DESIGN AND CONSTRUCTION OF THREE- PHASE EQUIPMENT PROTECTOR

BY

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DEDICATION

I dedicate this project report to the God of due season.

DECLARATION

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

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Finally, I thank my God for Giving me the strength and grace to come this far, and I equally thank Busola for standing by me always.

ABSTRACT

This report is based on the design and construction of a three -phase monitor. Unlike other phase monitors, that monitor only phase reversal, phase unbalance, over-voltage and under-voltage, the device that is reported in this project monitors phase loss only and thus it protects a three-phase equipment from failure due to single-phasing.

The device operates by de-energising the overload relay whenever there is a loss of one phase or more and re-energising it upon restoration of all the corresponding three-phases.

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CHAPTER ONE

1.0 INTRODUCTION

Three – phase motors are robust pieces of equipment widely used commercially and industrially in the modern times. These pieces of equipment are capable of years of dependable service, provided they are well maintained.[9,1]

A three – phase ac motor is also called a poly – phase induction motor and it is widely used for various industrial applications. Industries do encounter frequent failure of three – phase equipment and it was found that these failure were caused mostly by at least one of phase reversal, under voltage, over voltage, phase unbalance and phase loss.

Another important cause of motor failure is single – phase condition.[9] Therefore, the scope of this project work is to design and construct a device that will protect a three – phase equipment from the effect of single – phase condition. The major causes of three-phase equipment failures are:

i. Phase reversal

ii. Under voltage

iii. Over voltage

iv. Phase unbalance. [5,1]

Electrical engineers have been working tirelessly and several devices have been designed, constructed and developed to overcome all these problems. Monitoring devices have been designed to tackle all the causes of motor failures listed above. Some devices monitor phase reversal, under voltage, over voltage and phase unbalance altogether while some selectively monitor each phase problem.

1.1 THREE – PHASE LOADS

The most important class of three-phase load is the electric motor. A three phase induction motor has a simple design, inherently high starting torque, and high efficiency. Such motors are applied in industry for pumps, fans, blowers, compressors, conveyor drives, and many other kinds of motor-driven equipment. A three-phase motor will be more compact and less costly than a single-phase motor of the same voltage class and rating; and single-phase AC motors above 10 HP (7.5 kW) are uncommon. Three phase motors will also vibrate less and hence last longer than single phase motor of the same power used under the same conditions. Large air conditioning, etc. equipment use three-phase motors for reasons of efficiency, economy and longevity.[8]

Resistance heating loads such as electric boilers may be connected to three-phase systems. Electric lighting may also be similarly connected. These types of loads do not require the revolving magnetic field characteristic of three-phase motors but take advantage of the higher voltage and power level usually associated with three-phase distribution. Fluorescent lighting systems also benefit from reduced flicker if adjacent fixtures are powered from different phases.

Large rectifier systems may have three-phase inputs; the resulting DC current is easier to filter (smooth) than the output of a single-phase rectifier. Such rectifiers may be used for battery charging, electrolysis processes such as aluminium production, or for operation of DC motors.

An interesting example of a three-phase load is the electric arc furnance used in steelmaking and in refining of ores.

Generally, a three – phase equipment is associated with common problems arising from conditions like phase reversal, under voltage, over voltage, phase unbalance and rarely phase loss. However, phase loss is a typical problem facing industries in Nigeria today. The reason being that the nation of Nigeria is currently undergoing serious problem in its power sector.

1.2 AIMS AND OBJECTIVES

Erratic loss of a phase or phases due poor power supply becomes a significant problem to Nigerian economy today because most of the domestic and industrial pieces of equipment in the modern times rely on electricity for their operations. Hence, there is high demand for designs that will alleviate the problems arising due to poor power supply.

This project work is therefore aimed at a design that will protect a three – phase electrical equipment from failure due to phase – loss. Hence the project is titled "Three-Phase Equipment Protector".

CHAPTER TWO

2.0 LITERATURE REVIEW / HISTORICAL BACKGROUND

A three – phase equipment uses three – phase power supply and therefore, it is subject to failures caused by several conditions associated with a three – phase system. In chapter one of this project work, it was explained that several designs have been made to protect a three – phase equipment from faults arising from;

Phase reversal,

Phase unbalance,

Over voltage, and

Under voltage

2.1 CAUSES OF THREE-PHASE EQUIPMENT FAILURES

PHASE UNBALANCE:

This condition occurs in a three – phase system when single phase loads are connected such that one or two of the lines (phases) carry more or less of the load. This could cause motor to run at temperatures above published ratings. Most phase – unbalance monitoring devices are adjustable from 2 – 10% unbalance. The monitoring device is deigned to trip when any one of the three lines deviates from the average of all three lines by more than the adjusted set point.

Phase reversal:

It is a condition under which any two of the three phases are reversed. And it causes motor to run in the opposite direction. This may cause damage to driven machinery or injury to personnel. This condition usually occurs as a result of mistakes made during the routine maintenance or when modifications are made to the circuit. Already, a monitoring device has been designed and constructed to protect a three – phase equipment from faults arising from phase – reversal. The monitoring unit simply trips if the sequence of the three phases is anything other than A – B – C.

Under voltage:

This condition occurs when voltage in all three lines of a three – phase system drops simultaneously. Units have been designed to monitor under voltage condition in a three – phase system. This type of monitors are adjustable as a percentage of nominal voltage. The unit trips when the average of all the three lines is less than the adjusted set point for a period longer than the adjustable time delay drop – out.

