COMPARATOR

A comparator circuit compares two voltage signals and determines which one is greater. The result of this comparison is indicated by the output voltage: if the op-amp output is saturated in the positive direction, the non-inverting input (+) is greater, or more positive voltage than the inverting input (-), all voltage measured with respect to ground. If the op-amp voltage is near the negative supply. Voltage (in case, 0 volts, or ground potential), it means the inverting input (-) has a greater voltage applied to it than the non-inverting input (+).

4.3.2 COMPARATOR USING OPERATIONAL AMPLIFIER

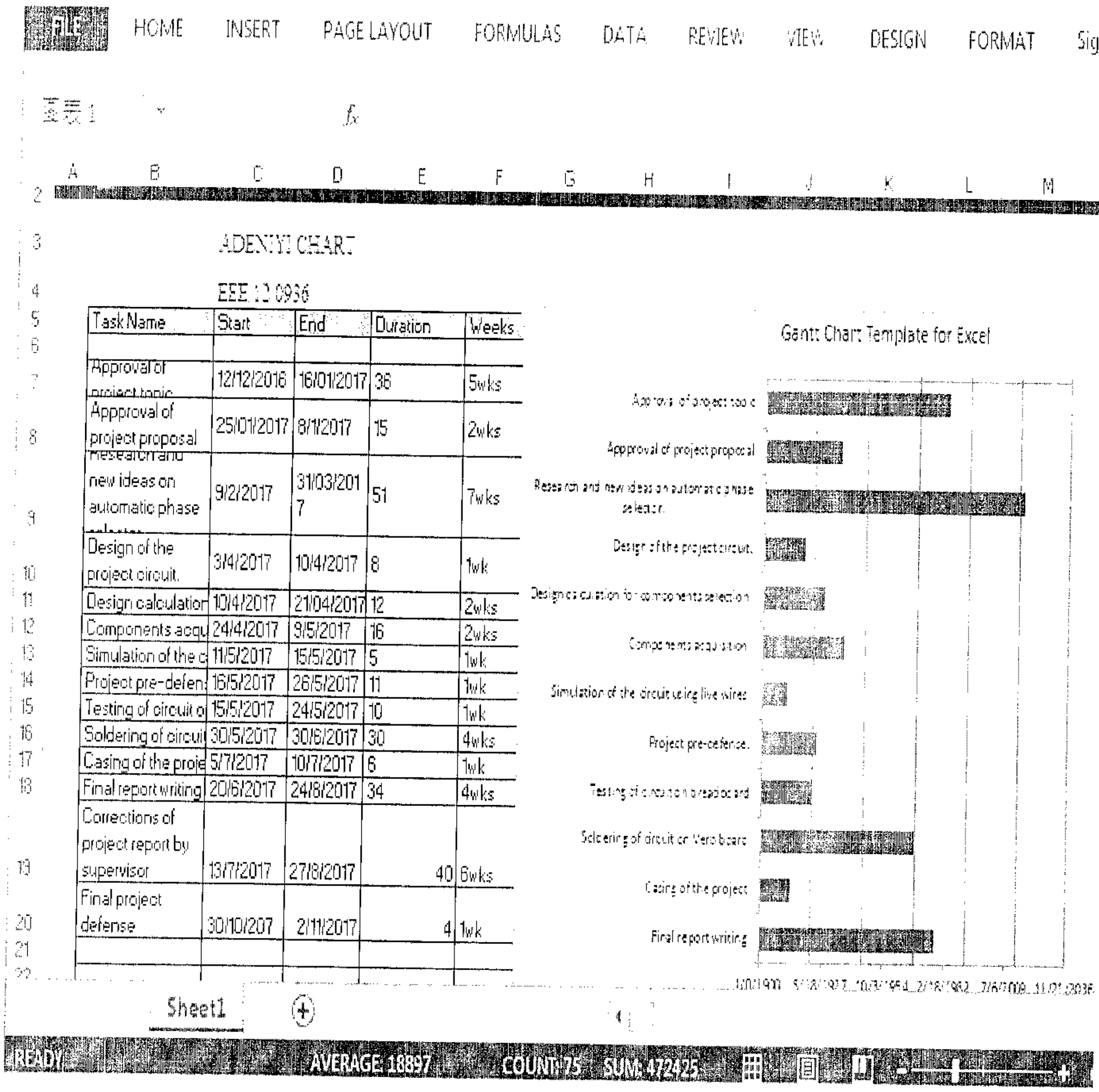
Often two voltage signals are to be compared and to be distinguish which is stronger. Thus the op-amp comparator is a circuit with two inputs and one output.

