DESIGN AND CONSTRUCTION OF AUTOMATIC STAR-DELTA STARTER

BY

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DEDICATION

I dedicate this project to almighty Allah the lord of the universe and beyond, the most beneficent and the most merciful, the provider and the sustainer of life Whom indeed all praises and thanks are due. I also dedicate this project to my beloved parent Mr. ABUBAKAR ACHA and ACHA REKIYA.

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INTRODUCTION

1.1 OVERVIEW

The first practicable AC motor with poly phase power transmission system was invented by Nikola Tesla in 1882 in France and the initial patent was issued in 1888 after Tesla had left for United States. The foundation for understanding the way the motor operates was laid in his scientific work. Since then starters have been available. The great importance attached to a star-delta starter as an electromechanical device for starting induction motor effectively cannot be overlooked. When normal supply voltage is directly applied to a three-phase induction motor, a very large initial current is drawn usually in the range of 2.5 to 10 times its full-load current and develops only 1.5 times its full-load torque to overcome friction and initial shaft momentum on heavy loads, [13]. This excessive current is objectionable because it has an upsetting effect on the following:

i. The power source

ii. The device itself and other equipment connected to the distributing network.

iii. The torque and starting requirement of a load.

In response to the above problems, the higher capacity induction motors must use some special type of starting device called STARTER. For induction motor having rating exceeding 0.37 KW the automatic star-delta starter is recommended which is in accordance with IEE Regulations with section 522 of the 16^{th} edition of the wiring regulation of rotation machines which says "Every electric motor having a rating above 0.37 KW shall be provided with control against excess current in the motor or in the cable between the device and the motor with control apparatus incorporating a suitable device affording protection, [5].

Under factory and workshop act, regulation is provided for the control of machines or plant used in factories when power is being supplied to them. An automatic star-delta starter is an indispensable controller as far as fairly large load is concerned and it cannot be waved aside in industries where electric motors are in use for daily operation. The star-delta starter intended to start a three-phase induction motor in the connection and to ensure continuous operation in the delta connection. It consists of three contactors and a timer. Initially the operator held a button or a handle in the star position until the motor runs to at least 80% of the rated speed then upon release the handle the delta contactor would engage the motor in the normal running configuration for continuous operation. In this project, instead of the usual manual changing from star to delta connection the changeover is controlled by a timer to make it automatic. The, delta and mains contactors are incorporated in the power circuit and star assembled with it is the control circuit which controls the actions of the contactors in the power circuit. The power circuit is a three phase supply while the control circuit is a single phase supply.

1.2 AIMS AND OBJECTIVES

The aims and objectives of the project are to design and construct an electromechanical device that will start a three-phase AC motor in star connection, to ensure continuous operation in the delta connection, to provide means for the protection of the motor and its associated circuit against operating overload and to switch off the supply from the motor.

1.3 STATEMENT OF PROBLEM

Electric motors have become one of the commonest machines used in driving machineries in factories and workshops, and appliances in our homes and offices. In Nigeria and beyond this development is expected to be increasing because the use of induction motor for the driving of machineries have been growing significantly for centuries. Personal experience in Niger state revealed that almost 98% driving machineries in areas where there are electricity uses electric motors. This statistic is a semblance of what is happening in other part of Nigeria and the world at large. The efficiency and performance of these motors largely depend on the method of starting them. Switching them directly to the supply mains is problematic and disturbing because of the in-rush current. This sudden demand for large amount of current reflects in the distributing network as objectionable voltage drop which causes stoppage of other equipment in the supply network. The sudden high starting torque that results from the starting current surge is not suitable for the production of delicate products such as fabrics, paper etc. The obvious way to circumvent these abnormal conditions is to design and construct a reduced voltage starter (Automatic star-delta starter) which will start the motor in a reduce voltage manner to ensure gentle start and smooth acceleration and as protects the motor.

1.4 SIGNIFICANCE OF THE PRORJECT

The project is intended to providing opportunities for electrical engineering students to transform their theoretical knowledge into practical and industrial application. By so doing, the student will be able to design and construct different types of control devices for starting motors.

1.5 JUSTIFICATION

The project "Automatic star-delta starter" when completed will be economically and commercially viable as it will provide an excellent means of minimizing the problems imposed by direct on line starting. It will eliminate unnecessary maintenance cost and increase productivity, in fact, a very efficient and affordable method for starting electric motor.

1.6 AREA OF APPLICATION

Automatic Star-Delta starters are widely used in industries, factories and workshops for starting and protecting industrial machines used in various works such as:

Grinding, pumping of various liquids, lifting of loads, etc.

In our homes and offices, they can be used to start air conditioners and some other appliances that require induction motor for driving

1.7 SCOPE AND LIMITATIONS

This project entails designing an electrical circuit for a STAR-DELTA STARTER, selecting exact or appropriate ratings of components and constructing the device base on the designed circuit and selected components to achieve the set objective.

1.8 METH0D0LOGY

This project consists of two parts, the theoretical part and the practical part. The theoretical part is covered in chapter one and two. In chapter one the project is fully and clearly introduce. The core concept and system involved are fully reviewed in chapter two. Design, selection of components and construction are carried out in chapter three. Test and commissioning are comprehensively done in chapter four. Chapter five ends the project by making some important recommendations and conclusions including the relevant materials that assisted me.

1.9 METHOD OF OPERATION

The device's operational method will better be understood by drawing the two circuit diagrams (i.e the power and control circuit) that made up the device. See the in figure 1.1 and 1.2 bellow.

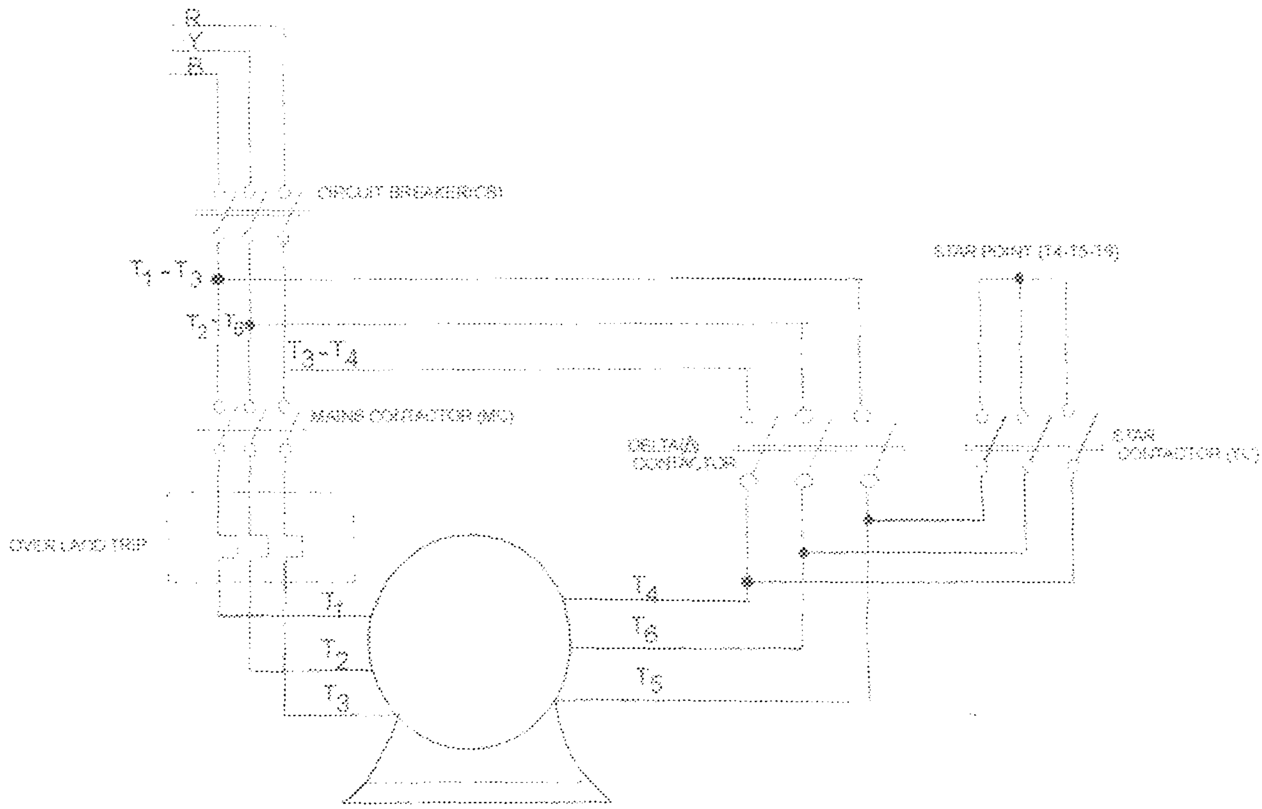

Fig1.1Automatic Star-Delta Starter power circuit.