Over voltage:

It is a condition under which voltage in all three lines of a three – phase system rises simultaneously. Over voltage protection is fixed at 110% of nominal voltage on most over-voltage monitors. The monitoring unit trips when the average of all three lines is greater than the fixed set point for a period longer than the time delay drop – out.

This project work comes up with a design and construction of device that functions uniquely. The design which is called "three-phase equipment protector" protects the three –phase machine by tripping whenever a three – phase condition turns to single – phase condition due to loss of one or two of the three phases. The device also reconnects upon restoration of all the three phases.

The importance of this project work cannot be over – emphasized because while other phase monitors protect three-phase motors from failures due to over-voltage, phase unbalance, phase reversal and under- voltage, three-phase equipment protector protects the motor from faults arising from single phase condition.

Single – phase condition is known as "single – phasing". The loss of a single phase on a three – phase system may be due to a blown fuse on the utility system or from the corresponding power station. Loss of a single phase may also result from a single – phase overload condition causing one fuse blow. The loss of one phase of a three – phase line can cause serious problems for three – phase motors. It may cause the motor windings to overheat and inhibits the motor from operating at its rated horse power. And worst of all, it can cause the motor to draw locked current.[1,12]

Therefore, three-phase equipment protector is very important and it is of great advantages since it protects the motor from:

i. Failure due to single – phase condition

ii. Inhibition due to phase – loss effect.

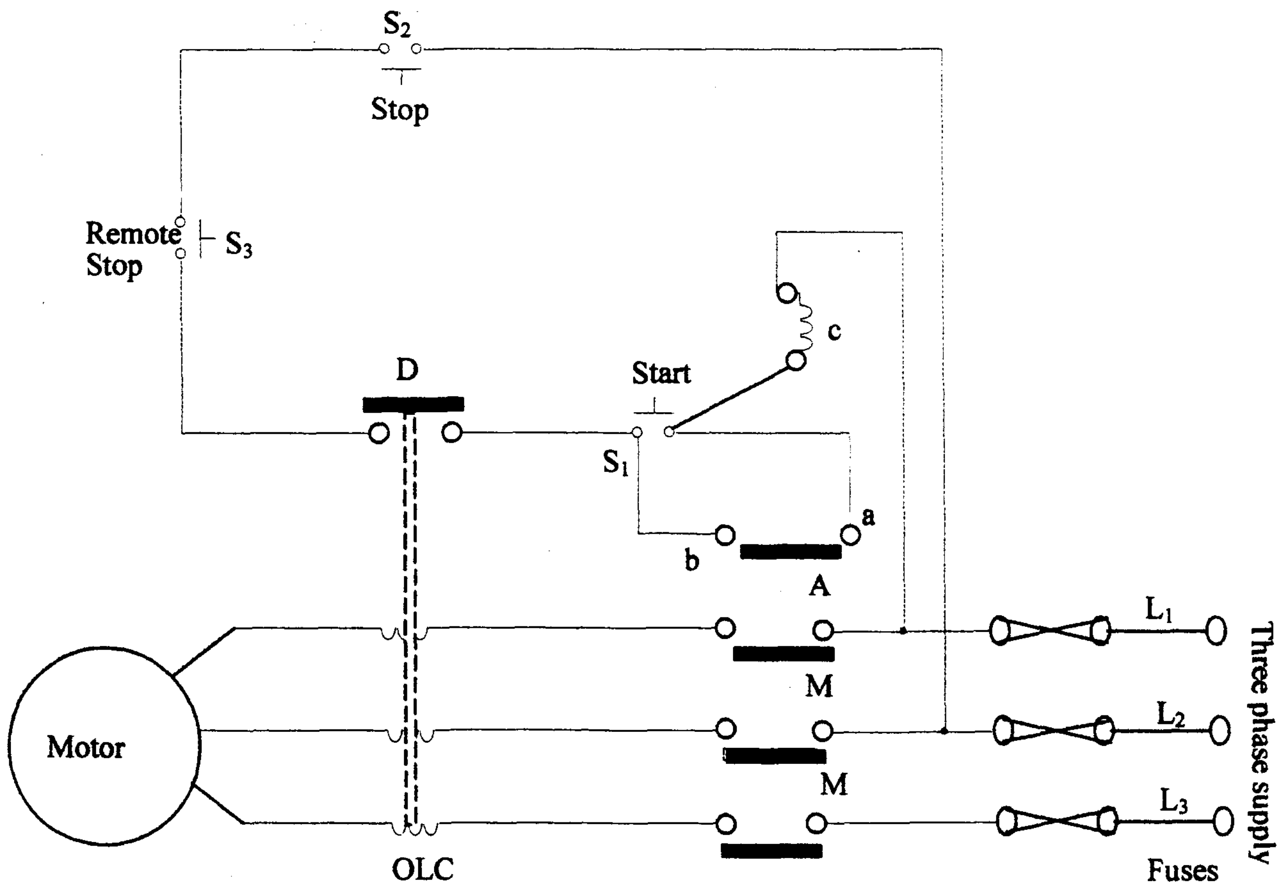
2.2 THEORETICAL BACKGROUND

Three – phase induction motor is the most popular type of a.c. motor. It is very commonly used for industrial drives since it is cheap, robust, efficient and reliable. It has good speed regulation and high starting torque. It requires little maintenance. It has a reasonable overload capacity.

