DESIGN AND CONSTRUCTION OF A THREE PHASE APPLIANCE PROTECTOR

BY

CHRISTOPHER IKECHUKWU EGWU
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DEDICATION

I solely dedicate this work to almighty God for his mercies and guardiance through thi s work and moreso to every beloved member of my family.

DECLARATION

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

CHRISTOPHER IKECHUKWU EGWU
Name of Student

18/01/2010
(Signature and date)

Mr Nwozor Olaniyi E.
Name of supervisor

18/01/10
(Signature and date)

For
Name of Head of Department

11 (May 6 2010)
Signature and date

Name of External Supervisor

09/03/10
Signature and date

ACKNOWLEDGEMENT

I would like to give thanks to the almighty God for His grace in helping me to commence and to complete my undergraduate studies. It hasn't been so easy, but God has kept me. I am so hopeful and have this assurance that He would yet keep me and grant me success in my quest for a sound career.

I would also use this medium to show my deep and profound gratitude to my wonderful parents for their contributions to my success. I also want to thank my siblings and friends for the wonderful encouragements they gave me in the course of this project.

Finally, I want to thank my project supervisor for his kindness, support and patience in the course of this project. May God bless them all, Amen.

ABSTRACT

Many of our costly appliances require three-phase AC supply for operation. Failure of any of the phases makes the appliance prone to erratic functioning and may even lead to failure. The circuit has relays that monitor the availability of all phases to switch on the appliance with a certain time delay in other to avoid surges or momentary fluct uations and switches off the appliance in the event of failure of one or two phases. The relays are connected in each module of the circuit in a logical AND gate manner.

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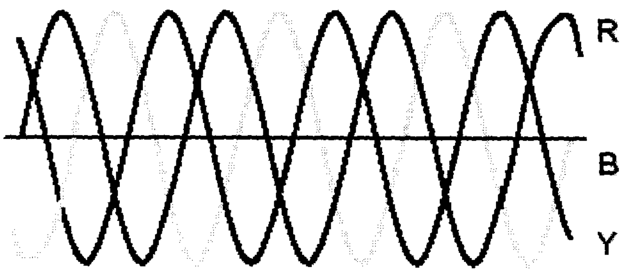
INTRODUCTION

Electricity, which was considered to be a matter of pride for its possessor, merely fifty years ago, has become the most necessary and vital ingredient of twenty-first century human life. Our dependency on electricity has increase to such an extent that we start our day by switching on an electrical appliance and end it by switching off the electric bulb. Innumerable electrical appliances such as a bulb, a tube light, fan, air-conditioner, mixer, washing machine, geyser, television and the list extends up to infinity. The household appliances don't need much power (electricity) to operate, and hence run well on single-phase electrical supply. But in day-today life we come across many situations in which large amount of power (electricity) is needed to perform the specified task such as in a flour mill, bore well pumps, factory machines etc. Here comes into operation another mode of power supply known as three phase power supply.

1.1 SCOPE OF WORK

Three-phase, abbreviated 3φ, refers to three voltages or currents that differ by a third of a cycle, or 120 electrical degrees, from each other. They go through their maxima in a regular order, called the *phase sequence*. The three phases could be supplied over six wires, with two wires reserved for the exclusive use of each phase. However, they are generally supplied over only three wires, and the phase or line voltages are the voltages between the three possible pairs of wires. The phase or line currents are the currents in each wire. Voltages and currents are usually expressed as rms or effective values, as in single-phase analysis.

As you are aware, to transmit power with single-phase alternating current, we need two wires (live wire and neutral). However you would have seen that distribution lines usually have only four wires. This is because distribution is done using three phases and the fourth wire is the neutral. How does this help? Since the three phases are usually 120’ out of phase, their phasor addition will be zero if the supply is balanced.



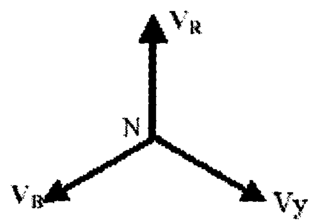


Figure (a) Three phase waveforms   Figure (b) Phasor Diagram

It is seen from figure (a) that in the balanced system shown, the three phases, usually designated R, Y, B corresponding to Red, Yellow and Blue, are equal in magnitude and differ in phase angle by 120^0. The corresponding phasor diagram is shown in figure (b). The voltage between any of the phases and the neutral is called the phase-to-neutral voltage or ***phase voltage*** Vp.

It is usual to call the voltage between any two lines as the line-to-line voltage or ***line voltage*** VL. If the R-phase voltage is VR = Vp.0, then the remaining phase voltages would be VY =Vp.-2p/3 and VB = Vp.-4p/3.

1.2 METHODOLOGY

The Three-Phase appliance protector is a device constructed to provide cost effective protection for three phase appliances and mostly industrial appliances in event of failure of one or two phases.

1.2.1 PRINCIPLE OF OPERATION

The basic circuit operation of three phase appliance protector is described here. It requires three phase-supply, three 12V relays and a timer IC NE555 along with 230V coil contactor having four poles. The relays RL1 and RL2 act as sensing devices for the various phases and are connected such that each acts as an enabling device for the subsequent relay. Therefore the combination of the relays forms a logical AND gate connected serially

The availability of phase R energizes relay RL1 and its normally opened (N/O) contacts close to connect phase Y to the input of transformer X2. The availability of phase Y energizes relay RL2 and its N/O contacts close to connect phase B to the input of transformer X3, thus applying a triggering input to timer IC NE555 (IC1). Therefore the delay timer built around NE555 triggers only when all the phases (R, Y and B) are available. It provides a delay of approximately four seconds, which energizes relay RL3 and its N/O contact closes to connect the line to the energizing coil of four-pole contactor relay RL4. Contactor RL4 closes to ensure the availability of the three-phase supply to the appliance.

