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DEPARTMENT OF ELELCTRICAL/ELECTRONICS ENGINEERING

FINAL YEAR PROJECT

ON

DESIGN AND CONSTRUCTION OF AUTOMATIC STAR DELTA STARTER FOR 3-PHASE INDUCTION MOTOR WITH REVERSE CAPABILITY

BY

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SUBMITTED TO
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DEDICATION

I dedicate this project to almighty God the creator and 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. Sanya Olusegun Adegbami. Finally, may Almighty God reward whosoever that had in one way or the other contributed positively to my life.

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CERTIFICATIONS

This project work titled "Design and Implementation of an automatic star delta starter for three phase induction motor" by Olusegun Joseph Adekoya, meets the requirements for the award of Bachelor of Engineering (B.Eng.) degree in Electrical and Electronics Engineering Department. Federal University Oye-Ekiti.

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ABSTRACT

Star Delta starters are probably the most common reduced voltage starters in the 50Hz industrial motor world (Known as star / Delta starters in the 60Hz USA world). They are used in an attempt to reduce the start current applied to the motor during start as a Means of reducing the disturbances and interference on the electrical supply.

The Star/Delta starter is generally manufactured from three contactors; an electromechanical timer and a thermal overload for operating a 3 phase motor at 440 volts at the mains supply 50 Hz. The interlocking arrangement of all the contactor coils is traditionally wired in 440 volts ac. However in this project we have taken up the same to operate a 3 phase motor at 440 volt ac mains supply 50 Hz with a set of 12 volt DC relays, electronically adjustable timer and a set of miniature circuit breakers. The interlocking arrangement of the relay coils and the electronic timer are all wired in low voltage dc of 12 volt fed from an inbuilt dc power supply for safe handling of the starter during the study, still retaining its application for a 3 phase motor starting with single phasing prevention.

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LIST OF ACRONYMS

D.O.L	Direct On Line
T.P.D.T	Triple Pole Double Throw
A.C	Alternating Current
N.C	Normally close
N.O	Normally Open

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In the name of God Almighty, most Gracious, most Merciful. all praise is due to God of the universe. I wish to express my profound gratitude to God for giving me the time and opportunity to start and complete my degree programme in good health.

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CHAPTER ONE

1.0 Introduction

Three phase induction motors are widely used due to their low cost, rugged construction, fast pickup, low maintenance and high efficiency. The direct online starters don't provide sufficient protections against voltage fluctuation and single phasing while induction motors are highly sensitive to these. Induction motors if not switched to delta mode of operation within a few seconds then motor can draw heavy current and burn out itself so sensitive protection and switching device are needed to avoid such conditions and protect the motor. For this purpose we use automatic star delta starters with relays and electronic timer with the help of which we can switch the mode of operation of the motor from star mode drawing low current to delta mode drawing the full load current. This will used for best protection of motor against high current. This method also having single phasing protection. Starting current having high value of current hen after to reduce this high current.

1.1 Background of the project

A motor controller is a device or group of devices that serves to govern in some predetermined manner in the performance of an electric motor. A motor controller might include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, selecting and regulating the speed, regulating or limiting the torque, and protecting against overloads and faults.

There are many types of starters:

Direct On Line (DOL)

Star delta starter

Auto transformer starter

Every electric motor has to have some sort of controller. The motor controller will have differing features and complexity depending on the task that the motor will be performing. Direct- on -Line (DOL) Starter is an easiest method for starting up three phase induction motor in which stator windings of the motor are connected directly to the main supply. When an induction motor is connected to the three phase supply, a very large current typically 6 to 7 times the full load current flows through the motor. This heavy current reduces as the motor accelerates to its rated speed. If induction motor is connected directly to the supply, the starting current will not damage the motor unless it is started and stopped repeatedly over a short span of time. If large rating induction motors are connected directly to the supply, a heavy starting current can damage the motor and also cause disturbance of voltage, i.e., voltage dip on mains supply. This can lead malfunctioning of other equipment connected to the same supply. This is the reason why DOL starters are limited to small rating motors where distribution system (mains supply) can withstand high starting currents without excessive voltage dips. The main purpose of any starter is to reduce the requirement of high starting current. If one consumer has an induction motor with a DOL starter, drawing a high current from the line, which is higher than the current for which this line is designed. This will cause a drop (dip) in the voltage, all along the line, both for the consumers between the substation and this consumer, and those, who are in the line after this consumer. This is the reason for careful selection of which starter to use. Due to this limitation and the need to reduce the heavy starting current Star-Delta starter was introduced, In a (squirrel) cage induction motor, Star-Delta starter is used only to decrease the input voltage to the motor so as to decrease the starting current. It is T.P.D.T(Triple Pole Double Throw) switch used to first start the motor with the winding connected in star and then switch for delta connection in running position. The starting current is reduced to approximately two-thirds. Since starting current is reduced. the voltage drops during the starting of motor in systems are reduced.