A three – phase induction motor essentially consists of two parts; the stator and the rotor. When a three – phase supply is connected to the stator of a three – phase induction motor, a rotating magnetic field is produced and the rotor starts rotating. Hence, a three – phase induction motor is self-starting. At the time of starting, the motor slip is unity and the starting current is very large. The purpose of the starter is not to actually start the motor. The starter of the motor performs two functions:

1. To reduce the heavy starting current.
2. To provide overload and under – voltage protection.

Three – phase induction motor is commonly started by using direct – on – line starter (D.O.L. Starter).



Direct-Online-Motor Starter Circuit

Fig. 2-1

The system in Fig.2.1 shows the connections for one type of the direct – on – line (D.O.L.) starter. In the direct – on – line method of starting motors, the machine is connected by means of a starter across the full supply voltage. Direct – on – line starter consists of a coil – operated contactor, C controlled by start and stop buttons which may be installed at convenient places remote from the starter.[13] On pressing the start push button S_1 (which is normally held open by a spring) the contactor coil C is energized from two line conductors L_1 and L_2. The three main contacts, M and the auxiliary contact, A close and the terminals a and b are short – circuited. Thus the motor is connected to the supply. When the pressure on S_1 is released, it moves back under a force due to the action from the spring. Still, the coil C remains energized through ab. The main contacts M remain closed and the motor continues to get supply. Therefore, contact A is also called hold – on – contact.

On pressing the stop push button (which is normally held closed by spring), the supply through the contactor coil C is disconnected. Since the coil C is de – energized, the main contacts M and contact A are opened. The supply to motor is disconnected and the motor stops.[1,4,5]

2.2.1 UNDER- VOLTAGE PROTECTION

When the voltage falls below a certain value, or in the event of failure of supply during machine operation, the coil C is de – energized. The motor is then disconnected from the supply.

2.2.2 OVERLOAD PROTECTION

In case of an overload on the motor, one or all the overload coils (O.L.C) are energized. The normally closed contact D is opened and the contactor coil is de – energized to disconnect the supply to the motor.

Short – circuit protection is enhanced by the fuses provided.

2.2.3 EQUATIONS

Let I_{st} = Starting current drawn from the supply mains per phase.

I_{fl} = Full load current drown from the supply mains per phase

T_{est} = Starting torque

T_{efl} = Full load torque

S_{fl} = Slip at full load

Given that rotor copper loss = s multiplied by rotor input;

$$3I_2^2 R_2 = \frac{sX2\pi n_s T_e}{2\pi n_s\, s} \text{ ------------------- } (1.0)$$

Therefore $$T_e = \frac{3I_2^2R_2}{2\pi n_s\, s} \text{ ------------------- } (1.1)$$

At starting, $s = 1$, $I_2 = I_{2st}$, $T_e = T_{est}$

Therefore $$T_{est} = \frac{3I_{2st}^2 R_2}{2\pi n_s X1} \text{ ------------------- } (1.2)$$

At full – load

$s = s_{fl}$, $I_2 = I_{2fl}$, $T_e = T_{est}$

$$T_{efl} = \frac{3I_{2fl}^2 R_2}{2\pi n_s X s_{fl}} \text{ ------------------------- } (1.3)$$

Therefore $$\frac{T_{est}}{T_{eft}} = \frac{(I_{2st})^2}{(I_{2fl})^2} X s_{fl} \text{ ------------------- } (1.4)$$

If the no – load current is neglected,

(I_{st}) X (effective stator turns) = (I_{2st}) X (effective rotor turns) ----------------- (1.5)

From equations (1.5) and (1.4)

$$\frac{I_{st}}{I_{fl}} = \frac{I_{2st}}{I_{2fl}} \quad \text{------------------- (1.6)}$$

From equations (1.3) and (1.6)

$$\frac{T_{est}}{T_{efl}} = \frac{(Ist)^2 \times s_{fl}}{(I_{fl})^2} \quad \text{-------------- (1.7)}$$

If V_1 = stator voltage per phase equivalent
Z_{e10} = standstill impedance per phase of the motor referred to stator

That is, the starting current is equal to the short – circuit current.
Combining equations (1.7) and (1.8), we get

$$\frac{T_{est}}{T_{efl}} = \frac{(I_{sc})^2 s_{fl}}{(I_{fl})^2} \quad \text{-------------- (1.9)}$$

The three-phase equation can be given by

Real power:
$W_{applied} = 3^{1/2}$ U I PF / 1000 (1)
where
$W_{applied}$ = real power (Kilowatts)
U = voltage (volts)
I = current (Amps)
PF = power factor - 0.7 - 0.95

Total power:
W = $3^{1/2}$ U I / 1000 (2)

Break horse power
$W_{BHP} = 3^{1/2}$ U I PF μ / 746 (3)
where
μ = device efficiency [1]

2.2.4 COMPARISON BETWEEN THREE - PHASE SYNCHRONOUS AND INDUCTION MOTORS

i. A synchronous motor is a doubly excited machine. Its armature winding is energized from an ac source and its field winding from a dc source. While an induction motor is a singly – excited machine its stator winding is energized from an ac source.

ii. A synchronous machine always runs at synchronous speed. The speed is independent of load. Whereas the speed of an induction motor falls with increase in load and its always less than synchronous speed.

iii. A synchronous machine is not self – starting. It has to be run up to synchronous speed by some means before it can synchronize to ac supply whereas an induction motor has got self starting torque.

iv. A synchronous motor can be operated under wide range of power factors, both lagging and leading by changing its excitation. While an induction motor operates only at power lagging factor, which becomes very poor at high load.

v. A synchronous motor can be used for power factor correction in addition to supplying torque to drive mechanical loads. An induction motor is used for driving mechanical load only.

vi. A synchronous motor is more efficient than an induction motor of the same output and voltage rating.

vii. An induction motor is cheaper than a synchronous motor of the same output and voltage rating. [1]

2.2.5 THREE – PHASE ELECTRIC POWER TRANMISSION

It is a type of poly phase system mainly used to power large motors and other such devices. A three – phase system is generally more economical than others because it uses less conduction material to transmit electric power than equivalent single – phase, two – phase or direct – current systems at the same voltage.