The rating contactor RL4 can be selected according to the full-load current rating of the appliances. Here the contact current rating of the four-pole contactor is up to 32A. the availability of phases R, Y and B is monitored by appropriate LEDs connected across the secondary windings of transformers X1, X2 and X3 respectively. Hence this circuit does not require a separate indicator lamp for monitoring the availability of the three phases. When phase R is available, LED1 glows. When phase Y is available, LED2 glows. When phase B is available LED3 glows.

1.3 AIMS AND OBJECTIVES

The circuit is designed to provide cost effective protection against equipment failure caused by voltage faults on three-phase systems, that is, the circuit is adapted to protect three-phase loads from unallowable variation in the main voltage, phase loss and phase imbalance, phase coincidence and incorrect phase sequence. The circuit is a efficiently applicable for the protection of refrigerating an air-conditioning installation, compressor plants and other equipments with an electric motor loads.

1.4 LIMITATIONS

Basically this protector circuit protects Three-Phase appliances from failure of any of the phases by disconnecting the power supply through the contactor and automatically restores the three phase supply (with reasonable time delay) when all phases are available. In the course of achieving this project some constraints were encountered and noted. One of such constraints was the scarcity of key components like the Industrial Relays, and secondly another limitation was the time delay which ought to be four seconds according to theory but practically the time delay is quite less than a second.

CHAPTER TWO

LITERATURE REVIEW / HISTORICAL BACKGROUND

Several years before now, there existed protective devices or elements that were used to protect our appliances. One of such is the fuse, and the simplest form of fuse is the burning fuse believed to date back in the 10th century and originating in china.

2.1 THE ELECTRICAL FUSE

In electronics and electrical engineering a fuse, short for 'fusible link', is a type of over current protection device. Its essential component is a metal wire or strip that melts when too much current flows. When the metal strip melts, it opens the circuit of which it's a part, and so protects the circuit from excessive current. A practical fuse was one of the essential features of Edison's electrical power distribution system. An early fuse was said to have protected an Edison installation from tampering by a rival gas lighting concern.

Within the 10th and 18th century, Fuses (and other overcurrent devices) came to be an essential part of a power distribution system to prevent fire or damage. When too much current flows through a wire, it may overheat and be damaged or even start a fire. Wiring regulations give the maximum rating of a fuse for protecting of a particular circuit. Local authorities will incorporate national wiring regulations as part of law. Fuses are selected to allow passage of normal currents, but to quickly interrupt a short circuit or overload condition.

The speed at which a fuse operates depends on how much current flows through it manufacturers of fuses plot a time current characteristic curve, which shows the time required to melt the fuse and the time required to clear the circuit for any given level of overload current. Where several fuses are connected in series at the various levels of a power system, it is very desirable to clear only the fuse (or other overcurrent devices) electrically closest to the fault. This process is called "coordination" and may require time current characteristics of two fuses to be plotted on a common current basis. Fuses are then selected so that the minor branch fuse clears its circuit well before supplying, major fuse starts to melt. In this way only the faulty circuits are interrupted and minimal disturbance occurs on other circuits fed by the supplying fuse.

Furthermore in the 19th century, it was discovered the when the fuses in a system are of similar types, simple rule-of-thumb ratios between ratings of the fuse closest to the load and the next fuse towards the source can be used. Then it was discovered that fuses are often characterized as "fast-blow", "slow-blow", or "time-delay", according to the time they take to respond to an overcurrent condition. The selection of the characteristics depends on what equipment is being protected. Semiconductor devices may need a fast or ultra fast fuse for protection since semiconductors may have little capacity to withstand even a momentary overload. Fuses applied on motor circuits may have a time-delay characteristic, since the surge of current required at motor start soon decreases and is harmless to wiring and the motor.

A fuse also has a rated interrupting capacity, also called breaking capacity, which is the maximum current the fuse can safely interrupt. Generally this should be higher than the maximum protective short circuit current. Miniature fuses may have an interrupting rating only 10 times their rated current. Fuses for small low-voltage wiring systems are commonly rated to interrupt 10,000 amperes. Fuses for large power systems where made to have higher interrupting ratings, with some low-voltage current-limiting "high rupturing capacity" (HRC) fuses rated for 300,000 amperes. Fuses for high-voltage equipment, up to 115,000 volts, are rated by the total apparent power (megavolt-amperes, MVA) of the fault level on the circuit.

As well as current rating, fuses also carry a voltage rating indicating the maximum circuit voltage in which the fuse can be used. For example, glass tube fuses rated 32 volts should where made never to be used in line-operated (mains operated) equipment even if the fuse physically can fit the fuse holder. Fuses with ceramic cases have higher voltage ratings. Fuses carrying a 250V rating may be safely used in a 125V circuit, but the reverse is not true as the fuse may not be capable of safely interrupting the arc in a circuit of a higher voltage. Medium-voltage fuses rated for a few thousand volts are never used on low voltage circuits, due to their expense and because they cannot properly clear the circuit when operating at very low voltages.

