DESIGN AND CONSTRUCTION OF AN UNDERVOLTAGE, OVERVOLTAGE, OVERLOAD CUT-OUT CIRCUIT DEVICE.

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DEDICATION

The project is dedicated to the glory of ALMIGHTY GOD for his mercies and grace in the course of my study. Also to my parents Mr.. And Mrs. .Dojio for their Unflinching support and prayers.

DECLARATION

I Dojio Omokafe Isaac, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also here by relinquish the copyright to the Federal University of Technology, Minna.

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I cannot forget to say a bigger thank to my friends that have seen me through to this point of my life. My thanks goes to my distinguish class mates

Lastly my thanks also goes to the lecturers of the department of electrical and computer engineering whose works have been tremendously used as an authoritative signpost.

ABSTRACT

Frequent fluctuation of power line and power failure has shown that electrical components have had their life span shortened. Practically, no power system can maintain voltage at rated valued at the consumer terminal at all times. Over voltage or under voltage may arise. Causes of this abnormalities or problem include the ability to have a balance network, switching surges, thunderstorm, physical contact between conductors of an electrical circuit, etc. this malfunction due to these condition may be either reversible or irreversible. In the second case, the properties will have change sufficiently operation to be impossible.

This may range from component unwanted change to total failure of the device. It is in this light of the aforementioned problems that efforts are being made to ensure the development and design of protective device with sensitivity and efficient operating ability.

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CHAPTER ONE

INTRODUCTION

.1 Preamble

Iost electrical equipments and appliances in Nigeria are design to operate at a steady voltage of 20V.The efficiency of these equipments is high this input voltage whereas any deviation from it auses a drop in the output efficiency. Over the years, it is difficult for utility companies (PHCN: OWER HOLDING COMPANY OF NIGERIA ETC) to provide a clean, consistence, and teady power required by the country`s demand.

'ower failure which constitute a complete loss of electric power to equipments are most often npredictable and are often disastrous when they do occur such that equipments in use without ower protection strategies suffer greatly. Even when there is no power failure, electricity voltages sometimes fluctuate thereby upsetting the operating equipment. Voltage fluctuations nay be in the form of under-voltage which occurs as a result of poor wiring, Overloaded circuits or deficiency in the utility system. Over-voltage also occurs when utility company supplies voltages which exceed the acceptable standards. Constant power failure and voltage fluctuation affects all equipments including refrigerators, air conditioners, television sets etc and causing a complete disruption of their operation or by gradually reducing their useful life.

Recent equipments are designed to operate using electrical power that falls within a specific range. Brownouts occur where the electrical supply voltage drops below this level. The low voltage places a strain on the electrical components contained within the equipment and can limit their operational life. It can also cause the immediate failure of those electrical components. A supply of voltage higher than the required maximum voltage can cause the equipments to burn or blow. A few short seconds of faulty power can wipe out appliances. Poor power quality entering equipments can not only affect the life span of the equipments but can also cost thousands of naira in repairs. Hence; protection of equipments is paramount.

1.2 Aim and objectives

The main purpose of this project is to design and construct a protection device that will protect against voltage fluctuations for all equipments using phase supply.

The objectives of this project among others are;

I. preventing the shortening of equipments lifespan
II. Preventing disruption or malfunctioning of equipments.
III. Preventing unnecessary spending on repairs.

1.3 Significance of study

This device is used to protect equipments from under voltage, over voltage and overload. It finds application in all electrical equipments which have been designed to operate at an input voltage within the range of 150V – 270V.

The device ensures that the components in the equipments work under the right voltage requirements thereby increasing their reliability within its useful life period. It reduces cost of maintenance that can be required due to damages caused by power fluctuations.

.4 Scope of study

'his protective device has been built especially for the protection of all equipments operating ,ithin the range of 150V and 270V.it cuts off the supply to the load whenever the input voltage s outside this range or when there is an overload resulting to excess demand of current.

.5 Method of study

- The construction of over-voltage, under-voltage, overload cut out device consists of the following: Schmitt trigger, Load switch and Visual indicator of over-voltage, under-voltage and normal line voltage. As shown in the block diagram below.

- The input voltage consists of a 240/15V transformer which keeps tag of the main voltage and supplies a corresponding stepped down value to the rectifier and filter stage.
- The power supply unit consists of a rectifier and smoothening capacitor, full wave bridge rectifier.
- The Schmitt trigger consists of comparators and resistors which are basically used to sense different variation of voltage.
- The load switch stag consists of transistor, relay and load. The transistor is used for both sensing voltage conditions and driving relay, and load is the output of this project and it is here that the "Cutting out" action is carried out.

CHAPTER TWO

Literature Review

2.1 Utility supply

Electricity is generated, transmitted, and used in the form of three-phase alternating current (AC). AC – electrical current that continually reverses direction, with this change in direction being expressed in hertz, or cycles per second. The current strength of AC electricity oscillates sinusoidal at 50Hz. Generators provide three such varying voltage outputs, delayed by one third of a cycle with respect to each other. The reason for this complexity is that generators, transmission lines, and motor can be designed to operate most efficiently when working with this three-phase AC. Additionally, and most importantly, transformers work only with AC. The normal voltage wave form is as shown in fig. 2.0.