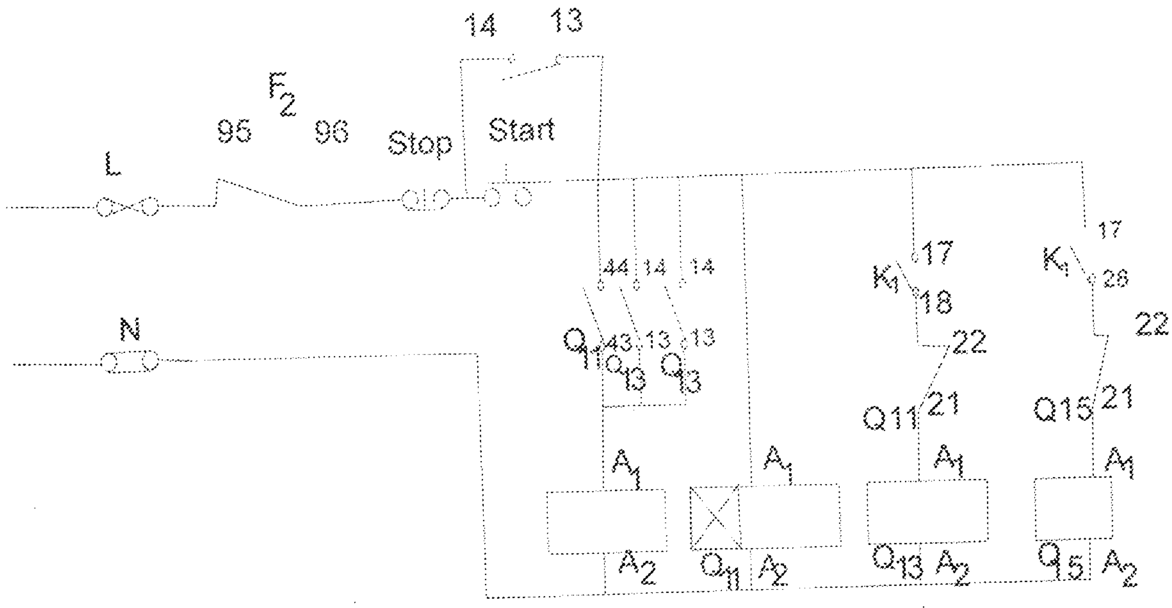

Fig.1.2 Automatic Start–Delta Starter Control circuit.

Q11: Mains contractor — 1=Start button

K1: Timing relay — 0= off

Q13: Star (YC) contractor — F2 95-96 = Overlord relay

Q15: Delta contractor (DC)

The circuits in figure 1.1 and 1.2 operate in the following manner: depressing the start button 1 (pushbution) energizes the timing relay k1, then the normally open contact K1 17 -18 closes instantly and applies voltages to star contactor Q_{13}. The star contactor Q_{13} closes and applies voltages to mains contactor Q11 via the normally open (N/O) contacts Q11 / 14-13 and Q11 / 44 – 43. The main contactor applied voltage to the motor M in star connection.

When the set changeover time elapse, the instantaneous contact ($K_1/_{17-18}$) opens the circuit of the star contactor Q13 and after some milliseconds, the delta contactor Q15 closed via K1 / 17 -28 of Q15 (delta contactor). Star contactor Q13 drops out. The delta contactor closes and switches the motor M to full mains voltage. The motor will now be running at is rated speed. At the same time, normally closed contact Q15/22-21 interrupts the circuit of the star contactor Q13 there by causing an inter locking against renewed switching on while the motor is running. The motor cannot start up again unless it is disconnected by push button 0, or an event of overload opens the normally closed contacts 95 – 96 of the overload relay F_2.

CHAPTER TWO

LITERATURE REVIEW

2.1 HISTORICAL BACKGROUND

The foundation of poly phase motors and starters was laid in 1888 in France by a renowned scientist Nikola Tesla [1]. The development of starters has been growing significantly. Deferent types of starters have been available with different relative merits and demerits associated them.

The poly phase induction motors are types of asynchronous AC motors where power is supplied to the rotating device by means of electromagnetic induction. Induction motors are widely used, especially poly phase system induction motors, which find wide application in industrial drives. Induction motors are now the preferred choice for industrial drives due to their constructional advantages; robustness and cheapness. [1]

Productivity can be improved in many ways. Purchasing new machines and developing new processes are the most obvious way to increase productivity. However maximum start-up time is one area that can be improved which may be overlooked. Proper method of starting AC induction motors can result in reducing downtime and increase high productivity.

The importance of poly phase induction motors at stand still is relatively small sand when such electric motor is connected directly to supply mains, the initial current will be high and the coil of the motor may be burnt out. Apart from this, if an induction motor is stared on full voltage, it will draw from the supply mains 2.5 to 10 times its normal running current [13]. No harm will be caused by this excessive flow of current because the motor is constructed to withstand the shock of starting.

However, on very large motors, it is desirable to take some measures to reduce the starting current to avoid damaging the machinery driven by the motor and other devastating effects. Electromechanical starting has been available since the invention of AC induction motors. Initially, the manual starters were more predominant than the electromechanical. Today, electromechanical starting is preferred either in full voltage o reduced voltage starting for three phase AC induction motors. The full voltage starting recommended for small motors of lower capacities where the power source can withstand the shock of starting without objectionable line disturbances being created. The phenomenon is known as DIRECT - ON- LINE STARTER.

In large motors where the starting torque needs to be developed gradually, or where the initial current will affect the line voltage, it is necessary to insert in the line some devices that will reduce the starting current. This type of device may be a resistance unit, an autotransformer or star-delta starter.

2.2 STARTERS

Starter can be as well be defined as an electric controller for accelerating a motor form rest to normal speed. It is therefore an important link between the motor and power supply. Generally, the method of starting of a particular squirrel cage motor is chosen on the basis of;

a) Design and size of the motor,

b) type of driven load and

c) Capacity of the supply lines.

Therefore, the methods of starting squirrel cage motors are principally classified into two viz;

Full voltage starting or direct-on-line and

Reduce voltage starting.

2.3 FULL VOLTAGE ELECTROMECHANICAL STARTERS (DIRECT-ON-LINE STARTER)

This is the most simple means of controlling the energy flow to an induction motor and relies on a single solenoid operated 3-phase switch called contactor to interrupt the power supply. This method is variously referred to as "Direct-On-Line", "across the line", etc. It is the usual form of control where low cost is the first and most important consideration. When this method is used, the starting current is the short circuit current. Depending on the size and design, the motor takes low power factor current of 6 to 10 times its full load current. As a result, it is most often used on small motor sizes up to 10 hp or 50 or where the supply is strong enough to withstand the inrush and starting current surges without causing unacceptable voltage drops.

2.3.1 Direct-On-Line and Its Mechanical Effects

Excessive acceleration of a rotor when mechanical load is small can produce torque oscillations in the shaft causing severe wear to gears and drives. Excessive acceleration when load inertia is high such centrifugal fans causes belt to slip in the pulleys, producing rapid wear and early failure. Chain drives experience problems of chain stretching and wear to sprockets.

2.3.2 Direct-On-Line and Its Associated Electrical Effects

The instantaneous high energy demand in one form is reflected in another, the excessive torque causing wearing on the mechanical drive component is simultaneously apparent in the electrical supply system as high currents. Since these currents flow through the switch gear contacts, etc and give rise to localized I^2R heating which is sufficient to cause erosion or melting of the contact surface. Again if the supply is weak, a sharp voltage dip will occur. In this method of starting the rate of temperature rise is high and the motor may get damaged if the start-up period is increased which may occur due to

i. Excessive load torque

ii. Insufficient rotor resistance

iii. Excessive voltage drops in the supply mains.

The simplicity and apparent low cost although attractive at first sight, hide the large costs penalties and increased maintenance, reduced transmission equipment life and higher risk of motor failure particularly when frequent starting and stopping is needed. In view of these, the system is therefore limited to small induction motor of typical rating of 3 hp. This paves way for the development of alternative systems to reduce the damaging effects when used for highest capacity electric motors.