Fuses where also noted to have markings in the 19^{th} century, and most fuses are marked on the body, or ends cap to markings shows their ratings. A "chip type" fuse feature little or no markings making identification so difficult. When replacing a fuse, it is important to interpret these markings correctly as fuses that may look the same, could be designed for different applications. Fuse markings where generally made to convey the following information;

- Ampere rating of the fuse
- Voltage rating of the fuse
- Time-current characteristic
- Manufacturer / part number /series
- Breaking capacity

In recent times it was observed that majority of fuse manufacturers build products that comply with set of guidelines and standards, based upon the application of the fuse. These requirements are devised by many different government agencies and certification authorities. Once a fuse has been tested and proven to meet the required standard, it may then carry the approval marking on the certification agency. Fuses come in a vast array of style and sizes to cater for the immense number of applications in which they are used. While many are manufactured in standardised package layouts to make them easily interchangeable, a large number of new styles are released every year. Cartridge fuses have a cylindrical body terminated with metal end caps. Some cartridge fuses are manufactured with end caps of different sizes to prevent accidental insertion of wrong fuse rating in a holder. An example of a fuse range is the "bottle fuse", which in appearance resembles the shape of a bottle. Fuses designed for soldering to a printed circuit board have radial or axial wire leads. Surface mount fuses have solder pads instead of leads.

Fuses used in circuits rated 200-600 volts and between about 10 and several thousand amperes, as used for industrial applications such as protection of electric motors, commonly have metal blades located on each end of the fuse. Fuses may be held by a spring loaded clip or the blades may be held by screws. Blade type fuses often require the use of a special purpose extractor tool to remove them from the fuse holder. While glass fuses have the advantage of a visible fuse element for inspection purposes, they have a low breaking capacity which generally restricts them to applications of 15A or less at 250VAC. Ceramic fuses have the advantage of a higher breaking capacity facilitating their use in higher voltage / ampere circuits. Filling a fuse body with san d provides additional protection against arcing in other overcurrent situation. Cartridge fuses are generally measured as the overall length and diameter of the fuse. Due to the large variety of cartridge fuses available, fuse identification relies on accurate measurements as fuses can differ only by a few millimetres between types. "Bottle style" cartridge fuses also require the measurement of the cap diameter as this varies between ampere ratings. Other fuse packages can require a variety of measurements such as;

- Body (width × height × depth)
- Blade or tag (width × height × depth)
- Overall length of fuse (when the fuse features blades or tags)
- Overall width of fuse (when the fuse features two bodies)
- Distance between blades (when radially configured)
- Width of mounting hole (when the fuse features tags)

In the 20th and 21st century, some other protective devices where designed to perform where fuses cannot. Most of this was done to be used in industrial environments to provide cost effective protection of the appliances used in industries. Some of this protectors are discussed and reviewed below.

2.2 THE DSP-L1 PHASE FAILURE AND ASYMMETRIC DETECTOR

The DSP-L1 detector is an electrical device that constantly monitors the voltage level of every phase of your electrical supply. If a phase unbalance (asymmetry), phase reversal or phase loss occurs, the DSP-L1 immediately opens the control circuit of the equipment it is protecting so as to prevent damage. When the phases return to normal, the DSP-L1 resets itself and closes the control unit, allowing the motor to be started up normally and safely.

2.3 MODEL 158 THREE PHASE MONITOR

The **Model 158** continuously monitors 3-phase power lines for abnormal conditions. When properly adjusted, the Model 158 monitor will detect phase loss on a loaded motor even when regenerated voltage is present. This device consists of a solid-state voltage and phase-angle sensing circuit, driving an electro-mechanical relay. When correct voltage and phase rotation are applied, the internal relay will energize. A fault condition will de-energize the relay. When the fault is corrected, the monitor will automatically reset. The Model 158 does not require a neutral connection, and can be used with Wye or Delta systems. Four versions cover 120V, 208/240V, 480V (60 Hz) and 380V (50 Hz). Voltage ranges are sufficient to allow for proper adjustment to existing conditions. A front-mounted LED failure indicator is provided. The “R” versions of the Model 158 Monitor have an additional LED indicator for RESTART, and a 5 minute short cycle timer, to delay restarting the motor.

TABLE 2.3.1 SPECIFICATIONS FOR MODEL I58 THREE PHASE MONITOR

MODEL	B158B	158B	A158B	EX 158B
Input Voltage	120vac	208/240vac	480vac	380vac
Adjustment range	85-125vac	160-260vac	380-500vac	300-400 vac
Frequency	60HZ	60HZ	60HZ	50HZ
Power consumption (per phase)	.25W	.5W	1.5W	1.25W
Transient	2500 VRMS of 10 msecs			
Repeat Accuracy	± 0.1% of set point (fixed conditions)			
Response Time	0.5 seconds			
Reset Time	Short cycle restart delay – 2 seconds "R" Version - 5 Minutes			
Reset Type	Automatic			
Dear Band	2%			
Output Contacts	SPDT 10A at 240Vvac resistive			
Expected Relay Life	Mech: 10million operations Elect: 100,000 operations at rated load			
Operating Temperature	-40° to +131° F			
Humidity Tolerance	97% w/o Condensation			
Enclosure material	ABS Plastic			
Mounting	Surface			
Weight	5 oz			

2.3.2 INSTALLATION:

Mount the model 158 Three phase monitor in a suitable enclosure. Attach 1/4" terminal lugs to the input voltage wires, and then connect them to the terminals on the Model 158 marked **ØA**, **ØB**, and **ØC**. Proper clockwise phase rotation should be confirmed, using a Time Mark Model 108A or 108B Phase Rotation Indicator or unit will show trip for Phase Reversal. Attach 1/4" terminal lugs to the load control circuit wires, then connect them to the terminals marked **C** and **NO**. Apply power. The **NO** contact will close when correct voltage is applied. If a Model 158R is being installed, there will be a 5 minute delay before the contact transfers. The green RESTART light should be ON during this 5 minute period.