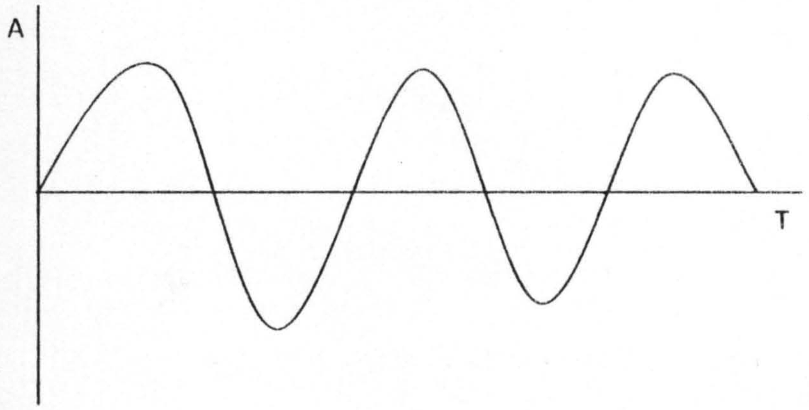

Fig. 2.0 Normal Voltage Waveform

Electrical power generated in Nigeria which is intended for commercial and industrial applications are produced at three-phase. Power generated for home use is distributed as three-phase but only as a rule; one-phase is used to serve a given house or houses. The other phases are used for other houses so as to balance the total load. The value of the single phase is nominally 240V to the ground.

One important task of the supply system is to provide consumers with electricity at constant voltage. All industrial and household electric appliances are designed to operate at a constant voltage. For example, a light bulb is designed to consume 100W (watts) at 240V.If the voltage is increased by even a small margin, the coiled filament will overheat and melt. Conversely, if the voltage drops below the nominal value, the lamp will not provide its intended light output.

It is difficult for utility companies to provide clean, consistent, and continuous power required by present growing population. Power failures and voltage fluctuations which are often unpredictable are becoming rampant due to the problems the utility companies are facing, and equipments without power protection strategies suffer greatly.

2.2 Types of power failures

Power failure can be categorized into two as shown below:

2.2.1. Power outages

Loss of all power phases is called power outage or blackout. Power outages are total interruptions of electrical supply.

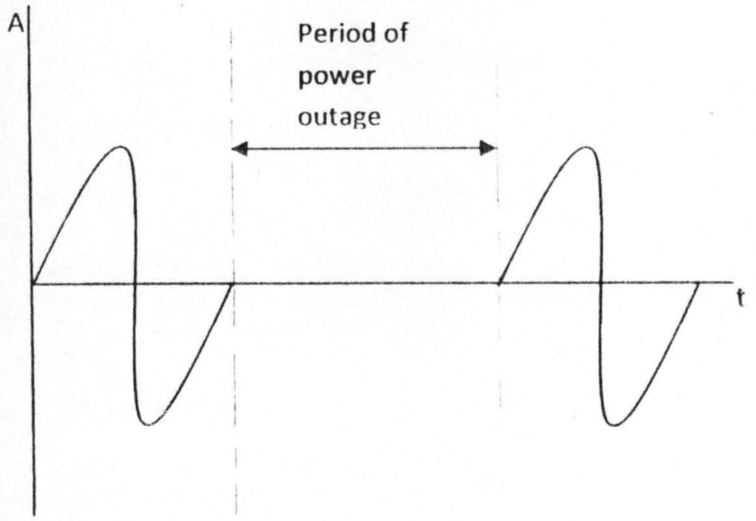

Fig. 2.1 Power Outage Waveform

Total failures or blackouts constitute a complete loss of electrical power to equipments. It can be total failure throughout an entire geographical location, a single building, group of buildings, or single electrical panel within a building.

These failures causes complete disruption of operation of equipments. These blackouts are often caused by excessive demand on the power grid electrical storms, auto accidents involving utility poles, an electrical utility company`s inability to meet user demand on an overloaded circuit.

2.3 Voltage fluctuation

Voltage fluctuations are changes or swings in the steady-state voltage above or below the designated input range for a piece of equipment as seen in fig 2.2

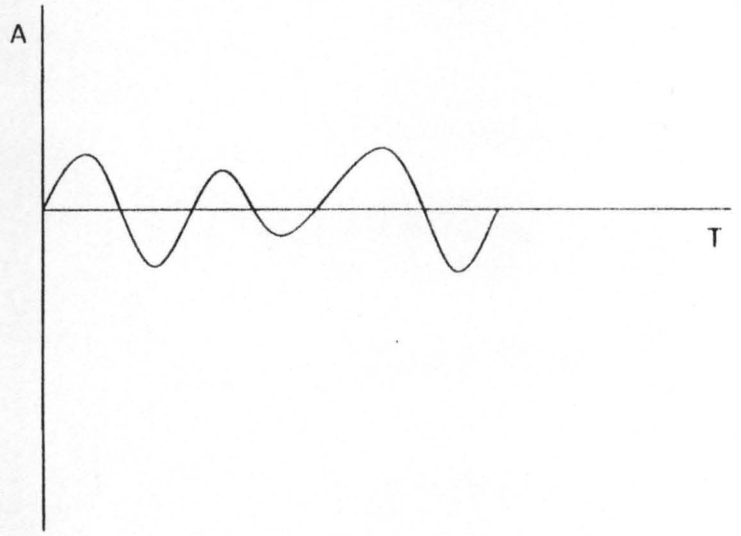

Fig. 2.2 Voltage Fluctuations Waveform

It causes equipment to start-up and shutdown fluctuations occur in various forms such as:

2.4 Sags

Sags are also known as brownout, they are short term decreases in voltage levels.