The relationship between starting torque, I_{st} and I_f be starting current and full load current respectively.

$$\frac{T_{st}}{T_f} = \left(\frac{I_{2rs}^2}{1}\right) \Big/ I_{2f}^2 \quad \left(\frac{rs}{s_f}\right) = \left(\frac{I_{2st}}{I_{2f}}\right)^2 \times s_f \text{ ---------- } (i)$$

If no-load current is neglected, then

$$\frac{I_{2st}}{I_{2f}} = \frac{I_{st}}{I_f}$$

Hence from (i),

$$\frac{T_{st}}{T_f} = \left(\frac{T_{st}}{T_f}\right)^2 s_f \text{ ---------- } (ii)$$

Since the stator current I_{sf} at start is equal short circuit current I_{sc} at rated voltage, then

$$\frac{T_{st}}{T_f} = \left(\frac{I_{st}}{I_f}\right)^2 s_f \text{ ---------- } (iii)$$

2.4 REDUCED VOLATAGE ELECTROMACHANICAL STARTERS

Since, the squirrel cage rotor is eclectically isolated; no alteration of its resistance or reactance can be made directly. Apart from using special device, the starting current of a squirrel cage motor can only be reduced by reducing the voltage applied to the stator. If the stator voltage of an induction motor is reduced from rated value to the fraction, then the short circuit current will be changed in the same proportion. The main flux that is determined by the reduced voltage and the magnetizing current will similarly fall if the magnetic circuit is not saturated. Furthermore, since the core losses are approximately proportional to the square of the flux density and consequently, the voltage, the in-phase component of the no-load current will be reduced in proportion to the reduced voltage. According to square law, torque is directly proportional to the square of the terminal voltage or the applied voltage. (i.e. $T \alpha V^2$) Therefore, a reduction in the applied voltage to the fraction V will reduce the starting torque to V^2 of its normal value. There are three main methods of electromechanical reduced voltage starting of induction motors, namely; (a) Primary resistor starting (b) Auto-transformer and (c) Star delta starting.

2.4.1 Primary Resistor Starting

In primary resistor starting, a resistor is connected in each motor line (in one line only in a single phase motor starter) to produce a voltage drop due to the motor starting current passing through the resistor. A timer is provided in the control circuit to short out the resistors after the motor accelerates to a specified speed. Thus the motor is started at reduced voltage but operates at full line voltage. Primary resistor starters provide extremely smooth starting due to the increasing voltage across the motor terminals as the motor accelerates.

Standard resistor starters provide two-point acceleration (or step of resistance) with approximately 70% of the line voltage at the motor terminals at the instant of starting. This makes it very useful in fabrics applications where even a small jolt in starting may tear the paper. Since the induction motor power factor at starting is quite low, the voltage across the starting resistor will be nearly at right angles to the applied voltage and hence, the net reduction in the voltage and hence, the net reduction in the voltage drop across the starting reactor will be nearly in phase with the supply voltage and hence, the net reduction in the applied voltage to the stator will be more. Let V_1 be the normal value of the stator voltage per phase and the stator voltage is reduced to yV_1 at starting. Then, the starting current is given as

$$I_{st} = \frac{xvi}{Z_s} \text{------------------------------------} (i)$$

Where Z_s = equivalent impedance of the motor referred to stator. Now V_1 / Z_s = short circuit current at rated voltage = $_{ISC}$

Therefore, $I_{sc} = yI_{sc}$

$$And\ \frac{T_{st}}{T_f} = (\frac{I_{st}}{I_f})^2 \times s_f = x^2\left(\frac{I_{st}}{I_f}\right)^2 \times s_f \text{------------------------------------} (ii)$$

Hence, starting torque with reactor starting /starting torque with D. O. L starting

2.4.2 Autotransformer Starting

Auto-transformer starting is one of the most effective methods of electromechanically reduced voltage starting. It is preferred to primary resistance starting when the current at the instant of starting from the line must be kept to a minimum value yet the maximum starting torque per line ampere is required. To understand auto-transformer starting fully, some electrical characteristics of motors that are often overlooked must be understood. First it is important to realize that the motor terminal voltage does not depend upon the load current and that the motor voltage will remain substantially constant during acceleration period. In other words the current to the motor may change because of the motor's changing characteristics, but the voltage to the motor will relatively remain constant. Secondly, auto-transformer may use its turn ration advantage to provide more current on the load side of the transformer than on the line side of the transformer. In auto-transformer starting, motor current and line current must be adequately distinguished because they are not equal as they are in primary resistance starting.

Two types of auto-transformer connections are in used today. One is open circuit transition and the other is close circuit transition. The basic difference between the two connections is that in the open circuit transition the motor is momentarily removed from the supply voltage. The close transition on the hand the motor is never removed from the power source when moving from incremental voltage to another. Note that both systems are used and function on the same principles. After critical analysis of the reviewed development above the need to develop a starting method that will meet electric motor users yearnings such as low cost, good performances etc.

2.4.3 Star-Delta Starter

This is the most predominant form of electromechanical reduced voltage starter which was initially operated manually. This method is applicable for motors designed to run normally with delta connected stator windings. The method is designed in two steps; the star or wye (Y) configuration and the Delta (Δ) configuration is for smooth and continuous acceleration of the motor.

In the course of this project, the changeover or the transition from one step to another i.e. from star to delta is controlled by a timing mechanism. This suggests the name of the device "Automatic Star-Delta Starter" This transition or change over is usually set to occur at least when the speed of the motor approaches 80% of the rated speed of the motor. There are two types of transition that take place in star-delta starting method. These are close circuit transition and open circuit transition. Close circuits transition is said to occur when the transfer from star to delta take place without the motor is being removed from the supply. In open circuit transition the motor is temporarily removed from the power source.

2.4.4 Star or wye (y) Connection

In this form of connection, the similar ends, say starts ends of the three coils (it could be finishing end as the case may be) are joined together at a point N known as the star point. In the case of a transformer the three conductors are replaced by one conductor called the neutral conductor. Such system of interconnections is known as 3Φ, 4-wire system.

The effect of starting a motor in star connection is to place the phase voltage across the stator windings in series. In this case each of the phase windings receives approximately 58% of the applied voltage and develop approximately 33% of the full load torque i.e. the applied voltage is reduce by $1/\sqrt{3}$ while the torque is reduced by $1/3$ of the lock rotor torque. More so, the line current is also reduced to one-third of that which would have drawn if the motor were directly connected to supply mains.

Relationship between starting torque T_{st} and Full load torque T_f.

I_{st} per phase $= Isc/\sqrt{3}$ per phase

I_{sc} = short circuit current

$Iy = Isc/3$, $T_{st} = I^2_{st}$ (s = 1)

Full load torque $T_f \alpha I^2_{st} / sf$

Then the ratio of T_{st} to T_f

$$\left(\frac{I_{st}}{I_{st}}\right)^2 S_f = \frac{T_{st}}{T_f} = \left(\frac{I_{sc}}{\sqrt{3}I_f}\right)^2 S_f$$

$$= \frac{1}{3}\left(\frac{I_{sc}}{I_f}\right)^2 S_f$$

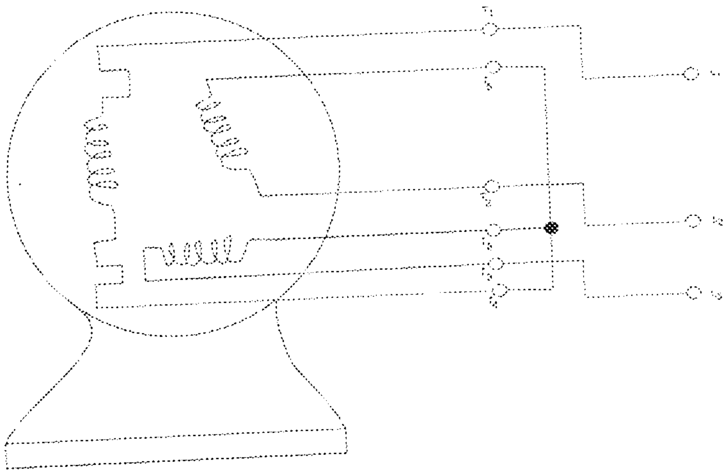

Fig2.1 3-phase motor connected for wye start.