2.4 MULTIFUNCTIONAL THREE PHASE MONITOR CM-MPS

The CM-MPS is a multifunctional 3-phase monitor. It monitors the phase parameters, phase sequence, phase loss, over and under voltage and phase unbalance. The threshold values for over and under voltage are adjustable in the range of Vmin 160-380 V and Vmax 220-500 V; resp. Vmin 90-220 V and Vmax 120-280 V with neutral monitoring (see table below). The threshold value for phase unbalance can be adjusted from 2-15%. If one of the above mentioned failures occurs, the output relay de-energizes. The failure is displayed via the LEDs. The adjustable trip delay with a range of 0,05- 10 s prevents nuisance tripping. If all parameters are within the adjusted limits, the output relay is re-energized automatically.

2.5 FAILURES PROMPTING THE NEED OF THE ABOVE REVIEWED PHASE MONITORS.

If there wasn't phase failures, then there wouldn't be any need of developing the phase monitors and protectors which go ahead to prove the saying that "necessity is the mother of invention". Some of these failures and the causes are discussed below.

2.5.1 PHASE LOSS AND UNBALANCE (ASYMMETRY)

The electrical motors, compressors, pumps and ventilators used by companies are usually powered by three phase electrical voltage, typically at 208, 240, 480 and 600 volts. The slightest incident affecting the transmission or distribution of electricity by your electrical facilities or a burnt fuse on your own electrical installation will cause the company to experience a sudden voltage loss or asymmetry on one phase. When this happens, your motors, compressors, pumps and ventilators will no longer be powered normally. They will continue to run for a few minutes, but will overheat substantially because only two of the three motor coils are working. It only takes a few minutes to inflict fatal damage on your motors, compressors, pumps or ventilators.

2.5.2 PHASE REVERSAL

This happens when your power utility or a contactor, working on the power lines inside or outside your facilities, may reverse two of the three phases by mistake. Most compressors or motors will react very badly to such situations. Your motors or compressors could suddenly begin to turn in the wrong direction, causing major collateral damage.

Three phase motors in most cases burn out due to loss of phase and atimes the relays the relays do not react simply because of the fact that overload relays have a limited range of application. For instance if your motor operates at an efficiency of 75% or less of its specified load, then a typical overload protection will not react.

2.5.3 REAL COST OF PHASE LOSS

- Cost of motor or compressor
- Cost of motor or compressor installation
- Cost of possible delayed shipment
- Cost of possible production losses
- Cost of overtime
- Cost of potential loss of orders
- Cost of collateral damages.

2.6 THEORITICAL BACKGROUND

The complete circuit of the project (THREE PHASE APPLIANCE PROTECTOR) is described here. It requires three phase supply, three 12V relays and a timer IC NE555 along with relay contactors having 20-30A current, 220-240V voltage rating all linked to form four poles contact. The relays RL1 and RL2 act as a sensing device for phases Y and B respectively. These relays are connected such that each acts as an enabling device for the subsequent relay. Therefore the combination of the relays forms a logical AND gate connected serially.

The availability of phase R energizes relay RL1 and its normally opened (N/O) contacts close to connect phase Y to the input of transformer X2. The availability of phase Y energizes relay RL2 and its N/O contacts close to connect phase B to the input of transformer X3, thus applying a triggering input to timer IC NE555 (IC1). Therefore the delay timer built around NE555 triggers only when all the phases (R, Y and B) are available. It provides a delay of approximately four seconds, which energizes relay RL3 and its N/O contact closes to connect the line to the energizing coil or relays acting as the four-pole contactor relay RL4. These relays or contactor RL4 closes to ensure the availability of the three-phase supply to the appliance.

The rating contactor RL4 can be selected according to the full-load current rating of the appliances. Here the contact current rating of the relays forming the four-pole contactor is up to 30A. the availability of phases R, Y and B is monitored by appropriate LEDs connected across the secondary windings of transformers X1, X2 and X3 respectively. Hence this circuit does not require a separate indicator lamp for monitoring the availability of the three phases. When phase R is available, LED1 glows. When phase Y is available, LED2 glows. When phase B is available LED3 glows.

The main advantage of this circuit is that it protects three-phase appliance from failure of any of the phases by disconnecting the power supply through the relays acting as contactors and automatically restores the three-phase supply to the appliance when all phases are available.

TABLE 2.6.1 SPECIFICATIONS

Electrical Specification	
Supply Voltage:	220-240 Volts AC, 50-60 Hertz, single
Surge Protection:	220-230V
Compatible Load Types:	Standard industrial appliances with 30A rating.
Power Plug:	Three 2-pin plugs for the three phases.
Controlled Outlet:	2-pin
Minimum Load:	No minimum load required

Maximum Load:	30 Amps (for resistive loads); 230V
Device power requirement:	240V 500mA

2.6.2 DESCRIPTION OF COMPONENTS USED IN THE PROJECT

- **RESISTOR:** The resistor is an electronic device used for resisting energy, current or electron flow. Basically 1kΩ resistor was used in each of the power modules to protect each of the LEDs. Also 100kΩ resistor was used in the timing circuit area.
- **CAPACITOR:** A capacitor is a device that stores electrical charge, using a positively charged surface and a negatively with a gap between them. Capacitors of $2200u_f$ were basically used in the circuit.
- **TRANSISTOR:** A transistor is a tiny electrical device that can switch on and off, letting current through or blocking it as necessary.
- **LIGHT EMITTING DIODES (LEDs):** Light emitting diodes are used in this project for detecting the presence or availability of phases Red, Yellow and Blue where appropriate.
- **IC NE555 TIMER:** The IC NE555 is the delay timer used in the circuit and its main function in the circuit is to alert the relay in front of it when all phases are made available.
- **RELAYS:** A relay is an electromagnetic device that acts basically as an electrical-control switch. It consists of a coil that is energized to magnetize a permeable iron

circuit actuate an armature. In this project, it basically gets energized and links up modules.