Cause: Sags are usually caused by the start-up demands of many electrical devices such as motors, compressors, elevators, shop tools, etc. Electric companies use sags to cope with extraordinary power demands, in a procedure known as rolling brownouts, the utility will systematically lower voltage levels in certain areas for hours or days at a time.

Effect: Sags reduce the efficiency and life span of electrical equipment particularly motor.

2.5 Surge

It is short increase in voltage, typically lasting at least 1/120 of a second

Cause: Surges result from the presence of high-powered electrical motors, such as air conditioners, and household appliances in the vicinity. When this equipment is switched off, the extra voltage is dissipated through the power line.

Effect: Electronics and electrical devices are designed to receive power within a certain voltage range and anything outside of expected peak RMS (considered the average voltage) level will stress delicate components and premature failure.

2.6 Noise

More technically referred to as Electro-magnetic Interference (EMI) and radio frequency Interference (RFL, electrical noise disrupts the smooth sine wave one expects from utility power.

Cause: Electrical noise is caused by many factors and phenomena, including load switching, generators, radio transmitters and industrial equipment. It may be intermittent or chronic.

Effect: It disrupt the switching time for electronic components, thereby minimizing their efficiency. It also causes the degradation of electrical insulation; equipment damage.

2.7 Harmonics

Harmonics are the periodic steady-state distortions of the sine wave, due to equipment generating a frequency other than the standard 50 cycles per second.

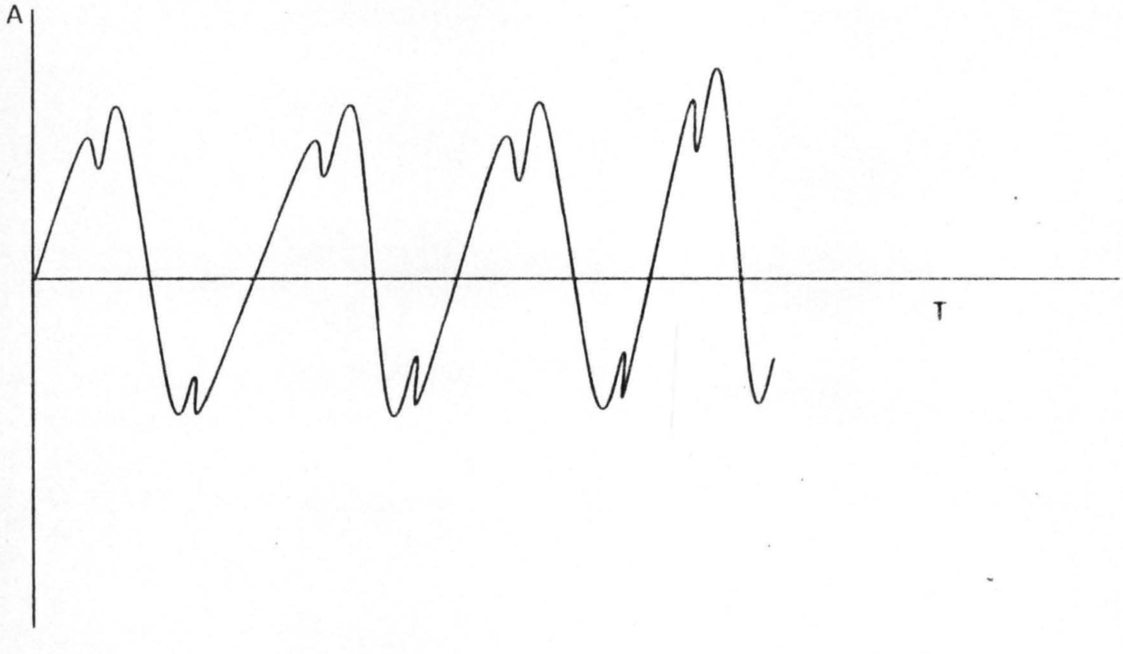

Fig. 2.3 Harmonics Waveform

Causes: Electronic ballasts, on-linear loads, variable frequency drives.

Vulnerable equipment: circuit breakers, phone systems, capacitors banks; motors.

Effects: Overheating of electrical equipment, random breakers tripping, hot neutrals.

2.8 Under voltage

This may arise when there is a fault or breakdown on transmission system and also when the demand for electricity is at its peak .This condition is dangerous to such equipment: refrigerator, vacuum cleaner, washing machines etc in effect there would be an increase in line current and because the voltage is low, the system draws more current from the line to compensate for the drop in voltage. This would lead to over heating and eventually cause fire.

Causes: Under voltage conditions result from poor wiring, overloaded circuits or a deficiency in the utility system.

Vulnerable equipments: All electrical and electronic appliances.