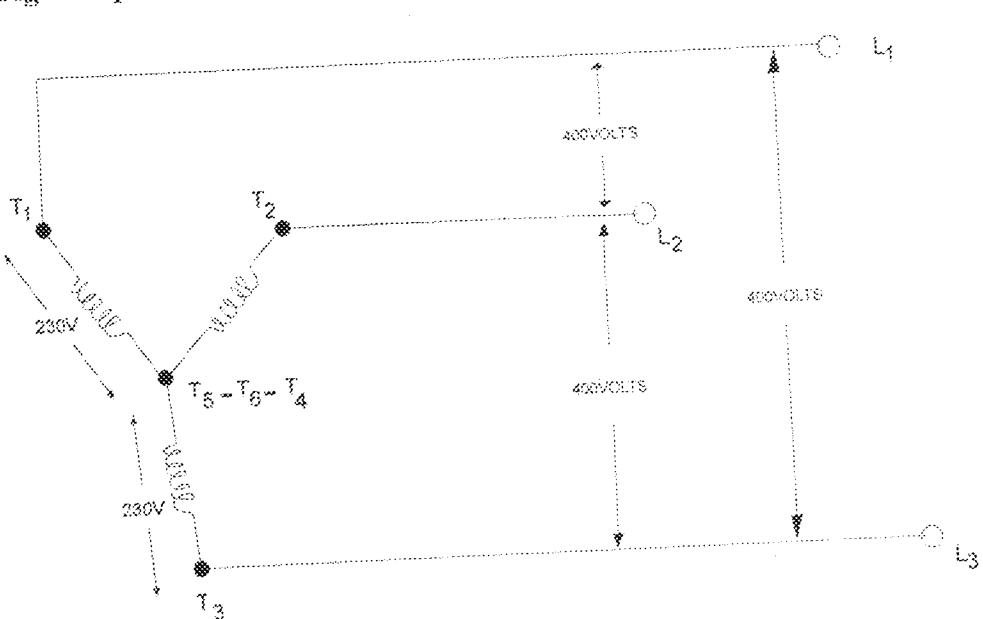

Fig2.1 a star arrangement in which each of the phase windings receives approximately 58% of the supply voltage

2.4.5 Delta (Δ) or Mesh Connection

This is the form of connection where by the non-similar ends of the coils are joined together to form a close mesh. In other words the starting ends of the one phase are joined to the finishing end of the other phase and so on. In this form of connection, each of the phase windings receives the actual applied voltage. Size the figures below for the connection.

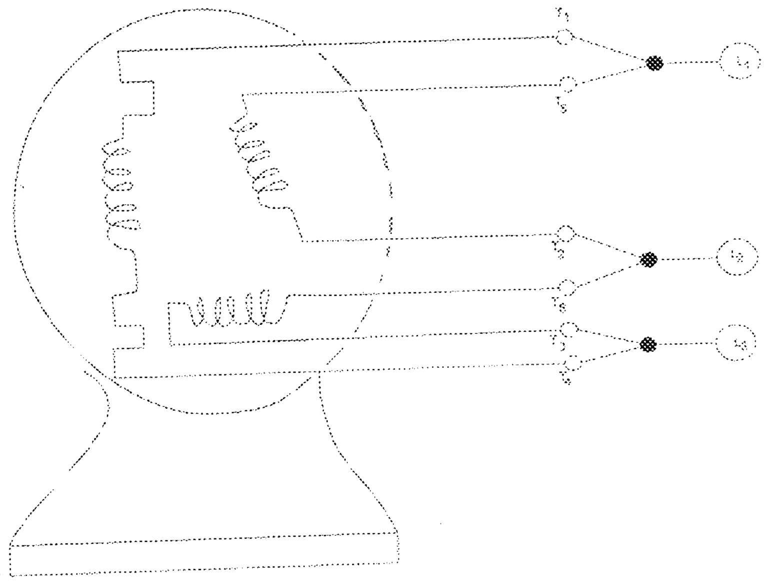

Fig 2.2 a 3Φ motor connected for delta run.

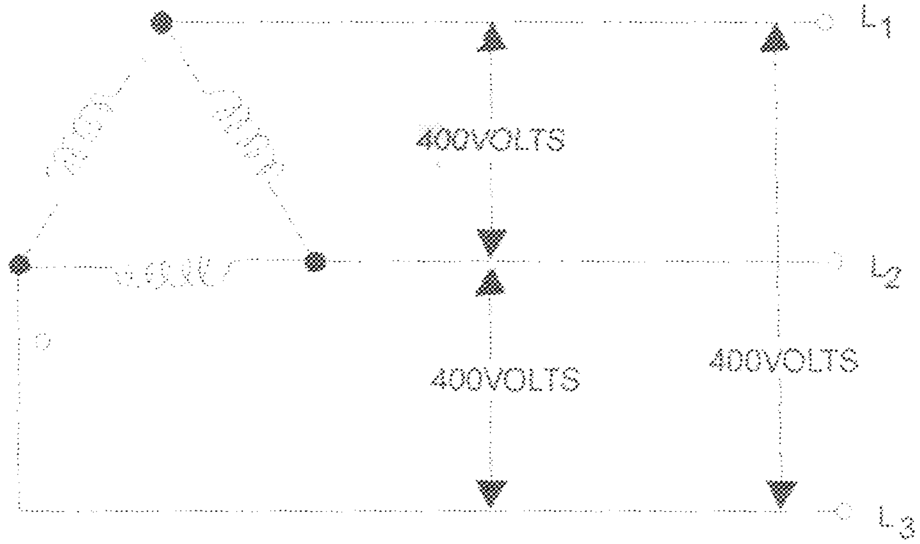

Fig 2.3 a delta (Δ) mesh arrangement with each phase winding receives exactly the applied voltage.

2.4.6 Current Surges in Star-Delta Starting

The initial current per phase flowing when the motor is started in star is $^1/_{\sqrt{3}}$ of the short circuit current in delta together with the transient per phase. This means that the starting current in star is one-third ($^1/_3$) of the short circuit current in delta plus the transient in each phase. The transient current varnish rapidly but the steady state is not reached appreciably until the motor has attained 80% of its normal speed. The transition from star to delta connection is advisable to be made when the motor speed reaches 90% of synchronous speed. Otherwise there will be current surges considerably greater then the full load current that may even be greater than the standstill current with the delta connection. In star-delta starting, while changing over to delta connection from star connection, the stator winding is open-circuited for a period of about 0.1 – 0.3 seconds. This type of transition is called open circuit transition. During this interval the excitation of the rotating magnetic field is withdrawn but the motor is under the mechanical influence of the rotating load and current still flowing in the rotor bars due to time delay necessary for the magnetic flux to collapse. Because of this there is residual flux 'frozen' on the surface of the rotating rotor, which cuts the stator windings, induced currents is developed that hold the original magnetic field and a voltage is also generated in the stator winding at a frequency depend on the rotor speed which has to be lower than the mains supply frequency. When the change over switch closes in the delta position, the same supply voltages are reconnected to stator windings. But the stator windings have already comparable value of back emfs which are functions of the motor speed with a relative time phase angle that may be any thing between 0° and 180°. If the relative phase angle between the supply voltage and the induced emf is nearly equal to 0°, the very large current surges in all the phases will occur which may be more severe than those dew to direct switching with the rotor stationary. [7]

2.4.7 Reasons for Using Star-Delta Starter

Large poly phase induction motors draw heavy current from the power lines when directly connected to the supply mains. The initial excessive current is objectionable because it reflects back to the supply mains to produce voltage drops that will in turn off causing stoppage of eh operation of the electrical equipment connected to the distributing network.

One of the most predominant reasons for using the star-delta starter is to reduce the large current drawn from the power company lines by the across-the-line start of a large motor. Star-delta starter reduces the initial inrush current by dividing the amount of currents into steps. This permits an incremental start that allows the utility voltage regulators sufficient time to compensate for the large current drawn. Star-delta starter in this case resolves the problem of large current surges by providing incremental current drawn over a long period of time.

In several industries, especially those dealing with paper and other delicate fabrics, care must be exercised to avoid sudden high starting torque (turning force) which could stretch or tear the product. To prevent this type of product damage or damage to gears, belts and chain drive, it becomes necessary to limit the start torque surge. Star-delta can be used to limit the excessive starting torque by providing gentle start and smooth acceleration. To understand how torque is reduced require the understanding of square law that says: torque is proportional to the square of the applied voltage (i.e. $T_s \alpha V^2$). When star connected, the applied voltage is reduced by $1/\sqrt{3}$ and hence the torque developed is reduced by $(1/\sqrt{3})^2$. For an instance, if the short circuit current I_{sc} which is equivalent to direct-on-line current is 6 x I = 6I and the torque is 2 x T = 2T. Therefore, in star-delta starting, the current will be $(1/\sqrt{3})^2$ x 6I = $1/3$ I_{sc}. Then the torque will be $(1/\sqrt{3})^2$ x 2T = $1/3$ T_{sd}

Where T_{sd} = the starting torque for direct-on-line.

Thus a reduction in voltage reduces current which in turn reduces the torque to provide a gentle start. As voltage increases so also does by current and torque too to provide smooth acceleration. It is important to note that at this junction, that star-delta starter as a reduce voltage starting device is not a type of speed controller. Rather it acts as a shock absorber or buffer to the load when it is starting. This calls for the understanding of how the speed of an induction motor is determined. That is by the number of poles and the frequency of the power supply (not the supply voltage). It is for this reason that a star-delta starter is not a speed controller and must not be used as one. The star-delta starter is designed for specific reasons, and speed control is not one of the reasons.