1.2 Statement of the problem

At the time of starting the motor, rotor is at standstill and the slip (between stator's magnetic field and rotor) is large which causes the large inrush of armature current (which is 6–7 times the rated value). This large current can damage the stator windings and burn the motor.

To avoid this situation, we use star delta starter. At the time of start, motor connections (stator connections) are made in star mode so impressed voltage is reduced by $1/\sqrt{3}$ (Phase voltage = Line voltage/√3) which reduces the starting current. Once the rotor is at 80–90% speed, centrifugal switch operates changing the connections from star to delta mode (full line voltage is impressed).

1.3 Motivation

Direct on line starter is the most commonly used three phase induction motor starter but due to its inability to limit starting current and as a result of that it can't be used for motor with rating higher than 5hp, these limitations induced an interest in me to design an automatic star delta starter which is capable of reducing starting current and being operated in backward direction.

A regular automatic star delta starter is designed only to be operated in forward direction this triggered my interest to improve it by designing and constructing an automatic star delta starter that can be operated in both directions forward and backward. this will widen it area of operations and this will in turn improve it efficiency.

1.4 Significance of the study

Star delta starter is necessary to limit this high starting current of three phase induction motor.

It could also be used as a substitute for ac drive (Variable frequency drive) in some cases.

It will improve the efficiency of star delta starter and its application will be extended to a wide range of operations e.g conveyor where forward and backward operations are required.

1.5 Project aim and objectives

Aim of this project is to design a prototype of an automatic star delta starter which during the starting period when the motor is connected in star at times it takes 1/3 line current and produces 1/3rd of the torque when the winding is connected with supply delta at that time motor gets the enough voltage and so it runs fast, and It limits the starting current. To achieve this aim the objectives are.

i. To do Rating Calculations of the devices/components used, I used national electric code 430-52 in order to determine the appropriate rating of the components, e.g contactor, thermal overload relay, miniature circuit breaker.
ii. To Design circuit diagram
iii. To Configure the circuit in star mode in forward and reverse directions
iv. To Configure the circuit in delta mode in forward direction

v. To Assemble the constructed units i.e components.

vi. To subject it to test continually until the desired result is achieved.

CHAPTER TWO

2.0 LITERATURE REVIEW

Induction motor starting poses many challenging problems to the machine, in the form of wear and tear, and to maintaining a stable supply of power. Engineers and technicians must take these considerations into account when deciding on a starting methodology. The dynamic characteristics desired during the starting process are often conflicting, and tradeoffs must be made based on system characteristics. These characteristics include the system robustness, efficiency, equipment cost, and machine lifetime. Many different methods have been developed to address particular induction motor starting problems associated with motor size and the stability of the connected network. Induction motors makeup a large part of the load in power systems and in industrial applications in particular. The three-phase AC squirrel cage induction motors are the preferred motor type due to their economical cost and robustness (Kjellberg & Kling, 2003), (Trzynadlowski, 2001), (Gobbi, Sa'diah, & Siang, 2003), (Chapman, 2005). They make up approximately 85% of industrial motors (Gobbi, Sa'diah, & Siang, 2003). Wound-rotor motors have an advantage during startup; because of their slip rings, resistance can be added to the rotor circuit. However, wound-rotor motors are more expensive and more difficult to maintain. Many reports have been published discussing the parameters that need to be taken into account during startup that can be used to judge the characteristic features of starting methods for a particular application(Kay, Paes, Seggewiss, & Ellis, 1999), (Larabee, Pellegrino, & Flick, 2005), (IEEE Std 399-1997, 1998), (Pillay, Nour, Yang, Datu Harun, 12 & Haw, 2009), and (McElveen, Toney, Autom, & Mountain, 2001). The common factors when considering the choice of starting method are: Inrush Current – This is the initial current seen by the motor during the starting operations. The inrush current directly relates to mechanical stress of the bearings and belts on the motor load (Cohen, 1995). The resistive or copper losses are proportional to the square of current, $I^2 R$, and therefore affect the efficiency. The power lost is dissipated as heat, causing thermal stress to the machine and affecting its upkeep cost and overall lifetime. Voltage Dip – The allowable amount of voltage dip is usually dependent on the size of the network and the load torque characteristics. The latter is due to the fact that the torque is approximately proportional to the square of the voltage. According to (IEEE Std 399- 1997, 1998), the allowable voltage dip range can vary between 80% and 95% of the rated value. The minimum voltage dip for NEMA type B motors is approximately 80%, given a static prime mover torque, so as to achieve the 150% of rated torque required to accelerate the rotor during starting (NEMA, 2009).Tables describing general use and the locked-rotor starting kVA are given Appendix C. In power systems a common voltage dip limit is 94% of rated voltage. Shunt capacitors and other reactive power compensators are often used to improve voltage response.