Effect: It places an excessive stress on the components.

2.9. Over voltage

This condition could be caused by either lightening or switching over-voltages. Lightening over voltage is as a result of a natural phenomenon while switching over voltage originates from the connection and disconnection of circuits breaker contact at switching.

The effect of over-voltage is hazardous to life and equipment. Over voltage will cause increase in torque in electric motors which may result in possible damage to all the mechanical coupling of the appliance. Other loads such as water heater, electric cooker and toasters could also get damaged. Over voltage conditions would cause the heating element to burn out quickly. Life span of electronic component will decrease as a result of over-voltage conditions. Filament of fluorescent lamps and bulbs are destroyed immediately there is an over-voltage condition.

2.9.1 Power protectors

Power protectors are to protect electrical and electronic equipments from this poor power supply. Devices have been built which are installed between the poor supply unit and the equipment that is meant to be powered. There are quit a number of these devices that are being implemented but only a few will be mentioned in this write-up.

2.9.2 Fuses

Fuses are safety devices used to protect an electrical circuit from the effect of excessive current. Its essential component is usually a strip of metal they will melt at a given temperature. A fuse is designed that the strip of metal can easily be placed in the electric circuit. If excess current surges through the circuit, the metal link will heat to its melting point and break. This action will open the circuit, stop the current flow, and thus protect the circuit. Recent fuse modification includes types that will permit a momentary overload without breaking the circuit. These are necessary for circuit that are used to power air conditioners, because initial surges of power can be expected with such appliances.

2.9.3. Circuit breakers

In high-voltage circuits, subject to frequent interruption and increasingly in residential wiring is provided by circuit-breakers instead of fuses.

Circuit-breaker- This is a switch designed to control an electrical power system by switching power on or off, under conditions of either normal or excessive load, in order to protect the electrical system in which it is connected. The circuit breaker may be controlled manually or automatically.

Operating conditions are unusually demanding, as a circuit- breaker may on the one hand be called upon under conditions of a short circuit on the load, requiring it to break a current that is many times the normal load current, and on the other may be required to close on to a short-circuited system in other to confirm that a fault exist. The circuit-breaker must therefore be reliable under static conditions, yet must operate virtually instantaneously when called upon to do so after a long quiescent period.

2.9.4 Automatic Voltage Regulator

The device is used to control voltage such that whether there is a surge, a sag or normal voltage supply, there is always a fixed range of values that will produce out. The range that most voltage regulators are set to is the voltages required by most equipment for their proper functioning.

2.9.5 Stabilizers

Unlike the automatic voltage regulator, no matter the input to the stabilizer once it is within its range, it will bring out a constant value.

2.9.6 Un-interruptible power supple

Since AC power is subjected to fluctuations short of full brown blackout that can damage equipment and cause data corruption. This power fluctuation can take the form of brownouts, minor power dips, small power surges or spikes, and undesirable line harmonics, none of these is good for sensitive electronic equipment hence, the equipment should be plugged into the UPS, which in turn is plugged into the wall before it gets to the appliance which will not encounter power fluctuations

In UPS, AC power from the wall outlet is used to charge batteries. Power is then taken from the batteries, piped through an inverter, and output again as AC for equipment when there is power failure. Since the batteries are always in use, there is no drop in AC output while the UPS switches its power source from the wall to its batteries.

However, some of these protection devices are inadequate in their performances. For example, a voltage stabilizer is inadequate in protection, when the input voltage is very low or high, especially when it is outside its range of operation .fuses are only used for over current protection. Most of them don't have time delay circuits hence, they supply input voltage immediately to appliances which could be detrimental to them especially those with compressors and motors