2.4.8 Full load Current of Motor and motor speed in star-delta starter.

AS said earlier, poly phase induction motors take high value of current to overcome friction and initial shaft momentum at the instant of starting. The revolving field of the stator induces this large current in the short circuit rotor bars. The current will be maximum when the rotor is at standstill and decreases as the motor comes up to speed. The current is excessive at start because of lack of counter emf (electromotive Force) at the instant of starting. Once rotation has begun, back emf is built up in proportion to speed and the current decreases. This means that motor windings have little resistance and the impedance which restricts the flow of current in the windings is actually the back emf. As the motor shaft turns faster this counter emf increases and opposes the current from the supply by the motor windings. At rated speed, this back emf is at its maximum and this result to due current rating for the motor.

CHAPTER THREE

DESIGN AND CONSTRUCTION OF AUTOMATIC STAR -DELTA STARTER

The design parameters and specifications refer to the factors and conditions to be met while designing the automatic star delta starter; and the right materials to be used for the construction. The reason is that some big motors required high current in starting them.

3.1 COMPONENTS AND THEIR SPECIFICATIONS

This automatic star delta starter will be design to start and control 20 h.p (15kw) induction motor. The components and materials required and their ratings are stated below,

1 Miniature circuit breaker - 63Amps

2 Contactors - 20Amps

3 Thermal overload relay - 8 – 17Amps

4 Timer relay - 220V, 5Amps, 0-60secs

5 Voltmeter - 0 - 300

6 1.5mm^2 and 2.5mm^2 Industrial flexible Cu cables

7 Mounting board.

3.2 MATHEMATICAL ANALYSIS OF HOW THE COMPONENTS WERE SELECTED.

The components and materials used for the project were selected based on the maximum load current of the motor at starting.

- Rating of the motor in kilowatts – 15kw

- Supply voltage (line voltage) – 400V

-Power factor of the motor – 0.85

3.2.1 Selection of Contactors

The following calculations were carried out to select the best current rating contactors.

Recall,

$P = \sqrt{3}V_L I_L COS\theta$, $COS\theta$ = power factor, P= load power in watts.

I_L = load current and V_L = Line voltage

$I_L = P/\sqrt{3}\ V_L COS\theta$

$= 1500 / \sqrt{3} \times 400 \times 0.85$

$= 25.5$Amps

The contactor current rating $= I_L \times 0.58$

$= 25.5 \times 0.58$

$= 15.8$Amps

Then putting tolerance of 4.2Amps, the rating of the contactors for the starter shall be 20Amps.

3.2.2Selection of Overload relay

Overload rating = load current (I_L) ×0.58

= 25.5×0.58

= 15.8Amps

Therefore, with tolerance the overload to be used for the starter ranges from 10-17Amps Type Tested Single Phase Preventing Preventer.

3.2.3 Miniature Current Circuit Breaker (MCCB)

The miniature current circuit breaker selected for adequate tolerance shall be 63Amps, manually operated with adequate space below for easy connection and operation. [11]

3.2.4 Selection of Cables

The I.E.E Regulation stipulates that all cables carrying current must be so selected as to be able to carry their rated current without deterioration. This why in choosing cables two factors have to be born in mind viz: and viz:

(a) The current carrying capacity of the cable and

(b) The voltage drop along the cable

The regulation states that the drop in the length of the cable should not exceed 2.5% of the normal voltage when the conductor is carrying the full load current disregarding the starting current.

The cables selected for the type of motor to be started are taken according to IEE Regulation table of diversity. Table 1M, which have current rating and voltage drop per ampere per meter. $2.5mm^2$ is selected for the power cable of 18A and 16mv while $1.5mm^2$ is selected for the control cable of 13A and 27MV respectively.

A conductor carrying a current is bound to have losses due to its own resistance. The losses in the conductor appear as heat and will raise the temperature of the insulation. The temperature to which it is safe to raise to insulation limits is the current that a cable carries. The heat loss and the equilibrium temperature reached depend on how the cable is installed.

The resistance of the cable also results in voltage drop along its length. Because of the voltage drop, the voltage at the receiving end is less than that at the sending end. The voltage drop must be kept reasonably low. [5]

3.2.5 Timer Relay

The timer selected for the construction of the starter has a delay time ranges from 0-60secs.The contact rating is 220V, 5A and power factor of one (p.f = 1).

3.2.6 Voltmeter

These were selected based on the supply voltage of 400V. The selected voltmeter ranges from 0-300V.

3.2.7 Mounting Board

A wooden type of mounting board was selected for it to serve as an experimental module for electrical engineering students.

3.3.1 BRIEF DESCRIPTION OF COMPONENTS USED AND THEIR FUNCTIONS.

The construction of a star- delta starter becomes very simple if the components are chosen accordingly, and the understanding of the principle of operation and function is also an added advantage for the understanding of its construction.

3.3.2 Contactors

Contactors are typical block types and comply with BS775. As standard, operating coils are fitted and these can be from main voltage or a transformer. Magnetic contactors are used to control motors ranging from 0.5HP to several hundreds of horse power. The sizes, dimensions and performance of contactors are standardized. They are made up of plastic materials which houses a coil supplied by a voltage.[5]

3. 3.2 Mode of Operation

A contactor is a device for operating or closing a circuit under load, conditions by push button control. The operation is usually electromagnetic, but it may also be Electro pneumatic. The contactor is ideal for automatic control and is made use of in many appliances and in particular, in many motor starters. It may be either air break or oil immersed. Energizing an electromagnet, which pushes a set of moving contact onto fixed contacts, usually closes contactors. A set of auxiliary contacts keep the electromagnetic coil energized while the main contact are closed. An open or stop button is used to open this circuit, thus causing the main contact to open by means of spring. The auxiliary contact opens at the same time so that contactor can not recluse automatically. This action gives the contactor an inherent no-volt released characteristic that is ideal when used in a starter circuit. There is a latched type of contactor that is used by an operating coil but without auxiliary contact so that it is held in the closed position by mechanical latched.

3.2.3 TYPES OF CONTACTORS

(a) High Voltage Contactors for Motor Control.

The use of high voltage control contactor for larger motors generally above 250HP(187.5KW) is becoming increasingly popular .The long range economic advantages are often being found to overcome the increase initial cost of installing high voltage equipment.

(b) Low Voltage Contactors for Motor Control.

The contactor is the central device for control system. It is the component in the starter, which opens and closes the circuit from the energy source to the apparatus under control.

3.3.3 Advantages of Magnetically Operated Contactors.

(1) Magnetic contactors considerably increase the safety of an installation.

(2) Space is saved, which often valuable in the velocity of the motor driven machine.

(3) Possibility of controlling a motor from different parts.

Below is a diagram of a magnetic contactor;