In a three – phase system, three circuit conductors carry three alter nating currents (of the same frequency) which reach their instantaneous peak values at different times. Taking one conductor as the reference, the other two currents are delayed in time by one – third and two – third of one cycle of the electrical current. This delay between "phases" has the effect of giving constant power transfer over each cycle of the current, and also makes it possible to produce a rotating magnetic field in an electric motor.

Three phase systems may or may not have a neutral wire. A neutral wire allows the three – phase system to use a higher voltage while still supporting lower voltage single – phase appliances.[2] In high voltage distribution situation, it is common not to have a neutral wire since the loads can simply be connected between – phases (phase – phase connection).[2,6]

Three – phase has properties that make it very desirable in electric power system. The properties are:

i. The phase currents tend to cancel out one another, summing to zero in the case of a linear balanced load. This makes it possible to eliminate or reduce the size of the neutral conductor on some lines, all the phase conductors carry the same current and so can be the same size for the balanced load.

ii. Power transfer into a linear balanced load is constant. This helps to reduce generator and motor vibrations.

iii. Three – phase system can produce a magnetic field that rotates in a specified direction. This simplifies the design of electric motors. Three – phase transmission

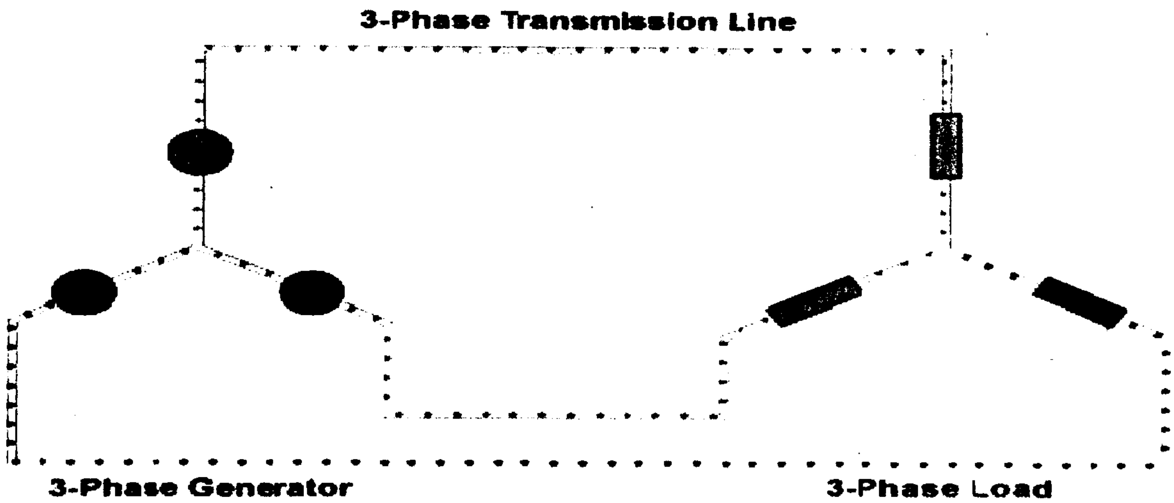


Fig.2.2

Three-phase current flow

Figure 2.2 shows a typical three-phase current flow. At the power station, an electrical generator converts mechanical power into a set of alternating electric currents, one from each electromagnetic coil or winding of the generator. The currents are sinusoidal functions of time, all at the same frequency but offset in time to give different phases. In a three-phase system the phases are spaced equally, giving a phase separation of one-third cycle. The power frequency is typically 50Hz in Nigeria.

Generators output at a voltage that ranges from hundreds of volts to 30,000 volts. At the power station, transformers "step-up" This voltage to one more suitable for transmission. After numerous further conversions in the transmission and distribution network the power is finally transformed to the standard mains voltage (*i.e.* the "household" voltage). The power may already have been split into single phase at this point or it may still be three phase. Where the stepdown is three phase, the output of this transformer is usually star (Y) connected with the standard mains voltage (220V in Nigeria) being the phase-neutral voltage. Another system commonly seen in is to have a delta connected secondary with a centre tap on one of the windings supplying the ground and neutral.

Single-phase loads may be connected to a three-phase system, either by connecting across two live conductors (a phase-to-phase connection), or by connecting between a phase conductor and the system neutral which is either connected to the center of the Y (star) secondary winding of the supply transformer, or is connected to the center of one winding of a delta transformer. Single-phase loads are usually distributed evenly between the phases of the three-phase system for efficient use of the supply transformer and supply conductors.