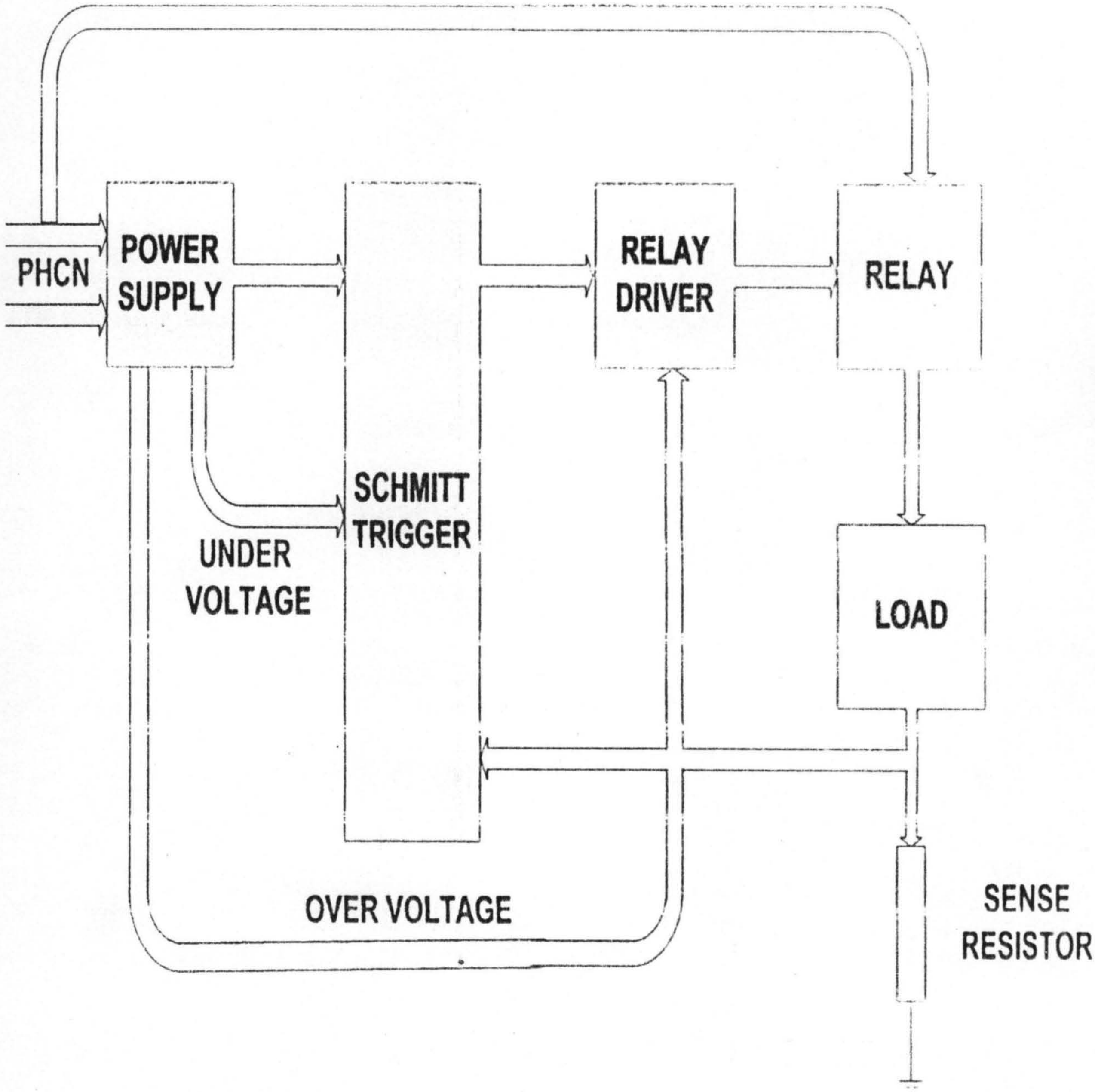

Fig. 2.4 Block Diagram

CHAPTER THREE

The automatic overvoltage, under voltage, overload detection system comprises the following subsystems:

1. Full wave rectified power supply

11. over voltage detector

111. over load detector

1V.10A DC relay power switch

Power supply

A system supply voltage of 9V was derived from 240/12V step down transformer as illustrated in fig 3.0.

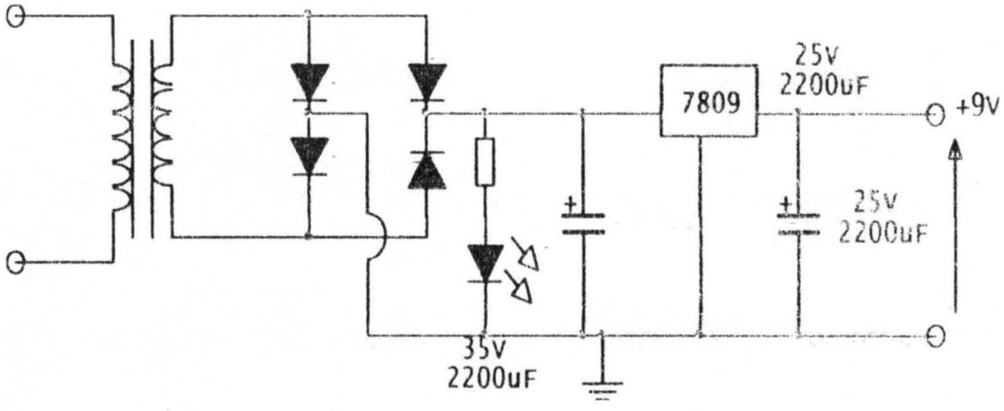

Fig. 3.0 System Power Supply

A 12V step-down transformer was used to reduce the AC mains voltage to a 12V AC and full wave rectified to DC as shown in fig 3.0.

The 12V AC voltage was converted to a DC voltage of peak amplitude.

$V_{DC\ PK} = (V_{RMS}\sqrt{}) - 1.4$

$12\sqrt{2} - 1.4$

$= 15.56V$

$V_{RMS} = 12V$, $\sqrt{2}$ = RMS - to – peak scaling converter

1.4 = voltage drop in two adjacent diodes of the rectifier.

The DC voltage was smoothened by a 25V 3300UF capacitance deduced from the expression:

$C = IT / V$

I = maximum load current

And $t = 1/2f = 1 / 2X50$

V = peak to peak AC ripple voltage.

The maximum load current was computed from the summation of the total system current.

Overvoltage detector----------5mA

Under voltage detector-----------50mA

Relay --------------------------------60mA

LEDS-------------------------------------20mA

∑ I--------------------------------135mA

The maximum AC ripple voltage was fixed at a value determined by the minimum input voltage into the 7809 regulator IC.