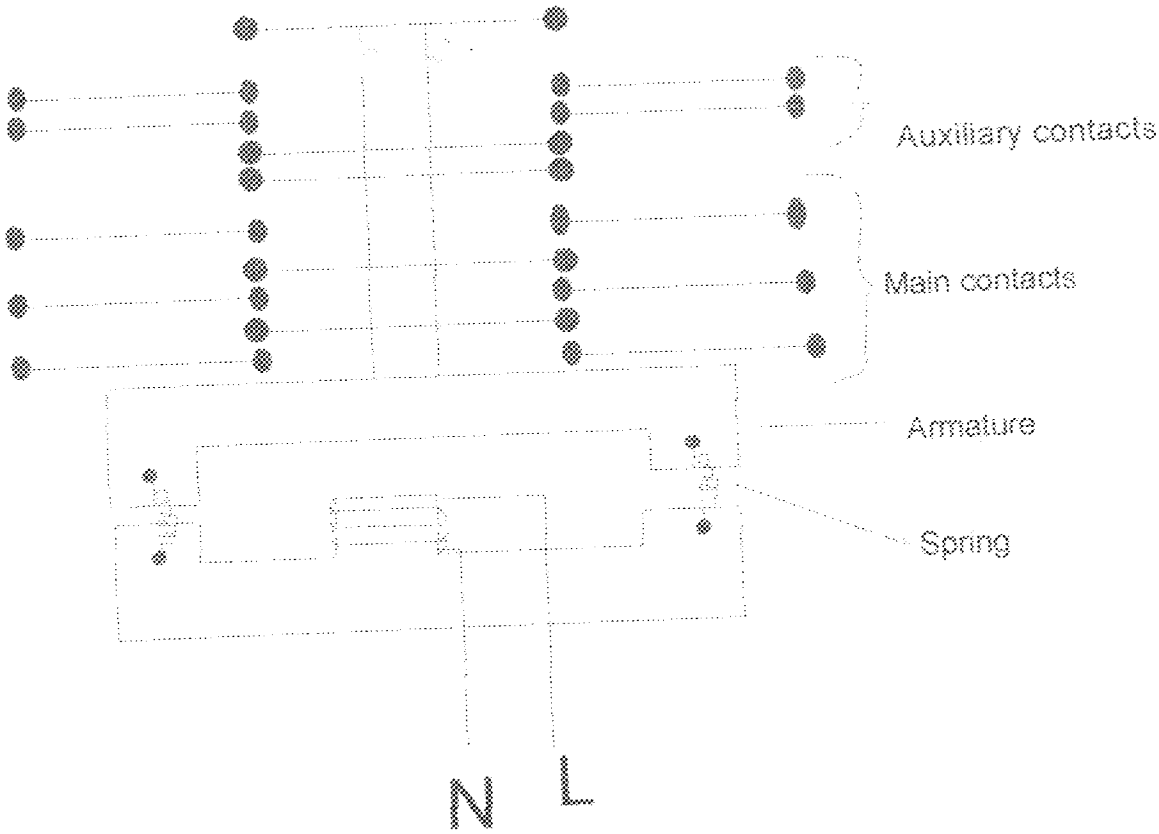

Fig 3.1 Electromagnetic contactor

3.3.2 Overload Relay

Relay can be described as low current device that utilizes electromagnetic induction to act as switching systems for the operating coil of a heavy current carried conductor in the contactor or circuit breaker. The purpose of the relay is to provide a standard, given protection to all type of electric motors. Relays are normally hand reset by pushbutton mounted on the cover. Auto reset design can be provided if the scheme permits.The relay has an easy replaceable heater and permanently fixed bi-metallic element Calibrations are in full load amperes. Relays embody sensitive single phasing prevention and ambient temperature compensated. Alternatively, electromagnetic relays can be provided with adjustable by rotating self-locking-dash pot. [5]

Generally relays are calibrated in amperes and should not be set to normal full load current.

Over Load Protection

To protect the induction motor against overload, an overload release is connected in series with the motor circuit. The overload release utilizes the load current to operate the circuit. There two types of overload namely;

a) Magnetic over load relay and

b) Thermal overload relay.

a) Magnetic Over Load Relays

These are usually of the instantaneous type and intended to protect the motor against internal short circuit, bearing, and seizing, an induction motor getting locked or hooked.

b) Thermal Overload Relay

For consideration, thermal over load relays are used. Fuses and MCB react to short circuits and thus provide protection against their consequences. However, their time – current characteristics are such that they do not provide real protection against sustained low level over loads. For example, a 30A HRC fuse will carry 40A indefinitely. This will not harm the cable if hey have been correctly sized and the fuse has been correctly matched to them. An electric motor over load to this extent would eventually burn out.

The I.E.E Regulation stipulates that over load protection should operate before the current exceed 1.5 times the current carrying capacity of the smallest conductor in circuit. In case protection for smaller over load is essential, the equipment requiring such protection should be supplied with an individual protective device forming an integral part of the appliances. [9]

Thermal relays are protecting the motor from running at a load level in excess of the manufacturer's recommended value. Thermal over load relays are in form of resistor wound round a bi-metallic strip. The resistor is connected in series with the motor while the bi-metallic strip is made to touch a normally close contact in the contactor coil. Should a contactor coil trips out, it will stop the motor that it is suppose to protect.

In this type of over load, an increase in current is interpreted as heat in the overload. For normal current, the heat produced is insufficient to cause deflection of the bi-metallic strip. In event of overload or when the current exceeds the predetermined value, the over load resistor of the element heat up the bi-metallic strip that bends out. The maximum deflection causes the tripping mechanism to open the circuit coil and consequently the main contact of the contactor of the starter. If an overload trips, it may be because the current on the unit is set to low or more likely, it could because the motor is operating in over load condition. If the setting on overload correspond to the value in the electrical circuit, then the fault must be located in machine and rectified before resetting the overload unit (manual reset).

3.3.4 Push Button

A push button is a switch activated by finger pressure. Two or more contacts open and close when the button depressed. Pushbuttons are usually spring loaded so as to return to normal position when pressure is removed. These two buttons (start and stop pushbuttons) are used to close and open the control circuit of the starter respectively.

The stop pushbutton is used to break the starter circuit. It is normally close switch. Below is a diagram of a start and stop pushbutton

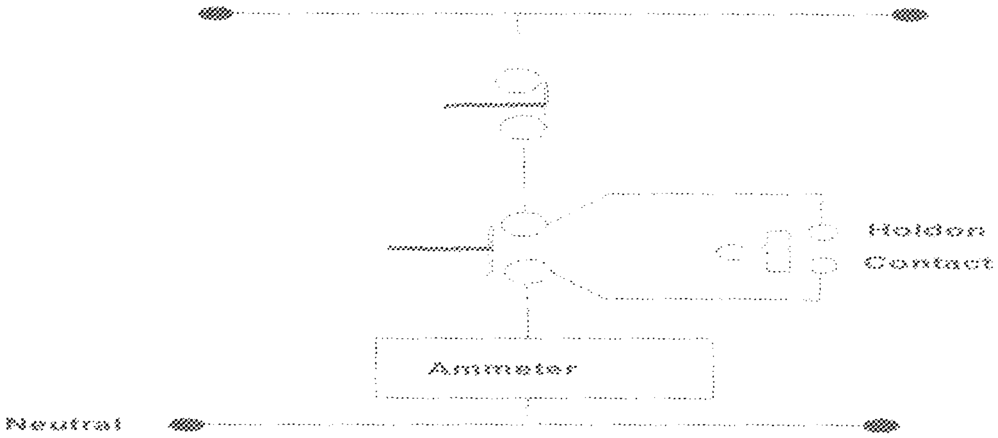

Fig. 3.2 Control circuit diagram for start and stop buttons.

3.3.5 Circuit Breakers

These are protective devices used to isolate faulty equipment from the supply at a very short time without causing damage to the equipment, the electrical circuit itself and operator of the electrical equipment. They are electromechanical devices capable of making and breaking of an electrical circuit under all conditions. Circuit breakers are of two types;

I) Current operated circuit breaker and

II) Voltage operated circuit breaker

For industrial purposes, other sophisticated circuit breakers are employed. For examples; oil circuit breakers that are used for heavy current switching and air circuit breakers also employed in high voltages but a very greater gap has to be maintained between phases. [8]

Circuit breakers operate basically under two conditions:

I) Normal condition and

Ii) Abnormal condition.

Circuit breakers operate under normal conditions for the following reasons:

I) Maintenance

II) Planned operation

III) Ascertaining the condition of the system after installation of new equipment for commissioning.

IV) Connection and disconnection of electrical equipment for one reason or the other.

Circuit breakers operate on abnormal conditions as a result of faults. Such types of faults are:

I) Short circuit fault

II) Under frequency

III) System instability

IV) Overloading

3.3.5.1 Miniature Current Circuit Breaker (MCCB)

This type of circuit breaker makes or breaks final sub-circuit either by magnetic or thermal action. They are essentially switches that may either be opened or closed by hand. It opens automatically when overloaded. However, they are differs from fuses in the sense that they contain no melting element.

The thermal-magnetic MCCB works on the principle of bi-metallic strip action. When excess current above its rated value flows, the bi-metallic strip is heated up. This heating effect causes the deflection of the bi-metallic strip with time lag action while the high speed protection against any short circuit is by the magnetic operation. Consequently it disconnects and reconnects the load. [6]

3.3.6TIMER RELAY

This is a control relay used in the circuit to control the changeover from star contactor to delta contactor so as to achieve the automatic operation of a star – delta starter which the project is base upon. The relay is calibrated in seconds, a coil rating of 220V and it is an electronic type. Figure 3.2.3 below shows the connection diagram of a timer relay.