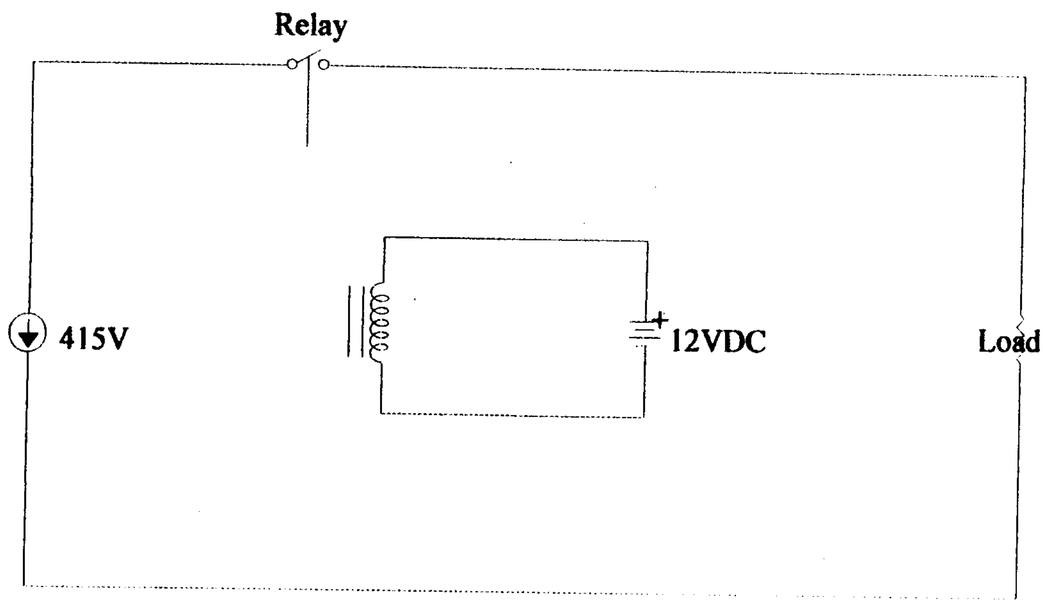
The neutral point of a three phase system exists at the mathematical center of an equilateral triangle formed by the phase points, and the line-to-line voltage of a three-phase system is correspondingly $\sqrt{3}$times the line to neutral voltage. Where the line-to-neutral voltage is a standard utilization voltage (for example in a 240 V/415 V system), individual single-phase utility customers or loads may each be connected to a different phase of the supply. Where the line-to-neutral voltage is not a common utilization voltage, for example in a 347/600 V system, single-phase loads must be supplied by individual step-down transformers. Where three phase at low voltage is otherwise in use, it may still be split out into single phase service cables through joints in the supply network or it may be delivered to a master distribution board (breaker panel) at the customer's premises. Connecting an electrical circuit from one phase to the neutral generally supplies the country's standard single phase voltage (230 VAC in Nigeria) to the circuit. The power transmission grid is organized so that each phase carries the same magnitude of current out of the major parts of the transmission system. The currents returning from the customers' premises to the last supply transformer all share the neutral wire, but the three-phase system ensures that the sum of the returning currents is approximately zero. The primary side of that supply transformer commonly uses a delta winding, and no neutral is needed in the The high voltage side of the network. Any unbalanced phase loading on the secondary side of the transformer will use the transformer capacity inefficiently, but equal current will be drawn from the phases feeding the primary delta winding, leaving the high voltage network unaffected.

If the supply neutral of a three-phase system with line-to-neutral connected loads is broken, generally the voltage balance on the loads will no longer be maintained. The now-virtual neutral point will tend to drift toward the most heavily loaded phase, causing undervoltage conditions on that phase only. Correspondingly, the lightly-loaded phases may approach the line-to-line voltage, which exceeds the line-to-neutral voltage by a factor of $\sqrt{3}$, causing overheating and failure of many types of loads. For example, if several houses are connected to a common three-phase transformer, each house might be connected to one of the three phases. If the neutral connection is broken at the

transformer or on the distribution line somewhere upstream of the transformer, all equipment in a house might be damaged due to overvoltage. This type of failure event can be difficult to troubleshoot if the drifting neutral effect is not understood. With inductive and/or capacitive loads, all phases can suffer damage as the reactive current moves across abnormal paths in the unbalanced system, especially if resonance conditions occur. For this reason, neutral connections are a critical part of a power distribution network and must be made as reliable as any of the phase connections.
Independent (or nearly so) three phase systems are sometimes interconnected using DC transmission (with the requisite transformation equipment) in order to isolate certain potential electrical transients from propagating from one system to another. [8]

2.2.6 THEORY OF RELAY

The magnetic field produced by a coil of current – carrying wire can be used to exert a mechanical force on any magnetic object. Placing a magnetic object near such a coil for the purpose of making the object move whenever the coil is electrically energized will give solenoid. The movable magnetic object is called an armature and most armatures can be moved with either direct current (DC) or alternating (AC) energized the coil. The polarity of the magnetic field is irrelevant for the purpose of attracting an iron armature. Solenoid becomes relay when it is used to actuate a set of switch contacts. Mostly, the current required to energized a relay coil much lesser than the current rating of the contact. [3,7]



Simple Relay Circuit

Fig.2.3

The schematic in Fig.2.2 shows a typical relay in which its coil is energized by the low - voltage (12 VDC) source, while the Single - Pole, Single - Throw (SPST) contact interrupt the 480 VAC circuit. Mostly, the current required to energized a relay coil much lesser than the current rating of the contact.

A relay may be used to actuate more than one set of contacts. The contacts mostly are normally – open, normally – closed, or the two combined.

When a relay is used to switch a large amount of electrical power through its contacts, it is called a contactor. Contactors generally have multiple contacts and those contacts are usually normally – open. This makes the power to the load to shut off when the coil is de – energized which is the normal state of a relay. Thus, a relay has the ability to allow a relatively small electric signal to switch a relatively large electric signal and also offer electrical isolation between coil and contact circuit.