For a regulated 9V output, the minimum input voltage into the regulator is 11V(from manufacturer specification sheet).

On a 15.5V pulsating DC supply, the maximum AC ripple voltage is thus:

15.5 – 11 = 4.5V.

The value of the capacitance therefore was

$$\frac{0.135 \text{ X } 1/(2 \text{ X } 50)}{4.5}$$

= 0.00135/4.5

= 3×10^{-4}

= 300uF

The above value of capacitance was the minimum required to meet worst case sstem specification outlived above.

The DC voltage was regulated by a 7809 9-Volt regulator; the regulated DC voltage was smoothened by a 2200μF capacitance.

3.1 Overvoltage/under voltage detector

This was designed around a potential divider network shown in fig. 3.1

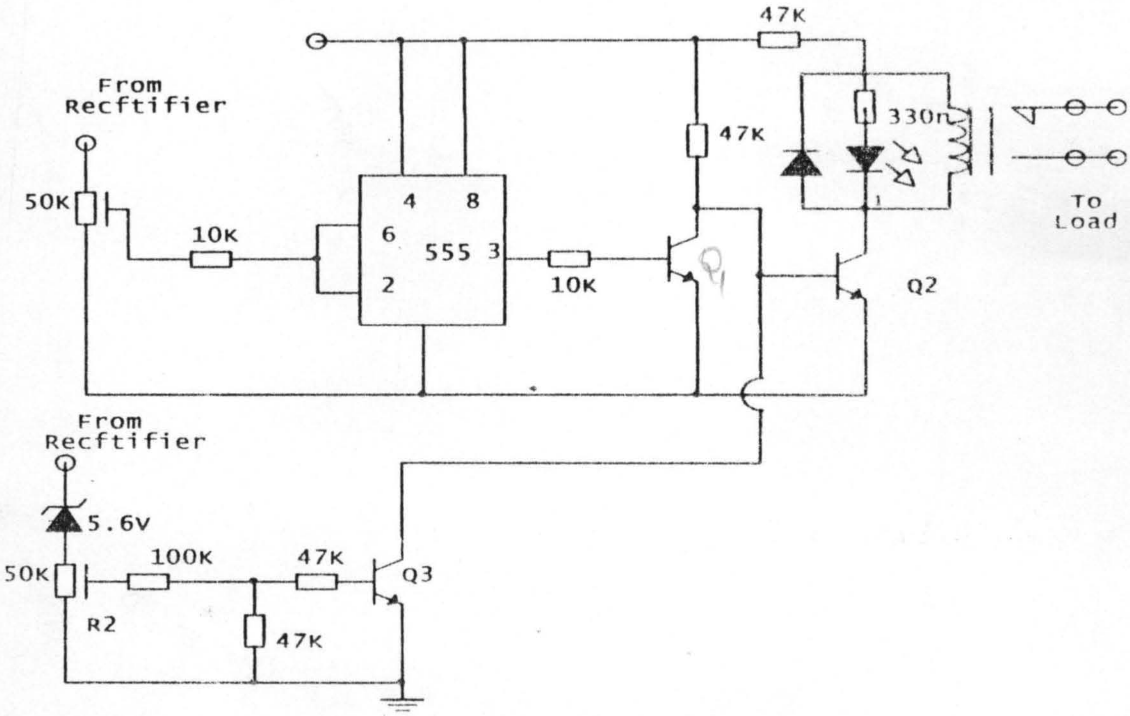

Fig. 3.1 under voltage / over voltage Detector

R1 sets the under voltage limit level, R2 seta the overvoltage limit level. The 555 was configured for Schmitt trigger operations with hystersis to ensure system stability.

The input into the Schmitt trigger was taken from the R1 potential divider, the 555device has an upper switching threshold of 2/3Vcc and a lower threshold of 1/3Vcc.on a 9V supply, the upper threshold is 2/(3 X 9) = 6V

And the lower is 1/3Vcc = 1/(3 X 9) = 3V

If a voltage lesser than 3V is fed into pins(6,2), of the device , pin(3) output is high.pin 3 remains high until the voltage level on pins (6,2) rises above 6V, at which point pin 3 goes low.pin 3 remains low until the voltage level on pins(6,2) falls below 3V, at which point pin 3 rises high again. This effect is known as hystersis and is incorporated into control systems to prevent oscillation and instability arising from a single point/comparison and switching.

R1 was adjusted such that the relay energized, using and auto-transformer, R1 was again adjusted, with the AC input voltage at about 130V, until the relay de-energized, that marked the under voltage cut-out level.

The input voltage was set to 260V and R2 adjusted until the relay de-energized. That marked the overvoltage cut off level.

Three transistors were used to effect relay switching (Q1 – Q3).

Q2`s collector was connected to a 6V relay, in parallel with an LED as shown in fig 3.1.

The 6V relay had a coil resistance of 100Ω.

$I_{relay} = V_R / R_R$

$= 6 / 100$

$= 60mA$

The LED was overated on a forward current of about 10Ma.A current limiting resistance of value deduced from the expression

$R_S = V_S - V_{LED} / I_{LED}$

$V_S = 6V$, $V_{LED} = 1.7V$, $I_{LED} \approx 14mA$

Was used.