- **RECTIFIER CIRCUIT:** This is a circuit that employs one or more diodes to convert AC voltage into pulsating DC voltage.
- **STEP DOWN TRANSFORMER:** This is a static piece of apparatus by means of which electric power in one circuit is transferred into electric power of same frequency in another circuit. In this project, a step down transformer of 12V was used.

2.6.3 OTHER MICELLANEOUS PARTS:

- Thick cardboard casing
- Transformer input of 220V / 12V 500mA
- AC cord with plug
- PCB / Screws.

CHAPTER THREE

DESIGN AND IMPLEMENTATION

Comprehensive steps taken in the design of this project is carefully explained in this chapter and arranged according to modules leading to the complete project. The various components used in the design were carefully assembled and tested on a bread board before soldering on the main board (Vero board). Basically the modules forming the whole circuit are divided into five parts and the diagrams justifying them are explained below.

Basically the circuit consists of;

- Three power supply units
- Timing circuit
- Relay circuit.

3.1 BLOCK DIAGRAM

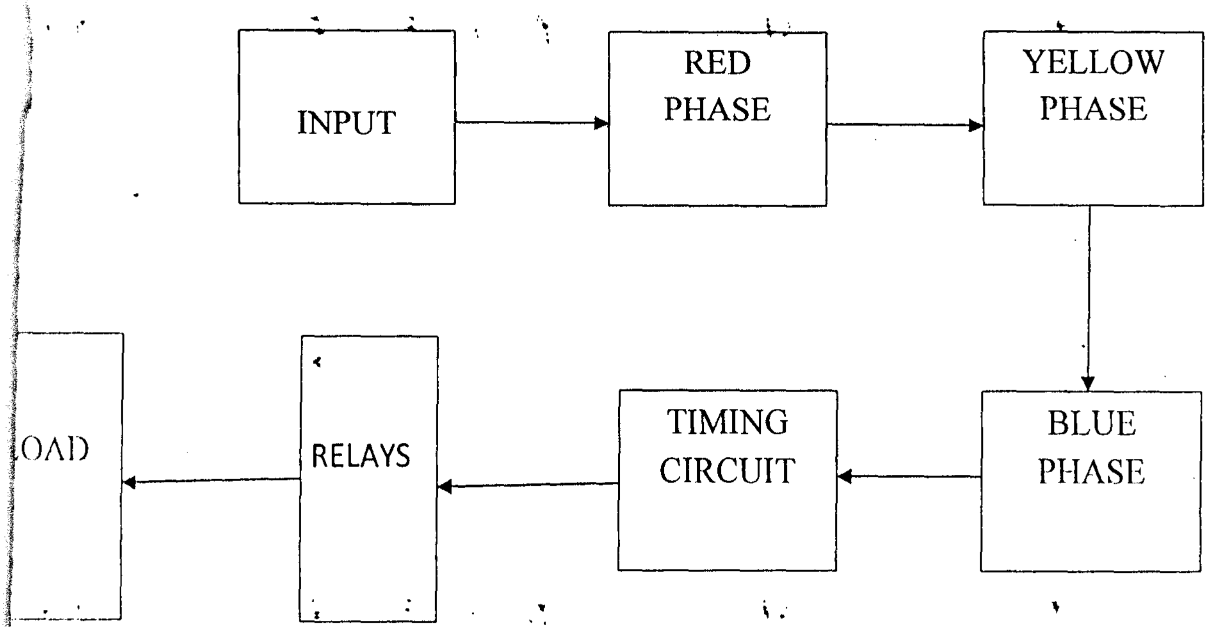


FIG 3.1 BLOCK DIAGRAM

3.2 THE POWER SUPPLY UNITS

The power supply units consist of a step down transformer, bridge rectifier, filtering capacitor, and power indicator.

The transformer steps down voltage from 220V AC to 12V AC. This voltage is then rectified (converted to DC), afterwards the ripples are filtered using filtering capacitor then to drive the relay. Also a power indicator (LED) is there to indicate that the line is alive. Below are circuit diagrams of the various modules forming up the whole circuit.

3.2.1 MODULE ONE

This module consists of a 220V AC to 12V AC, 500mA transformer connected to a full bridge rectifier which converts the AC to pulsating DC and a capacitor that smoothens is connected along sides an LED used as an indicator. A relay is connected which gets energized and the normally opened (N/O) contacts close to connect the Y phase to the input of the next transformer.