2.2.7 TYPES OF RELAY

The importance of relays cannot be over-emphasized both in electronics and electrical power systems. Typically, relays are used electronic devices like power inverters and in power systems devices like medium and high voltage circuit breakers. Common types of relays are:

i. Overload relays,

ii. Neutral relays,

iii. Biased relays,

iv. Polarized relays,

v. Permopolarised relays,

vi. Slow-release relays,and

vii. A.c. relays

i. **Neutral Relays:** The neutral relays have a magnetic coil which operates at a specified current regardless of the voltage applied. It is the most elementary type of relay.

ii. **Biased Relays:** Biased relays have a permanent magnet above the armature. The relay operates if the current through the coil wingding establishes a magnetomotive force (mmf) that opposes the flux by the permanent magnet. If the fluxes are in the same direction, the relay will not operate. Even for a greater current through the coil.

iii. **Polarised Relays:** It also operates only when the current through the coil is in one direction. It consists of a diode connected in series with the coil which blocks the current in the reverse direction.

The polarized relay is different from the biased relay majorly because biased relay allows current to pass through in the reverse direction

Without tripping whereas polarized relay blocks current in the reverse direction.

iv. **Permopolarised Relays:** They are also called magnetic stick relay. This type of relay has a magnetic circuit with high remanence. Two coils, one to operate (pick-up) and the other to release (drop) are present. The relay is activated by a current in the operate coil. On the interruption of the current the armature remains in picked up position by the residual magnetism. The relay is released by a current through the release coil.

v. **Slow-release Relays:** This type of relay has a capacitor connected in parallel to its coil. When the operating current is interrupted the release of relay is delayed by the stored charge in the capacitor. The relay releases as the capacitor discharges through the coil.

vi. **Relays for A.C:** These are neutral relays and picked up for a.c. (alternating current) current through their coil. These are very fast in action and used on power circuits of the point motors, where high current flows through the contacts. A normal relay would be slow and make sparks which in turn may weld the contacts together.

vii. Overload relays are specialized circuit breakers used with industrial motors to protect motors from damage caused by overload or electrical faults. Single – phase and multi – phase power systems typically include an overload relay for interrupting power in the conductors when a fault condition occurs, such as ground fault, phase loss, over-current or undercurrent condition. An overload relay is essentially a sensor that is connected between power supply and the load and upon the detection of a current overload condition, disconnects the load from the power supply. An overload relay is usually designed to operate over a wide range of values and the user usually set the trip current based upon the specifications of the motor in use. In the past, overload relays have been of the thermal type wherein a bimetal actuator is heated directly or indirectly as a function of the motor current and operates to effect interruption of the motor circuit under overload conditions. The coupling length of a latch released by the thermal deformation of the bimetallic plate is adjustable according to a kind of a load to facilitate adjustment of time from the start of flow of an overload current through the load until the disconnection of the load from its power supply. More recently, overload relays have been designed to utilize electronic circuitry responsiveness to signals derived from the secondary windings carrying the motor currents. [10]

CHAPTER THREE

3.0 DESIGN AND IMPLEMENTATION

The process of design and construction of this project involves the use of the following:-

i. Three 220v – relays (a.c)