$R_s = 6 - 1.7 / 0.014$

$= 330\Omega$

The total collector current of Q2 was then (60mA + 14mA) = 74mA

$I_B = I_c / \beta$

$= 0.014 / 2 X 10^2$

$= 3.7 X 10^{-4}A$

$R_B = (V_B - V_{BE}) / I_B$

$= (15.5 - 0.7) / 0.00037$

$= 14.8 / 3.7 X 10^4$

$= 4 x 10^4$

$= 40000\Omega$

$= 40k\Omega$

A value of 47KΩ was used to allow for switching under every possible condition, expecially at low AC line voltage.

Q1 was driven by the 555 when the voltage on pins(6,2) of the device falls below 1/3Vcc (i.e 3V).the base resistance for Q1 was calculated from the expression :

$R_B = (V_B - V_{BE}) / I_B$

$I_C = 15.5 / 47K\Omega \approx 3.5 \text{ X } 10^{-4}$ A

$= 350\mu A$.

Q1 has a gain of 200

$I_B = I_C / H_C$

$= 350\mu A / 200$

$= 1.75 \text{ X } 10^{-6} A$

$R_B = (6 - 0.7) / 1.75 \text{ X } 10^{-6}$

$5.3 / 1.75 \text{ X } 10^{6}$

$= 3 \text{ X } 10^{6}\Omega$

The value derived was rather too large. To guarantee switching at the lower input voltage limit, it was reduced to 10KΩ with the input voltage on pins (6,2) of the 555 $\leq$ 3V ,pin 3 is driven high, turning on Q1, which cuts off base current due to Q2, de- energizing the relay.

If the input voltage reaches the minimum of about 160V, the voltage on pin (6, 2) rises to 6V, forcing pin 3 of the 555 low cutting off Q1, current flows into the base emitter junction of Q2 and the relay energizes.

The overvoltage condition was detected by Q3. At normal AC line conditions, Q3 is cut- off. However when the input AC voltage rises to about 260V,Q3 is forward biased, cutting off the base due to Q3 and forcing the relay off. The relay is reconnected when the input AC voltage falls below 260V.

3.3 Overload (over-current) detection

Load-resistance inserted in series with the load as shown in fig 3.

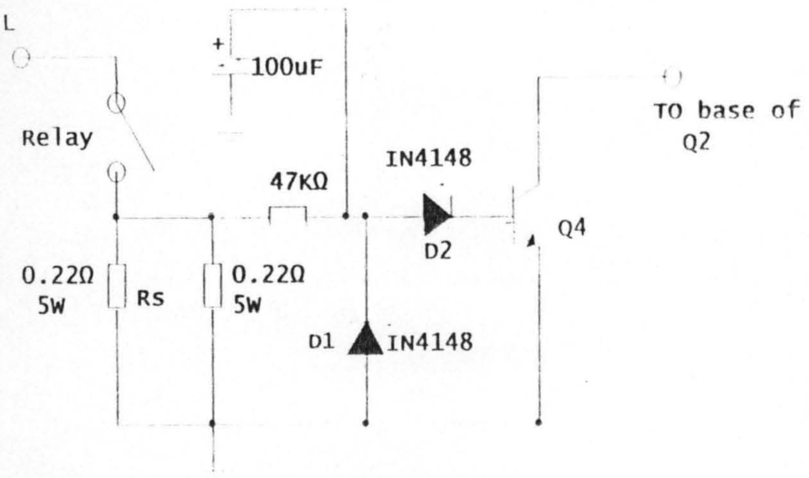

Fig. 3.2 over load Detector

The two parallel connected 0.22Ω resistances produced a 0.1Ω resistance. The resistor was connected to a half-wave rectifier as in fig 3.3.

0.7V RMS. The voltage across the resistor is sinusoidal in nature, is converted to a unipolar DC by D1 which removes the negative excursions, passing only the positive peaks through D2.

D2 feeds into an NPN transistor whose collector was connected to the base of Q2, driving the relay.

When a load current exceeding 7a flows through the resistor, Q4 is forward biased cutting off Q2 and de-energising the relay. The load is thus disconnected from the 240V 50 Hz supply.

A power on indicator was provided across the rectified DC voltage. The current through the LED was limited by a resistance calculated from the expression

$R_S = (V_S - V_{LED}) / I_{LED}$

$V_S = (15.5 - 1.7) / 0.01$

$= 1.38K\Omega$

A 27KΩ resistance was used instead. since the operating current of an LED ranges from 5mA – 20mA