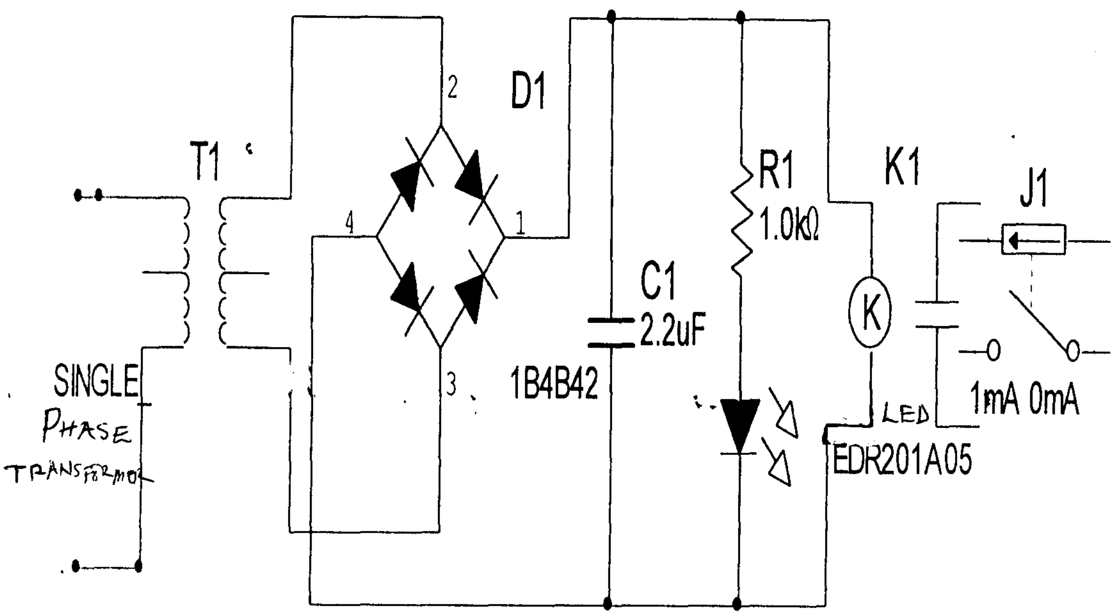


FIG 3.2 RED PHASE

3.2.2 MODULE TWO

This module also consists of a 220V AC to 12V AC, 500mA transformer connected to a full bridge rectifier which converts the AC to pulsating DC and a capacitor that smoothens is connected along sides an LED used as an indicator. A relay is connected which gets energized and the normally opened (N/O) contacts close to connect the B phase to the input of the next transformer.

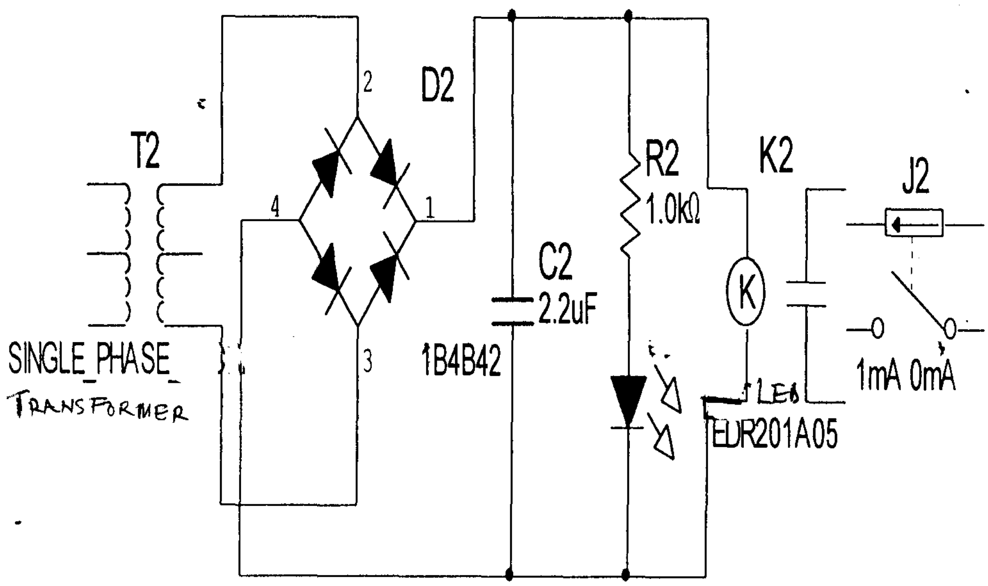


FIG 3.3 YELLOW PHASE

3.2.3 MODULE THREE

The third module consists of the third transformer, full wave bridge rectifier, a capacitor, the LED, a timing circuit and a relay. When the blue phase above is connected to the input of the thirds transformer, a triggering input is applied to the timer IC NE555. The delay timer triggers only when all the phases are available and provide delay of fractions of seconds which energizes the third relay and its normally opened (N/O) contacts close to connect the lines to the energizing four relays acting as contactors.