Frequency Dip –

To maintain system stability it is important to retain as close to the fundamental frequency of the system as possible. The frequency dip is usually not considered as important as the voltage dip.

Acceleration Time

The time it takes to approximately reach the rated speed of the motor. It is often indicative of other parameters such as torque and current. Faster acceleration time is desired, but often means that high-rated current and other undesirable affects occur. However, a longer acceleration can mean that the applied torque is too low and that a still significant current is applied over a longer span of time resulting in a still too high amount of thermal stress to the motor.

Torque

The speed-torque curve is used to represent the required torques of the motor for different speeds. During startup the initial locked rotor starting torque must be met to overcome the potential energy at stand still, and the accelerating torque must be exceeded to maintain acceleration or the motor will stall (IEEE Std 399-1997, 1998), (Larabee, Pellegrino, & Flick, 2005), and (Kay, Paes, Seggewiss, & Ellis, 1999). Figure 1 shows a generic speed-torque characteristic of a motor; at zero speed is the locked rotor torque, the acceleration torque is the torque required at any time up to the maximum torque. The starting torque is inversely proportional to the square of the terminal voltage, while the inrush current is inversely proportional to the terminal voltage. Care must be taken to balance the reduction of the inrush current and the starting torque.

Reactive Power and Starting Power Factor

It is important to take into account the high reactive power consumed by the motor. In such a case, the rating of the upstream equipment may need to be rated higher than the steady-state condition

(Kay, Paes, Seggewiss, & Ellis, 1999). The reactive power during startup is closely related to the voltage dip. Typical values of the power factor are about 0.20 for motors under 1000 HP (IEEE Std 399-1997, 1998). The locked rotor kVA per HP is defined for each NEMA code letter, see Appendix C, which can help determine the expected starting reactive power corresponding with the starting power factor (Chapman, 2005).

Robustness

The ability of the starting method to perform consistently, time after time or upon emergency.

Cost

The expense of the starting equipment and installation process. Interoperability is also an important consideration.

Many of these considerations are related, and tradeoffs between them are made to choose the starting method and size the generator-set. Sizing the generator set is a practical engineering problem that boasts a particular expertise and special software tools. It should be noted that the impact of the startup process dynamics on the fatigue of the induction motor is generally much less than the impact on the motor's mechanical load (Kjellberg & Kling, 2003), (Cohen, 1995), (McElveen, Toney, Autom, & Mountain, 2001). The thermal stress must be taken into consideration when determining induction 15 motor rotor bar fatigue and motor expected lifetime (Cabanas, et al., 2003). This work focuses on the system dynamics and is not a long-term reliability analysis.