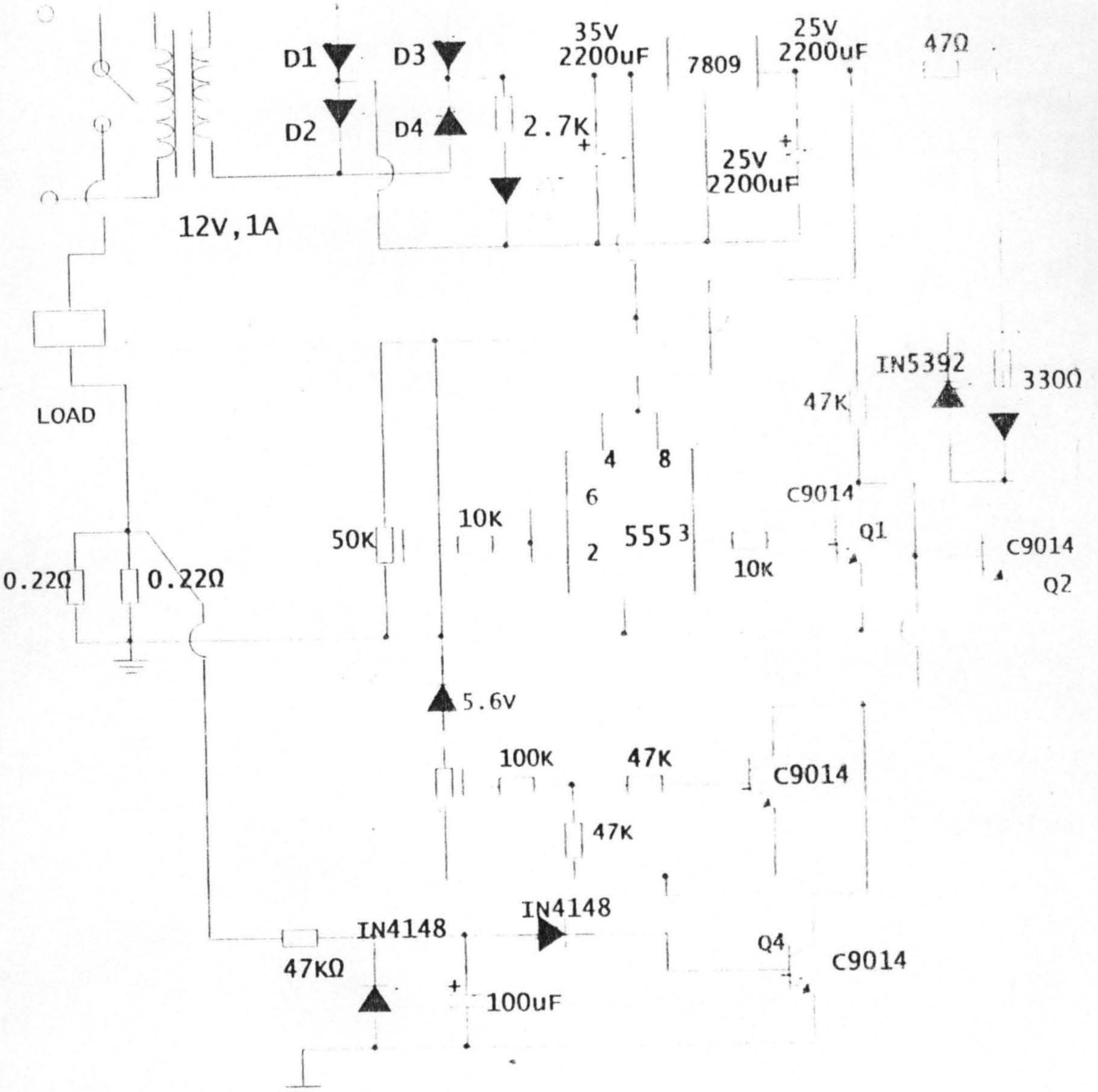

Fig. 3.3 Circuit Diagram of the Device

CHAPTER FOUR

TEST, RESULT AND DISCUSSION

4.1 Test

All the components were tested (test of continuity, rated voltage, current etc.) using a multimeter. before the connection of all components. For final presentation and testing, an auto transformer was used to supply the different voltages (under voltage, over voltage and normal voltage conditions) to test the cut-out of the system.

4.2 Result

Under normal operating condition of the line voltage, the system would work, i.e. setting the upper and the lower limit of the voltage from the pre-set buttons to the voltage from the line voltage and the voltage needed by the appliance.

But if the line voltage is outside the pre-set ranges of voltage value, the electro-mechanical relay trips the system off

4.3 Discussion

This circuit was constructed using a Schmitt trigger, a relay driver, etc. These components were tested to ensure they were in good working condition. An auto transformer was used to supply the different voltages (under voltage, over voltage and normal voltage conditions) .The output of the circuit device was set to Ac under voltage (100V), Ac overvoltage (260V) and normal voltage conditions in-between the two abnormal voltages. The pre- set was set within and out of these AC voltages to energize or de-energize the relay. A bulb was used as an indicator to check if the system is ON/OFF.

4.4 Summary

The table below shows the relationship between the auto transformer and the pre-set values of the circuit.

Table 4.4 Showing input voltage against output state

AUTO TRANSFORMER O\P	CIRCUIT MODE
LESS THAN 100V	OFF
HIGHER THAN 160V	OFF
BETWEEN THE PRESETED VALUE	ON

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The circuit device is switched ON when the AC is within the ranges of the pre- set voltage i.e. the switching device is switched ON,(the relay is energized) and outsides this range the relay is de- energized

5.2 Recommendations

To increase reliability and lifespan of appliances e.g. television sets, Radio sets, fans and other household appliances. This device should be manufactured along side home appliances as a guard.

For future work it can be improved upon by making it digital, with 7 segment display and using a microcontroller to make it automatic.

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