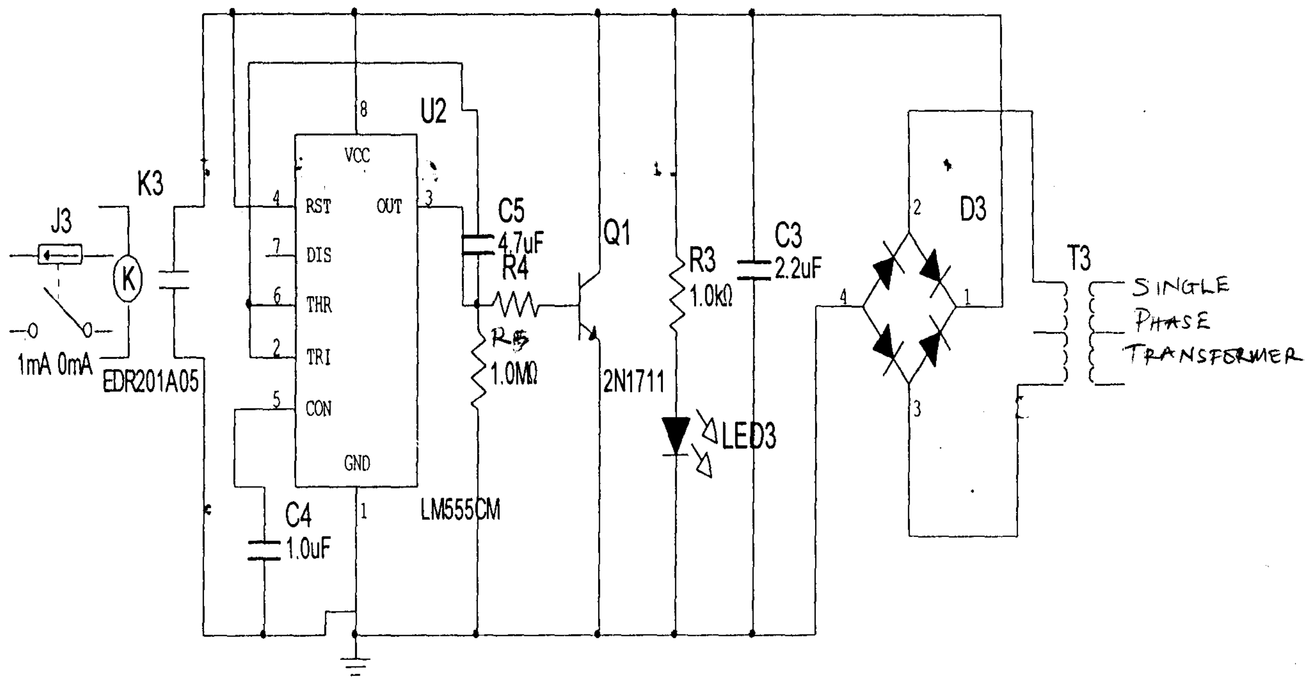
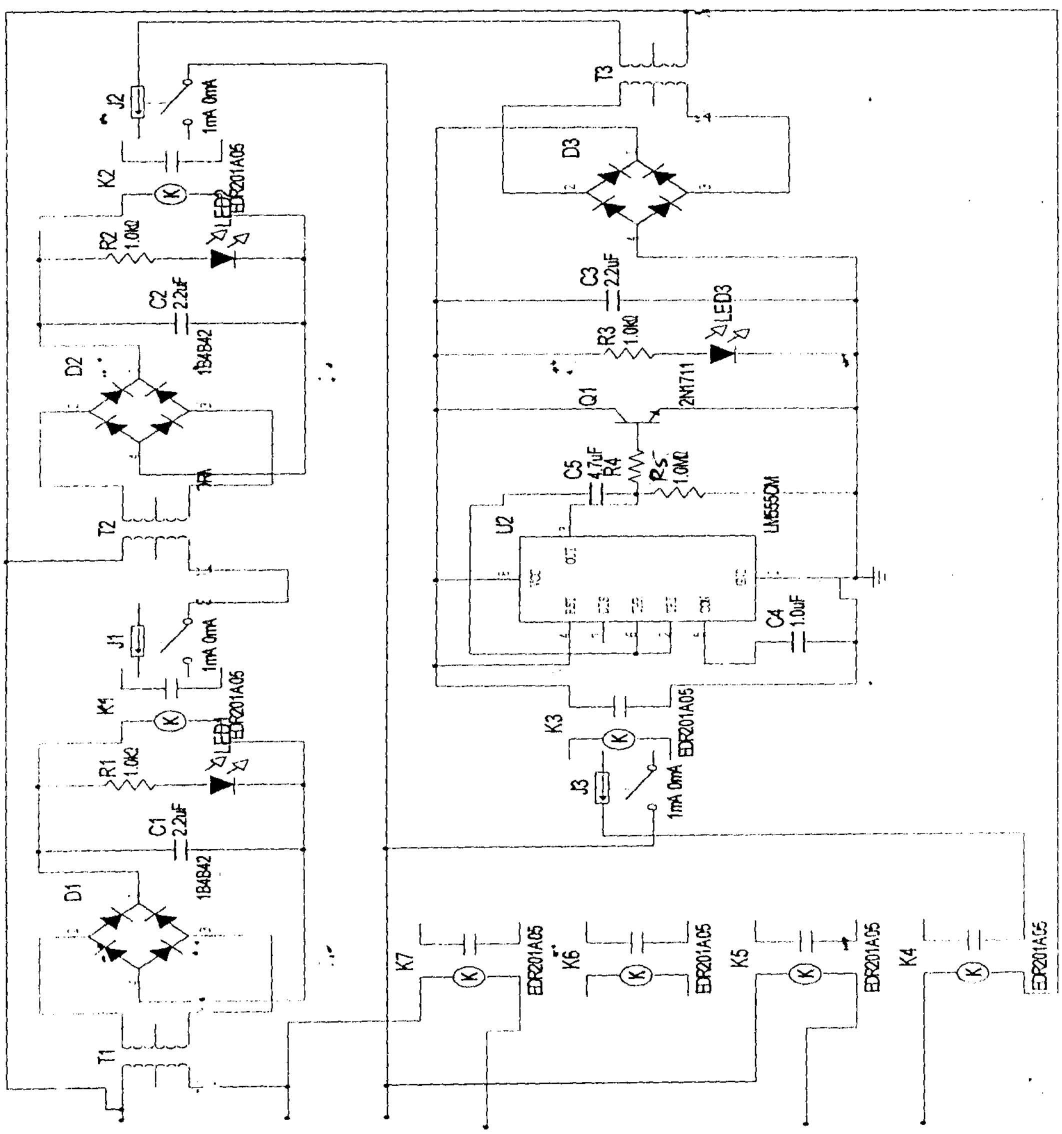


FIG 3.4 TIMING CIRCUIT

3.3 CIRCUIT DIAGRAM



KEY

T_1, T_2, T_3 : SINGLE PHASE TRANSFORMER

L O A D

FIG 3.5 CIRCUIT DIAGRAM

3.4 MATHEMATICAL ANALYSIS

3.4.1 POWER SUPPLY UNIT.

Peak voltage = $\sqrt{2} \times V_{rms}$

V_{rms} and secondary of transformer = 12V

$V_{rms} = \sqrt{2} \times 12 = 16.97$

Q = It = C_{dv}

It = C_{dv}

C = It/dv

But T = $1/2f$

And current supplied by transformer = 0.5 Amps

But for one to get dv, the voltage at which the relay will not be energized is less than 10V. That is to say that the relay would take 10V – 12V to operate.