The two input can be compared with each other i.e. one of them can be considered a reference voltage, V_{ref}. A fixed reference voltage V_{ref} is applied to the inverting (-) input terminal and sinusoidal signal is applied to the non-inverting (+) input terminal. When V_{in} exceed V_{ref}. The output voltage goes to positive saturation because the voltage at the inverting (-) input is smaller than at the non-inverting (+) input. On the other hand, when V_{in} is less than V_{ref} the output voltage goes to negative saturation. Thus output voltage V_{out} changes from one saturation level to another whenever $V_{in} = V_{ref}$. In short the comparator is a type of an analog to digital converter (ADC). At any given time the output voltage waveform shows whether V_{in} is greater or less than V_{ref}.

The comparator is sometimes referred to as a volt-level detector because for a desired value of V_{ref}, the voltage level of the input voltage V_{in} can be detected. (Jacobowitz 2000).

Diodes D_1 and D_2 are provided in the circuit to protect the op-amp against damage due to excessive input voltage. Because of these diodes, the differential input voltage V_d is clamped to either + 0.7V or - 0.7V, hence the diodes are called clamp diodes. These are some op-amps with built in input protection. Such op-amps need not to be provided with protection diodes. The resistance R_1 in series with V_{in} is used to limit the current through protection diodes D_1 and D_2 while resistance R is connected between the inverting-input terminal and V_{in} to reduce the offset problem.

4.4 PROJECT MANAGEMENT



Task Name	Start	End	Duration	Weeks
Approval of project topic	12/12/2016	16/01/2017	36	5wks
Appproval of project proposal	25/01/2017	8/1/2017	15	2wks
Research and new ideas on automatic phase selector	9/2/2017	31/03/2017	51	7wks
Design of the project circuit.	3/4/2017	10/4/2017	8	1wk
Design calculatior	10/4/2017	21/04/2017	12	2wks
Components acqu	24/4/2017	9/5/2017	16	2wks
Simulation of the c	11/5/2017	15/5/2017	5	1wk
Project pre-defen	16/5/2017	26/5/2017	11	1wk
Testing of circuit o	15/5/2017	24/5/2017	10	1wk
Soldering of circui	30/5/2017	30/6/2017	30	4wks
Casing of the proje	5/7/2017	10/7/2017	6	1wk
Final report writing	20/6/2017	24/8/2017	34	4wks
Corrections of project report by supervisor	13/7/2017	27/8/2017	40	6wks
Final project defense	30/10/207	2/11/2017	4	1wk

Figure4.7 Gantt chart of the project management

CHAPTER FIVE

5.0 CONCLUSION

The effective phase selector is not only advanced procedure (technique) for the connection of the load to the phase, costing to the customer the least, automatically, but also helps in increasing the system's reliability. safety and reduced human stressed of manual operation (concept of automation). It is a safe method due to the presence of electronic components whose working voltage levels is considerably low. The whole setup is static one thereby causing less power loss as compared to the circuits with moving parts and contacts operated manually (mechanical relays). Because of the compact size it is equally suitable for the household purposes.

5.1 CONTRIBUTION TO KNOWLEDGE

This project show the technological advancement in power system voltage control, which helps to lay a foundation of research work about the automatic three phase voltage selector system.

5.2 LIMITATIONS

This work covers only a three phase automatic phase selector which can only be used for providing a means of switching from one phase of AC mains to another in the case of failure in the existing phase and which also give indication when power fails in the whole phases.

The operating voltages is 240V/240V and the maximum load current it can handle is 100Amp. Therefore, the system should not be use under condition higher than these.