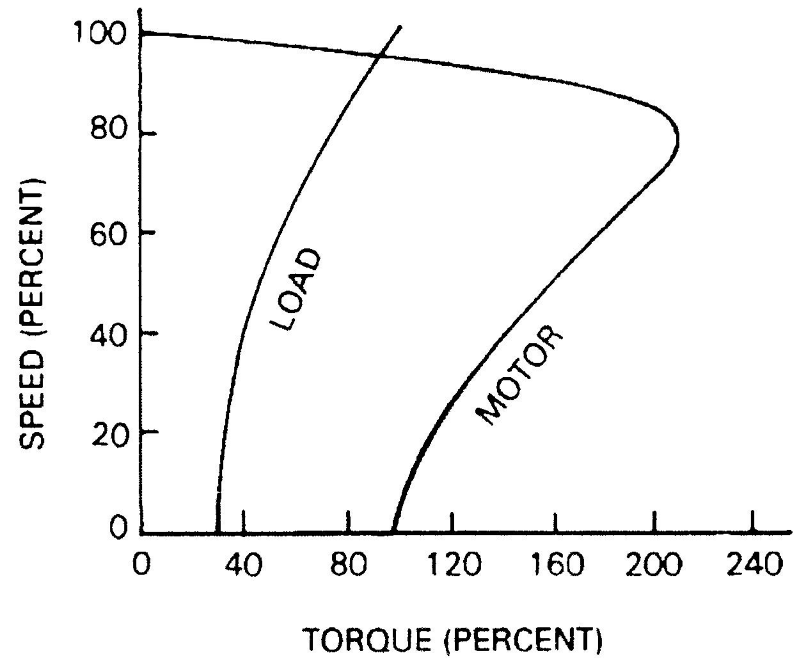

Fig. 2.1: Generic Speed-Torque of a Motor and Associated Load

Taking into consideration the technology of the starting equipment, the starting methods can be divided into electronic drives and those that are not, i.e. conventional electrical network equipment. Other categorizations focus on the voltage manipulation as applied to the terminals. It is typical to separate the methods into the variations of the following categories: full voltage, reduced voltage, incremental voltage, soft-starter, and variable frequency drives (Patil & Porate, 2009), (Larabee, Pellegrino, & Flick, 2005), (McElveen, Toney, Autom, & Mountain, 2001), (Pillay, Nour, Yang, Datu Harun, & Haw, 2009), (Kjellberg & Kling, 2003), and (Bellarmine, Suri, Robinette, & Dreadin, 1994). In this thesis the methods have been divided into the following functional categories based on their physical characteristics and function: full voltage, electromechanical reduced voltage, and soft-starters. Variable Frequency Drives (VFD) are considered beyond the scope of this thesis because they completely decouple the electrical system. Another starting technique (not included in this thesis) is to control the applied torque of the attached prime mover, such as the fluid coupling method. Other methods not discussed below include single-phase starting of a three-phase motor that can be found in work by (Badr, Alolah, & Abdel-Halim, 1995). The reader is also referred to (Ansari & Deshpande, 2009) for a review the problems associated with unbalanced voltage starting.

2.1. Full Voltage Techniques

These methods include the direct-on-line method and conventional circuit introductions that connect the full terminal voltage to the motor stator.

2.1.1. Direct-On-Line (DOL)

DOL is the traditional and simplest method of motor starting, and most other methods are baselined against it. It is also often called across the line start. This method is the direct connection of the terminal voltage to the motor stator with no additional components, and also for this reason is most economical in terms of installation cost and ease of use. It is also one of most reliable and robust methods. Of all the starting methods it produces the highest inrush current, usually six to eight times the rated current, and the highest starting torque: and due to the high starting torque it has the shortest acceleration time (apart from the shunt capacitor start) (Larabee, Pellegrino, & Flick, 2005) and (Pillay, Nour, Yang, Datu Harun, & Haw, 2009). The DOL method is most commonly used for small motors relative to the size of the generation and system, due to the fact that the startup of a small motor will only have a low impact on the system, and in particular the voltage drop (Cohen, 1995), (Kay, Paes, Seggewiss, & Ellis, 1999), and (Pillay, Nour, Yang, Datu Harun, & Haw, 2009). Other drawbacks include the mechanical stress put on 17 the motor's load and the low startup efficiency due to the high reactive power consumed at startup. This approach is typically not suitable for large motors.

2.1.2. Shunt Capacitors

Connecting a capacitor in parallel to the motor can help compensate the reactive demand from the motor during startup by supplying a leading current and thus improve the power factor while still achieving high starting torque because of the full voltage. This provides some relief to the supply source. The shunt capacitance may be left connected if they are properly rated so as to provide power factor correction; or removed as the motor approaches rated speed. In reference (Larabee, Pellegrino, & Flick, 2005) the authors state that the shunt capacitance that is left connected should never be sized larger than the motor's magnetizing current. Capacitor starting may be used in conjunction with other starting methods. Work done by (Li, Zhao, Yang, & Zhang, 2009) presents a method with a startup capacitor array using a dynamic controller, which allows for capacitor switching so that the reactive support power can be varied. Shunt capacitor starting is analyzed and compared to other starting methods in references (Patil & Porate, 2009), (Li, Zhao, Yang, &