ii. Rectangular – wooden base

iii. Transparent – rectangular – plastic casing

iv. Four – core cable

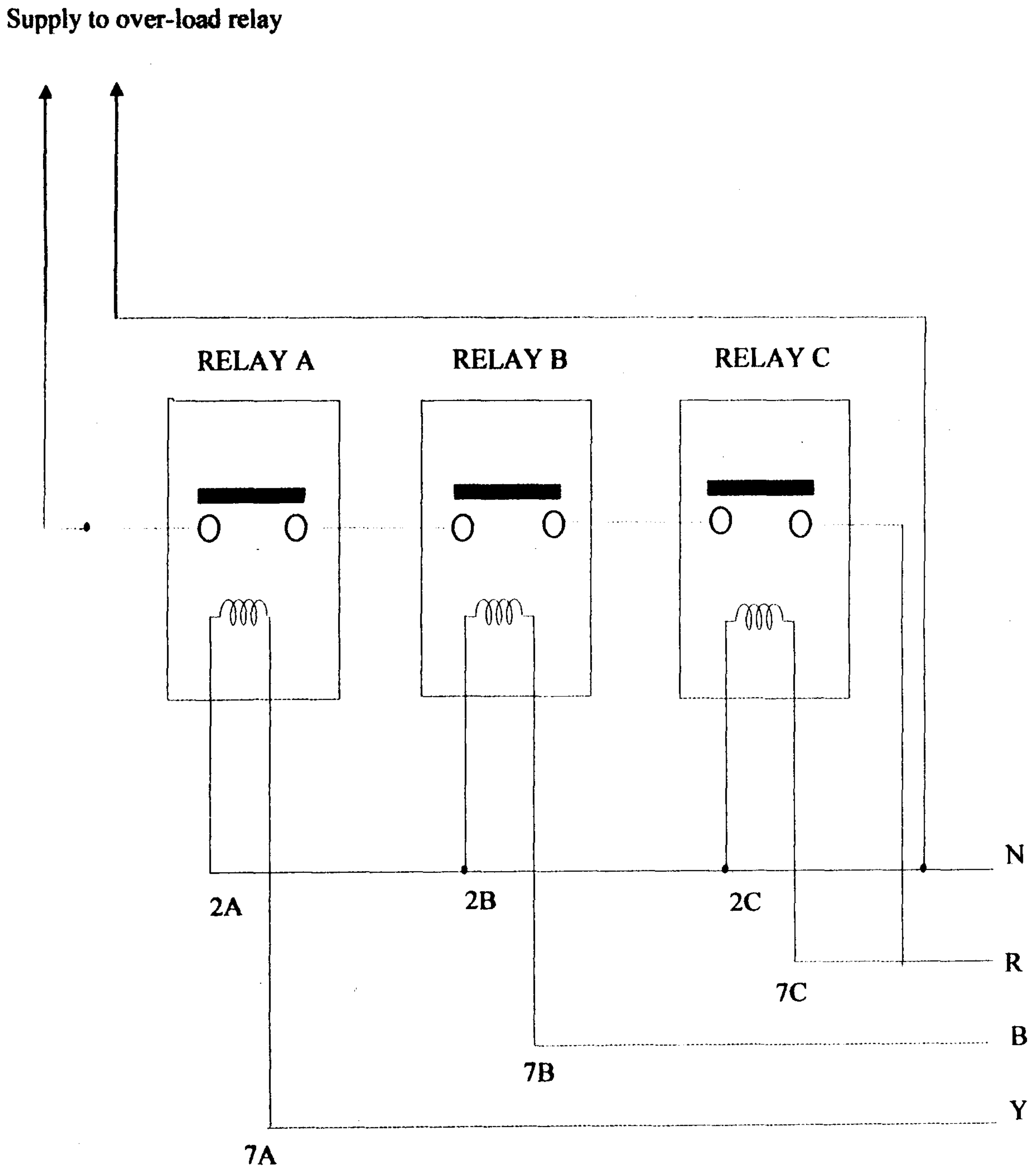
v. Three – phase plug

vi. Three – phase supply

The three 220v – relays were fixed to the wooden base in a serial fashion along the length of the base. This ensures that the relays are firmly fixed and it provides rigidity against pulling force.

The transparent – rectangular – plastic casing is a non-conductor [3] and it was designed both to house the relays and to provide easy access for inlet and outlet of the required cable. Also, the casing was designed to allow easy opening and closure in the event of maintenance.

The four – core cable is necessary since the device is designed for three – phase systems. One core stands for neutral, N while the remaining cores stand for L_1, L_2, and L_3. Where L_1, L_2, and L_3 are the respective phases of the three – phase supply. The four – core cable has one of its ends connected to the three – phase plug while the other end is connected to the input end of the device.



Three-phase equipment protector circuit

Fig.3.1

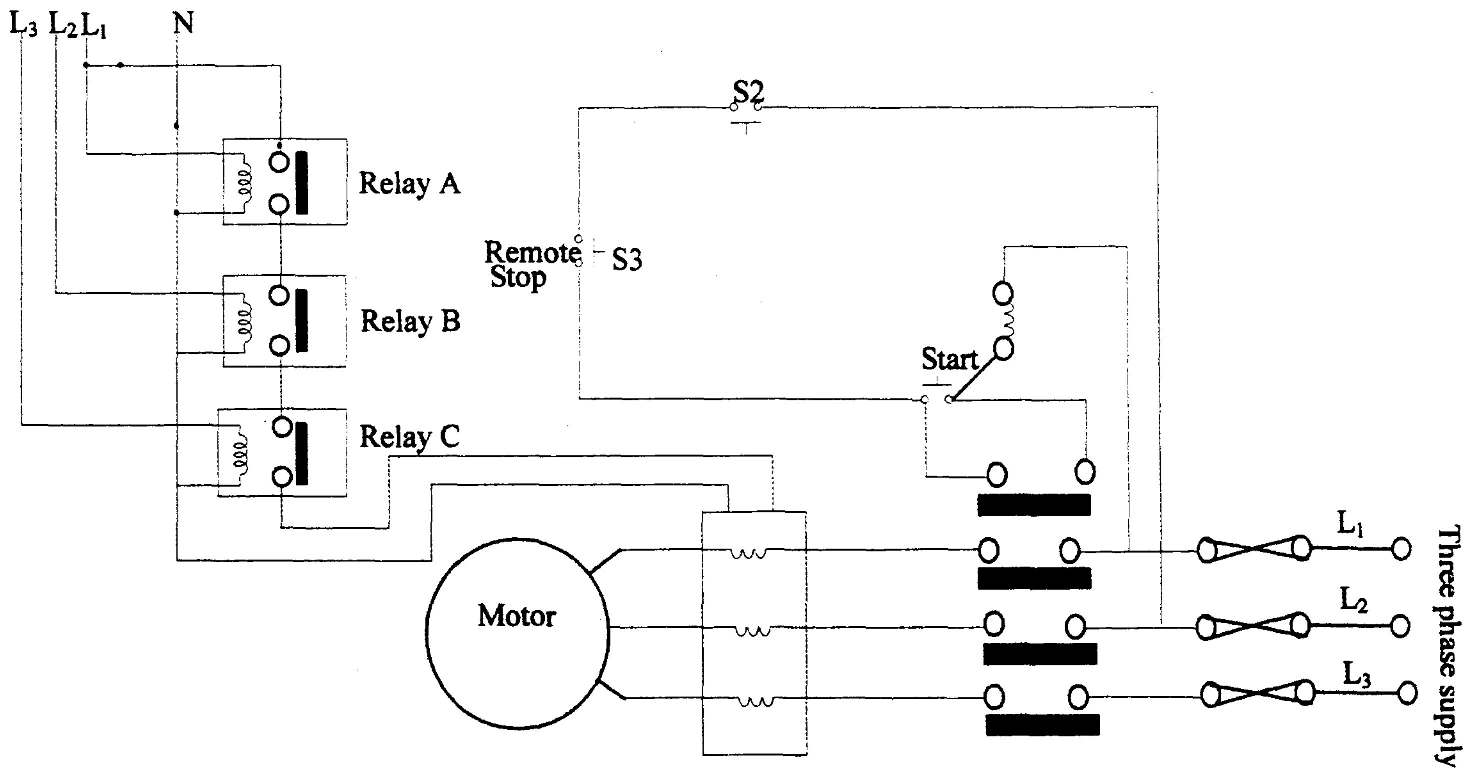
The four – core cable supplies power to the input of the protective device and the output is supplied as single – phase.