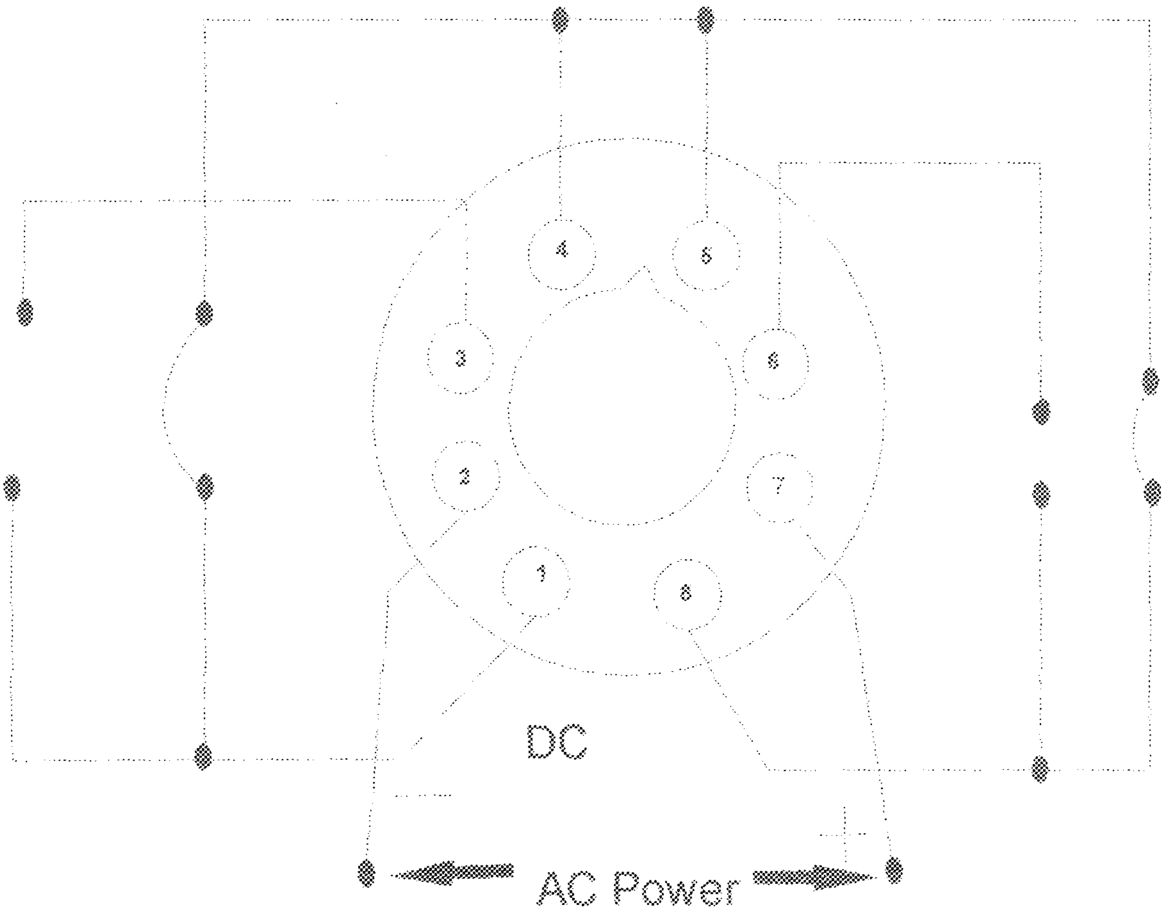

Fig 3.3 Connection diagram of the timer

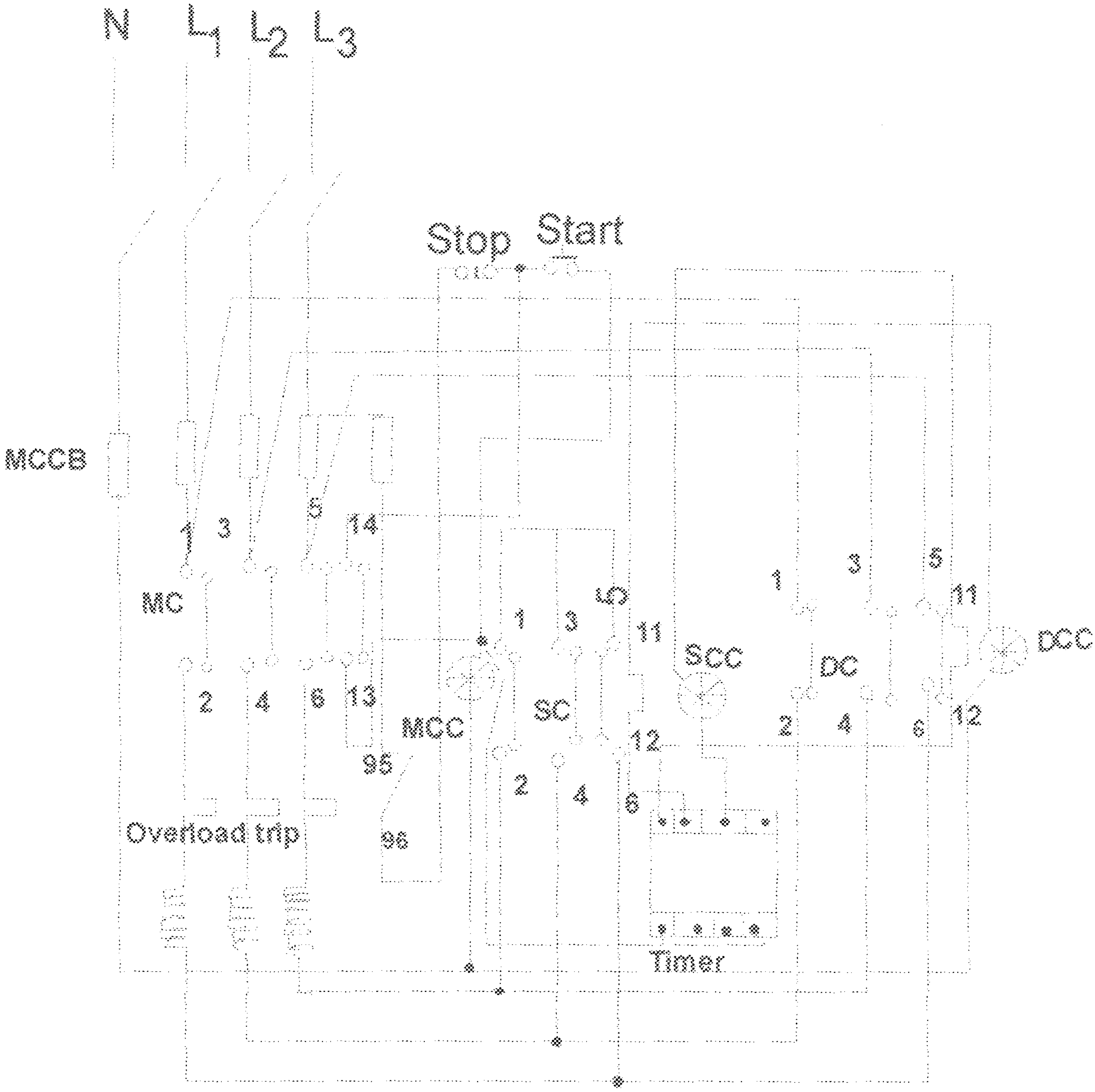

Fig.3.4 Connection diagram of An Automatic Star-Delta Starter.