Zhang, 2009), (Lewis & Woodbury, 1978), (Stout, 1978), (Williams & Griffith, 1978), and (Liu, Jiang, Hu, & Zhou, 1997). In general, capacitor starting is used for relatively large motors that need fast starting or improved efficiency during startup. In the system tested by (Stout, 1978) it was found that capacitor starting could reduce up to half the maximum voltage dip as compared to the DOL start and still maintain other adequate starting characteristics. Capacitor starting is a reliable and robust method for motor starting on weak electrical system (Kay, Paes, Seggewiss, & Ellis, 1999).

2.1.3. Electromechanical Reduced Voltage Techniques

The electromechanical reduced voltage methods can be implemented through conventional circuitry, such as resistors and transformers. During these reduced voltage startup methods, the thermal capability due to the increased time to reach rated speed must be taken into consideration. Transient current surges are produced from open circuit transitions, but with closed circuit transitions these switching transients are avoided. 1.2.1. Star-Delta The star-delta (wye-delta) starting method controls whether the lead connections from the motor are configured in a star or delta electrical connection. The initial connection should be in the star pattern that results in a reduction of the line voltage by a factor of $1/\sqrt{3}$ (57.7%) to the motor and the current is reduced to 1/3 of the current at full voltage, but the starting torque is also reduced 1/3 to 1/5 of the DOL starting torque (Kjellberg & Kling, 2003). The motor must be delta connected at rated voltage. The transition from star to delta transition usually occurs once nominal speed is reached, but is sometimes performed as low as 50% of nominal speed (McElveen, Toney, Autom, & Mountain, 2001). The star-delta method is usually only applied to low to medium voltage motors (Larabee, Pellegrino, & Flick, 2005) and (McElveen, Toney, Autom, & Mountain, 2001). The operation of the star-delta method is simple and rugged, and is relatively cheap compared to other reduced voltage methods with only additional contactors added to the cost (Pillay, Nour, Yang, Datu Harun, & Haw, 2009). However, the system cannot be modified once installed without considerable rework. Closed-circuit transitions can be performed to avoid open-circuit current surges.

2.1.4. Autotransformer

An autotransformer uses tap changes to reduce the low voltage as needed on the low side connected to the motor terminal. Therefore, the current can be reduced during startup, however the torque is also reduced as the square of the voltage and needs to be taken into consideration to ensure enough torque is supplied during acceleration. The authors in (Larabee, Pellegrino, & Flick, 2005) claim that 10% of the full load torque margin should be supplied at all points on the speed-torque characteristic curve. As the motor speeds up, the line is switched to the full voltage. Common taps range from 50- 80% of the rated voltage (Williams & Griffith, 1978), (Pillay, Nour, Yang, Datu Harun, & Haw, 2009), (Larabee, Pellegrino, & Flick, 2005), and (IEEE Std 399-1997, 1998). IEEE Standard 399-1997 provides a table describing the currents at the typical 50%, 65%, and 80% of full voltage as 25%, 42%, and 64% of the current realized at full voltage during startup, respectively. A practical advantage of the autotransformer is the ability to provide different tap changes so that a wide range of applications, which vary in their starting torque and inrush current needs, can be performed. The star-delta starter is electrically equivalent to an autotransformer tapped at 57.7%. However, autotransformers have a higher cost than other conventional electromechanical starting methods (Pillay, Nour, Yang, Datu Harun, & Haw, 2009). Autotransformer starting is simulated and compared to other methods in (Patil & Porate, 2009).

2.1.5. Primary Resistor or Reactor

A switchable primary series resistor or reactor bank can be added at the motor terminals to limit the current or limit change in the current, respectively. The resistor bank will cause a drop in voltage across it reducing the current. The heat dissipated from the resistor also needs to be taken into consideration. Series resistor starting is usually only performed for small motors (Larabee, Pellegrino, & Flick, 2005). When using a series reactor bank, it will oppose the inrush current initially and reduce the terminal voltage proportionally. The most advantageous characteristic of the series reactor starting is that the voltage increases over time as a function of the rate of change of the current without additional control. The added reactance will also further increase the starting reactive power and thus lower the starting efficiency. Switching transients will also occur if it is connected in an open-circuit.