3.1 CIRCUIT ANALYSIS

Fig.3.1 shows how the components are connected to form a protective circuitry for a three-phase equipment. The various points on each relay are used for the appropriate connection. L_1, is connected to point 7 on the first relay, L_2, on point 7 on the second relay and L_3 on point 7 on the third relay. The neutral is connected to point 2 on the first relay, point 2 on the second relay and point 2 on the third relay. Point 3 on the first relay is connected to point 1 on the second relay. Point 3 on the second relay is connected to point 1 on the third relay while 3 on the third relay is extended.

The connection on point 3 on the third relay and the neutral cable were extended out from the transparent – rectangular – plastic casing through the outlet to form single – phase output.

The single – phase output was meant to be connected to the overload relay according to Fig.3.2 in order to energize or de-energize the overload relay under set conditions.



Complete Cicuit Diagram

Fig.3.2

CHAPTER FOUR

4.0 TESTS, RESULTS AND DISCUSSION

The realization of the aims and the objectives of this project was achieved during the process of testing the device designed and constructed.

In the light of this project, the device can only be used where three-phase supply is available and applicable. That is, the phase-loss monitor designed and constructed in the project is specifically designed for three phase equipment.

During the process of testing, the output terminal of the device is connected to the overload relay while input terminal is connected to the mains socket of a three phase supply.

The device was tested and observations were made under the following conditions;

i. Full three-phase supply,

ii. Loss of one of the three -phases ,

iii. Loss of two of the three-phases, and

iv. Loss of all the three phases

4.1 RESULTS

The observations that were made under the conditions listed above indeed fostered the realization of the aims of the project.

Upon connecting the device to both the supply and overload relay terminal , the following observations were made;

i. The device produces about 220V (ac) at its output terminal whenever the three phases of the three-phase supply system are all complete.

ii. The device does not give any output whenever there is a loss of any one phase of the three phases.

iii. The device does not give any output whenever there is a loss of two phases of the three phases

iv. The device does not give any output whenever there is a total loss of all the three phases.

v. The device gave a humming sound when all the three phase-supplies were complete.

vi. An electric burn was noticed few minutes after the device was connected to three-phase supply and there was no output thereafter.

4.2 DISCUSSION

The device of under test was designed to take-in three-phase supply at the input terminals and give out a 220V (ac) at its output terminal which is meant to energize the overload relay which in turn starts off the three-phase equipment.

The observations highlighted in this projects are simply the operations of the phase loss monitor. The diagram on page ... can be used to discuss the operations of the phase-loss monitor.

4.3 OPERATION OF THE DEVICE

The coils of the three relays are energized whenever the three phases; R,B and Y are complete. Hence the circuit closes and current flows through the output terminal.

i. A loss of one of the three phases automatically de-energizes one of the coils of the three relays which in effect renders the circuit open and thus the device does not give output.

ii. When two phases are lost in a three-phase system that supplies the phase-loss monitor, the two coils of the two corresponding relays are de-energized and this in effect opens the circuit. Hense the device gives no output under this condition.

iii. A total loss of all the three phases de-energizes the three coils of the three relays and this opens the circuit. Thus the device does not give output under this condition.

CHAPTER FIVE

5.0 CONCLUSIONS

The introductory chapter of this project work shows that three-phase equipment fail more times than not due to single-phasing ; a term which simply means a change from a three-phase condition to a single-phase condition as a result of loss of one or two of the three phases that constitute the three-phase system.

The testing and result in chapter four of this project also clearly show that the device designed and constructed in this project functions solely as an electrical device which protects a three-phase equipment by disconnecting the overload relay of a three phase equipment from the supply whenever there is a loss of one phase or more in the three-phase system and also, by reconnecting the overload relay upon restoration of the three phases.

Hence the aims and objectives were achieved in the presences of two limitations like lack of adequate supply of three-phase voltage, difficulty in accessing sufficient pieces of three-phase equipment.

This project work is however not without limitation as the scope of its design does not cover the times or cases when the relay is faulty and due for replacement. However, whenever one of the three relays is faulty or even all of them, there will be no output.

Therefore, subsequent design should be centered on added features that will automatically indicates that one or all the relays are faulty.

According to the observations discussed earlier in chapter four of this project, the device which was designed and constructed in this project only gives output when the three-phase supply is complete. That is a loss of one phase or more of the three- phases renders the circuit open and hence gives no output. Thus the overload relay is not powered and in turn, the three-phase equipment cannot be started off.

Therefore, having tested the device successfully with the highlighted observations, the aims and the objectives of this project have been achieved.

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