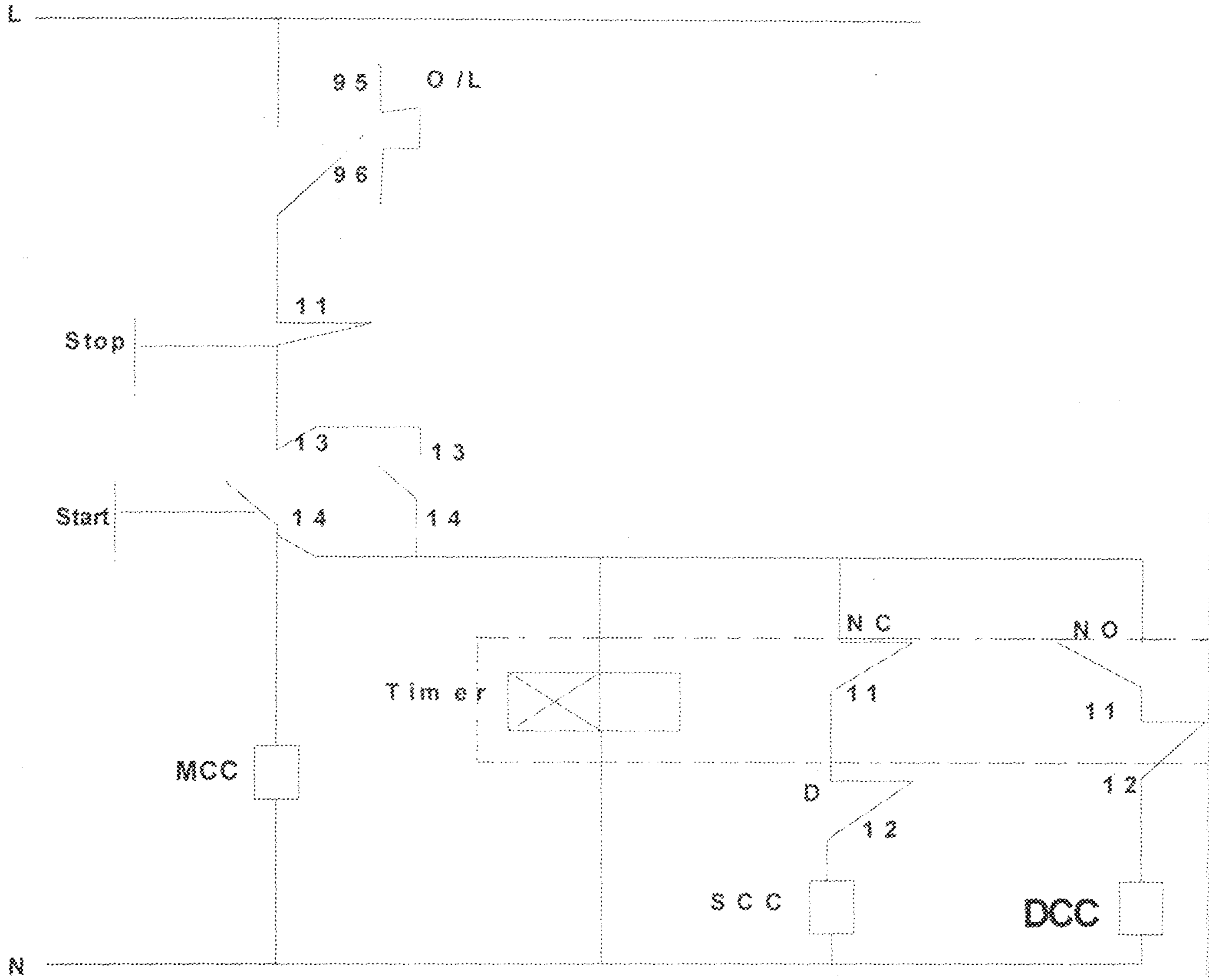

Fig.3.2.4 (b) Control diagram line for An Automatic Star-Delta Starter. 3.4.

Nomenclatures: MC = Main contactor

MCC = Main contactor coil

SC = Star contactor

SCC = Star Contactor coil

DC = Delta Contactor

DCC = Delta Contactor coil

O/L = Overload

NC = Normally Close

NO = Normally Open

3.4 principle of Operation of the Starter

Pressing the start pushbutton energizes contactor MC, SC and the timer relay, the star contactor connects the motor terminals to the supply causing the motor to start in star configuration. After the preset time has elapsed, the time required for the motor to run to about 90% of its rated speed, the normally close contact is now open in opposition dropping out the contactor SC.the normally open contact closes, through energizing Contactor DC. The contactor DC upon being energized, applied the line voltage to the motor terminals and there by causing the motor to run at full voltage without causing any damage.

Pressing the stop button drops all contactors, there by stopping the motor. Contactors DC and SC are sometimes electrically interlocked. This is to ensure that when SC is in operation, DC is not energized simultaneously. [8]

3.5 CONSTRUCTION AND ASSEMBLY OF COMPONENTS

This project entails the construction of a reduced voltage starter that can start and control a 20 horse power (15 kilowatts). three-phase squirrel cage induction motor. To achieve this, three contactors were used; the star, delta and main contactors. The components were assembled on a mounting rail that was screw to a wooden board. Unlike other constructions which involve the assembly of components in a metal casing, this construction involved the assembly of components on a wooden box with a plastic glass cover. This was done in other for the construction to serve as an experimental module for electrical engineering students.

The assembly process started with the screw of the mounting rail to the base of the wooden board inside the box and then inserting the components one after the other on the rail. The contactors were arranged side by side on the rail. The timer-relay was incorporated and the terminals were connected to the appropriate terminals of the contactors. The thermal overload was screwed to the main contactor. With the aid of electrical tape, the control and power cables were neatly clipped to prevent them from entangling. The pushbuttons, ammeter and voltmeter were fixed on the casing cover.

3.6 POSSIBLE FAULTS AND REMEDIES

FAULTS	REMEDIES
1. Motor completely dead	Check voltage at isolator terminals.
2. Contactor starter does operate although supply at isolator is correct.	i) Check overloads trips; interlock and starter controls are not correctly set to start position. ii) Test continuity of contactor coil and its associated circuits.
3 Fuse blow or overload trips operate when any is made to start	i) Check that the motor is free to rotate

the motor.	ii) Check that starter is operated correctly. iii) Test for insulation resistance.
4. Three - phase motor buzzes or hums but refuses to start	i) Check that the supply voltage are available at all three phases of the *motor terminals*. ii) Test each phase of motor winding for continuity. iii) Test the rotor circuit for continuity.
5. *Starter of motor not holding in* ON position although motor start correctly.	I) Test for no–volt coil for short circuit. In the case of series motors or starters where no coil is not in series with a shunt winding. Check the no-volt coil for continuity.
6 Inability of the contactor to close open i.e. faulty contacts.	i) Cleaning of the contactors' surface.

Table 1.1 Possible faults and remedies

3.7 LIMITATIONS AND PROBLEMS ENCOUNTERED.

High inrush current produces excessive line resistance drops. To limit this, provision is made for smooth acceleration so that driven machinery and equipment are not subjected to an undue mechanical stress caused by starting torque surge. Hence the need for a star – delta type of starter in an induction motor.

The first problem encountered during the construction of the project was mainly on the cost of the materials used.

Secondly was the epileptic nature of power of supply during period of testing which really delay its completion.

The project covered only a forward control starting device. In other words, it is not meant to operate the motor on a reverse direction because reverse control system was not provided.

The test was carried out to ensure that there was no physical contact between live conductors or the neutral conductor. The analogue multi-meter was also used. The test was also positive for all the components.

4.2.3 The control circuit test

This was done to ensure that the control circuit was properly connected and in good working condition. It was done by passing power through the circuit to energize the contactors and then observing their speed of operation. The timer relay was tested to that it operated at the preset time. The test was positive for the control circuit.

4.3 COMMISSIONING

After all the tests discussed above were carefully carried out, a 20 horse power induction motor was connected such that the terminals: U1, V1, W1 and U2, V2, W2 of the motor were correctly connected to the corresponding terminals of the automatic star delta starter. The terminals from the breaker were correctly and properly connected to the supply mains. The timer was set to various times as shown; 10secs, 20secs, and 30secs respectively. The line voltage was switched ON and the start push button was depressed for start. Thus the motor started in star connection but after the set delay times elapsed it changed to delta connection for continuous operation. After it was allowed to run for some times, the stop push button was depressed and the motor finally stopped

CHAPTER FOUR

TESTING AND COMMISSIONING

4.1 PHYSICAL INSPECTION

The power and control circuit wirings were inspected for conforming to the standard wiring diagram. The various connections were also inspected for partial contacts, short circuit or open circuit and interchange of phases. The general inspection revealed conformity with standard wiring diagrams and accurate connections in all the part of the installation.

4.2 TESTING

The tests carried out were quantitative and non-quantitative in nature. In the quantitative test, the objective was to obtain accurate readings from a measuring instrument such as the analogue multi-meter. In the non-quantitative test on the other hand, information form was obtained.

4.2.1 Continuity test

This test was carried out to ensure electrical continuity in all the conductors. The analogue multi-meter was used throughout for the testing.

The contactors were tested by depressing their tabs and test their opposite terminals.

The circuit breakers were tested by switching ON and testing their terminals.

The overload relay`s contacts were also tested for continuity. The continuity test was positive for all the components.

4.2.2 Short Circuit Tests

est was carried out to ensure that there was no physical contact between live conductors or the al conductor. The analogue multi-meter was also used. The test was also positive for all the onents.

The control circuit test

vas done to ensure that the control circuit was properly connected and in good working condition. It one by passing power through the circuit to energize the contactors and then observing their speed ration. The timer relay was tested to that it operated at the preset time. The test was positive for the ol circuit.

OMMISSIONING

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CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 RECOMMENDATIONS

The theoretical knowledge imparted to the students in lecture class needs to be practiced. Therefore, to challenge and improve students' practical knowledge, project of this nature is highly recommendable.

It would be better appreciated on the part of the students if the department is able to supply the students with all the require components, even though the students would have to pay for it. This would reduce the risk associated with travelling a long distance in search for components to buy.

I also recommend that the department should organize the departmental library to enable the students have access to different textbooks.

Finally, final year project should be started early 300 level to enable the students gain more practical knowledge of it.

5.2 CONCLUSION

I must frankly say that this project has really transformed my theoretical knowledge into practical knowledge of electrical engineering as far as starters and electric motors are concerned. It has so far increased my knowledge in the course.

The importance attached to control and protection of electric motor cannot be over-emphasized, it enables fairly large motors to be run smoothly without any problem to the motor and other consumers of electricity in the distributing network.

The project is advancement over the manually operated type; the transition is rather done automatically by the starter itself.

The project finally made us to bridge the gap between the theory and the practical aspect of the electrical engineering. It clearly proved that whatever is being taught as theory can equally be put into real practical work.

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