2.1.4 Soft-Starter Techniques

A soft-starter is any solid-state electronic circuit based device that manipulates the supply voltage prior to connecting to the motor terminals. Many different topologies for soft-starters exist, and many of them are presented in the literature (Charles & Bhuvameswari, 2009), (Solveson, Mirafzal, & Demerdash, 2006), (Li & Liu, 2009), (Rajaji, Kumar, & Vasudevan, 2008), (Youxin, Zezhong, Yalan, Peigang, & Wanquan, 2007). The standard soft-starter consists of thyristors or SCRs that manipulate the source signal via control of the thyristor firing angles (Chapman, 2005).

The soft-starter can be based on controlling different starting characteristics, including current, torque, and voltage, and can be easily adjusted based on the different loadings. Two basic types of soft-starters are the voltage ramping and current limiting types. The voltage ramping soft-starter is able to gradually increase the voltage from a preset level, as low as 0V, to the rated voltage; the result being a very smooth startup. The current profile generally follows the voltage profile for voltage ramping soft-starters. One of the drawbacks of the ramping soft-starter is increased harmonics, which produce extra heating (McElveen, Toney, Autom, & Mountain, 2001). The current limiting soft-starter senses the current at the motor so that the fire angle can be controlled in a manner that the voltage is regulated to maintain the desired current. Of course, the tradeoff of lower current equating to lower torque still applies. Typical values of the current limit are 175% to 500% of the rated current of the motor (Larabee, Pellegrino, & Flick, 2005).

The soft-starter adds significant flexibility in operation (e.g. acceleration time and winding heat) and interoperability, due to the fact that it is more sensitive to the mechanical load characteristics (Kjellberg & Kling, 2003). This also results in lower maintenance cost and increased lifetime of the mechanical load, and can result in improved energy efficiency. However, the tradeoff is the increased operational complexity, and soft-starters are generally expensive devices (McElveen, Toney, Autom, & Mountain, 2001). Limitations include harmonics produced by the electronics and the installation distance from the motor. They are common in higher power applications due to their operation flexibility and improved lifetime of equipment (Patil & Porate, 2009). As an example of a more recent soft-starter control designs, (Youxin, Zezhong, Yalan, Peigang, & Wanquan, 2007) simulate a voltage ramping soft-starter using fuzzy logic to control a controller reactor in Matlab Simulink. The results are compared to the DOL method. The research performed by (Rajaji, Kumar, & Vasudevan, 2008) implements an artificial neural network trained fuzzy logic inference soft-starter in Matlab/Simulink. It combines the speed and torque to determine the firing angle to maintain steady ramping of the motor speed. (Li & Liu, 2009) built a fuzzy logic based soft-starter that controls the motor current based on the sensed current magnitude and rate of change. (Solveson, Mirafzal, & Demerdash, 2006) use Matlab to simulate dynamic modeling of different soft-starting firing angle mappings and compare the starting time, torque profiles, and thermal stress. The method is verified against the DOL starting method. The authors in reference (Charles & Bhuvameswari, 2009) apply a shunt reactor with a soft-starter using Matlab/Simulink to simulate. The shunt reactor helps protect the connected system from the voltage dip.

2.2 REVIEW OF RELATED LITERATURE

INTRODUCTION

Star Delta starter is probably the most common reduced voltage starter where 50Hz dominates. (Known as Wye/Delta starters in the 60Hz world). It is used in an attempt to reduce the start current applied to the motor during start as a means of reducing the disturbances and interference on the electrical supply. Component: The Star/Delta starter is manufactured from three contactors, a timer and a thermal overload. The contactors are smaller than the single contactor used in a Direct on Line starter as they are controlling winding currents only. The currents through the winding are 1\√3 = 0.58 (58%) of the current in the line. this connection amounts to approximately 30% of the delta values. The starting current is reduced to one third of the direct starting current.