Therefore dv = 12 – 10 = 2V

$$C = \frac{0.5 \times (1/2 \times 50)}{dv}$$

$$C = \frac{0.5 \times (1/2 \times 50)}{2}$$

C = $2500u_f$

Approximately = $2200u_f$ (my capacitor value).

For the indicators (LEDs),

V_{CC} = 12V

V_{LED} = 1.7V

I_{LED} = 20mA (max)

But let I_{LED} = 10mA

Therefore the resistance value will be,

$$R = \frac{V_{CC} - V_{LED}}{I_{LED}}$$

$$R = \frac{12 - 1.7}{10mA}$$

R = 1030Ω which makes it approximately

R = 1000Ω = 1KΩ.

3.4.2 THE RELAY UNIT.

The relay unit consists of a switching transistor and a relay. The transistor is used in saturation and cutoff mode. The resistor 100KΩ is the base resistor that ensures the use of this transistor in this region.

Now,

$$V_{CC} = I_C R_C + V_{CE}$$

V_{CE} equals zero at saturation

Therefore,

$V_{CC} = I_C R_C$

R_C = 400Ω (Resistance of Relay)

$I_{C = 12/400}$

I_C = 0.03A

$h_{fe= Ic/Ib}$

But h_{fe} = 350 (from data rate)

$I_{b=} \dfrac{I_C}{h_{fe}}$

I_b = 0.0000857A

3.4.3 THE TIMING UNIT

$V_b = I_b R_b$

Where V_b is the output from 555 Timer which is ⅔ of V_{CC}

Therefore,

⅔ × 12 = 8V

$R_b = \dfrac{8}{0.0000875}$

R_b = 91428.571Ω which makes it approximately,

R_b = 100KΩ.

The circuit timing is,

$T = 1.1 \times R \times C$

R in this case is the indicator resistance

$T = 1.1 \times 1000\Omega \times 2.2u_f$

$T = 2.42$ secs.

CHAPTER FOUR

TESTS, RESULT AND DISCUSSION

The project (THREE PHASE APPLIANCE PROTECTOR) before and after construction was put to series of tests so as to reach the desirable standard. These tests are carefully outlined in the sub-headings below.

4.1 CONSTRUCTION DETAILS

During the construction of the project, the components to be used at each instance were properly tested with a multimeter to be sure of the desired specification required at each instance. The test was also done when each module of the construction was completed till the last module summing up the whole circuit was reached. This now led us into the detailed testing and reaction of the full and completed project.

4.2 TESTING AND REACTION

After completion of the whole project, it was tested to check if truly the absence of one phase will affect other phases or not, and so the test was carried out by plugging each of the three input wires representing the phases one after the other in sequence. Under normal condition as the modules were arranged, the RED phase has to be available before the YELLOW phase and finally the BLUE phase.

The first input wire was plugged in and the RED phase was available. Now from the test we decided to plug in the third input wire expecting the BLUE phase to be available but it wasn't. This was simply because the YELLOW phase was not available hence proving that any other arrangement will not make all phases available except they are plugged in sequence.

Finally the reaction and observation that was noticed in testing the circuit was that it (THE THREE PHASE APPLIANCE PROTECTOR) works with the principle of a logical AND Gate that needs all input to be one (1) for all phases to be present.

4.3 RELEVANCE OF RESULT

After a successful test of the project work, it was discovered that with the three phase appliance protector one could save a lot of cost which are listed below.

- Cost of motor or compressor
- Cost of motor or compressor installation
- Cost of possible delayed shipment
- Cost of possible production losses
- Cost of overtime
- Cost of potential loss of orders
- Cost of collateral damages.

4.4 PROJECT CASING

The project after construction was carefully arranged in a casing so as to make it look attractive and presentable. Also, proper ventilation was provided to allow air into the circuit to avoid overheating of components.

4.5 LIMITATION / SHORTCOMING

The major shortcoming in the project is the timing which is less than a second when each phase is made available. From the calculations made in chapter three ,it is expected that when a phase is plugged it takes approximately two seconds to be available but during testing, this was not the case.

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CONCLUSION

In conclusion, the three phase appliance protector is a project that was designed to provide cost effective protection for our three phase appliances or industrial appliances in the event of failure of one or two of the phases. After the construction the circuit was tested to see how it works and it was seen that when the THREE PHASE APPLIANCE PRTECTOR detects a missing phase in the appliance and restores it only when all phases are complete.

5.1 PROBLEMS AND RECOMENDATIONS

One of the major problems encountered in this project was the sourcing of an industrial contactor that probably would have made the circuitry more compact. Since the industrial contactor was not used, relays having similar current ratings were used. Though it made the circuitry look a little cumbersome but the main purpose was still achieved. For future work on this project or related projects to this, I'll still advice the use of industrial contactors instead of relays.