Mc Granaghan et al(2002) published that Direct-On-Line starter is the most common starting method available in the market. The components consist of only a main contractor and thermal or electronic overload relay. The disadvantage with this method is that it gives the highest possible starting current. A normal value is between 6 to 7 times the rated motor current but values of up to 9 or 10 times the rated current exist. During a direct-on-line start, the starting torque is also very high, and is usually higher than required for most applications. Autotransformer is another starting method known auto starter or compensators. In this type of starter reduced supply voltage is given to the motor with the help of autotransformer at the time of starting. Jun-ichi et al(2013) When motor gathers speed the autotransformer is disconnected and the full supply voltage is given to the motor. This type starter is used in star connected or delta connected, the cost of obtaining this starter is high due to the requirement of auto transformer and It is rarely used in industry. O. Despe and J. Wang (2005)Star Delta starter could also be achieved using Gate turn thyristor (GTO) instead of electromechanical relay, The Gate turn off thyristor (GTO) is a four layer PNPN power semiconductor switching device that can be turned on by a short pulse of gate current and can be turned off by a reverse gate pulse.

K. Sundareswaran and B.M. Jos(2005) It has high blocking voltage capabilities and high over current capabilities but On state voltage drop and the associated loss is more.

Shittu et al (2014)Automatic star delta connection can as well be achieved by using relays and microcontroller as timer device is a standalone system that is capable of switching the motor from star to delta mode of operation to keeping the system functioning properly, this method also having single phasing protection. Starting current having high value of current hen after to reduce this high current, it is one of the cheapest ways to reduce the starting current for three phase induction motors as it is in the order of three to four times that in case of direct online starter.

2.2.1 Working Principle of Star-Delta Starter

According to Jiguparmar (2012) This is the reduced voltage starting method, Voltage reduction during star-delta starting is achieved by physically reconfiguring the motor windings as illustrated in the figure 2.2 below. During starting the motor windings are connected in star configuration and this reduces the voltage across each winding 3. This also reduces the torque by a factor of three.

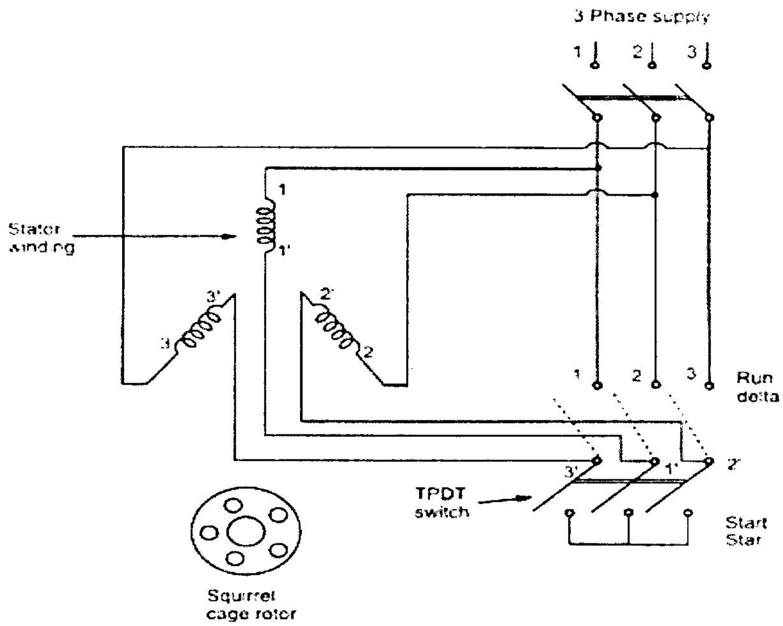

Fig.2.2 Scheme – Working Principle of Star-Delta Starter

After a period of time the winding are reconfigured as delta and the **motor** runs normally. Star/Delta starters are probably the most common reduced voltage starters. They are used in an attempt to reduce the start current applied to the motor during start as a means of reducing the disturbances and interference on the electrical supply.

The Star/Delta starter is manufactured from three contactors, a timer and a thermal overload. The contactors are smaller than the single contactor used in a Direct on Line starter as they are controlling winding currents only. The currents through the winding are 1/root 3 (58%) of the current in the line.

There are two contactors that are close during run, often referred to as the main contractor and the delta contactor. These are AC3 rated at 58% of the current rating of the motor. The third contactor is the star contactor and that only carries star current while the motor is connected in star.

The current in star is one third of the current in delta, so this contactor can be AC3 rated at one third (33%) of the motor rating.

Star-delta Starter Consists following units

1. **Contactors** (Main, star and delta contactors) 3 No's (For Open State Starter) or 4 No's (Close Transient Starter).
2. Time relay (pull-in delayed) 1 No.
3. Three-pole thermal overcurrent release 1 No.
4. Fuse elements or automatic cut-outs for the main circuit 3 Nos.
5. Fuse element or automatic cut-out for the control circuit 1No.

EQUATION OF STAR-DELTA CONNECTION

A) STAR CONNECTION

Phase Voltage Vs = 3 Phase Voltage

= V1 x 1/√3

Phase Current IS1 = Phase Voltage Vs / Z

= √3 x V1 / 3Z

Line Current = Phase Current IS1

= √3 x V1 / 3Z

B) DELTA CONNECTION

Per Phase Voltage Vs = 3 Phase Voltage V1

Phase Current IS2 = Phase Voltage Vs / z

= V1 Z

Line Current = √3 x Phase Current IS2

= √3 x V1 / 3Z

COMPARISON BETWEEN CONVENTIONAL AND PROPOSED STAR DELTA STARTER

Conventional star delta starter

This method is used in case of motors which are built to run normally with a delta-connected stator winding. the six terminals as shown in fig.2.3 below from the three phases of the stator must be available on motor terminal box. The starting of induction motor with the help of conventional automatic star delta starter is done. The time delay in this starter, before changing over from the star to delta connection should be sufficient to allow the motor peak up to its normal running speed. This period may be taken as 10 second, but could be less for a lightly loaded motor and greater for a slow starting heavily loaded motor. In an automatic star-delta starter, this delay is obtained by using a timer as shown in fig.2.4 below. During starting period motor should start in star mode, applied voltage is reduced by rated operated voltage. Since the starting current of motor will have reduced 1/3rd of the current with compared to the delta connection. Since the torque developed by induction motor is proportional to the square of applied voltage. Therefore, star delta starting reduce the starting torque by 1/3rd that of the direct online starting.

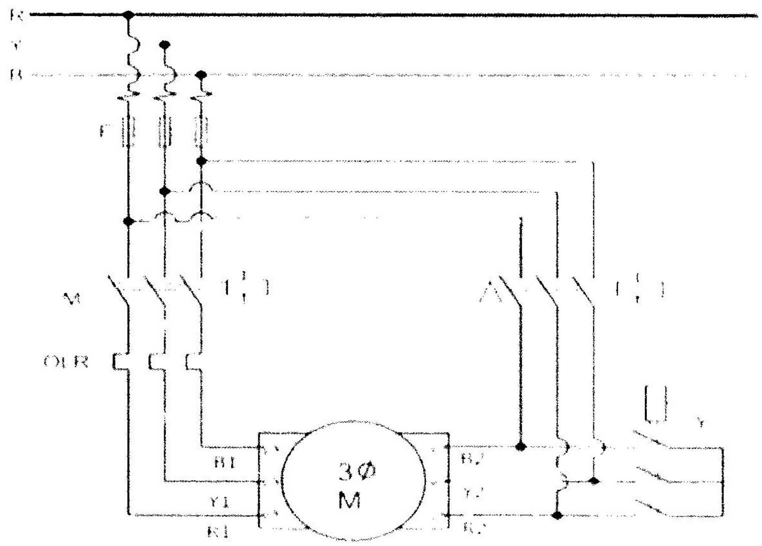

Fig.2.3 power circuit diagram star delta starter

Fig.2.4 control circuit diagram

Existing Electromechanical Star-Delta Starter Consists Following Units:

1. Contactors (Main, star and delta contactors).
2. Time relay (pull-in delayed).

3) Three-pole thermal over current release.

Disadvantages of conventional star delta starter
Its runs in forward direction only
Its application is limited due to the above listed limitation

Proposed star delta starter
Its operation is similar to the conventional star delta starter only that is distinguished with its special capability of forth and back operation, this can be achieved by using four contactors, Timer relay, thermal overload relay, miniature circuit breaker (one pole and three pole).

Advantages of the proposed star delta starter

1. It limits the starting current.
2. The protection against the over load.
3. The protection against the over voltage.
4. The equipment connected with same line is protected.
5. It is cheaper than auto transformer starter.
6. Reverse c

CHAPTER THREE

3.0 Methodology

This chapter will explain about the methods used to complete the project and the steps taken to design the project.

The design steps for the completion of the project are stated below

1. Determining the appropriate ratings of the components/materials
2. Design of the circuit diagram
3. Assembling of the units and implementation
4. Testing of the design
5. Cost analysis.

Fig.3.0 below shows the fundamental block diagram of an automatic star delta starter

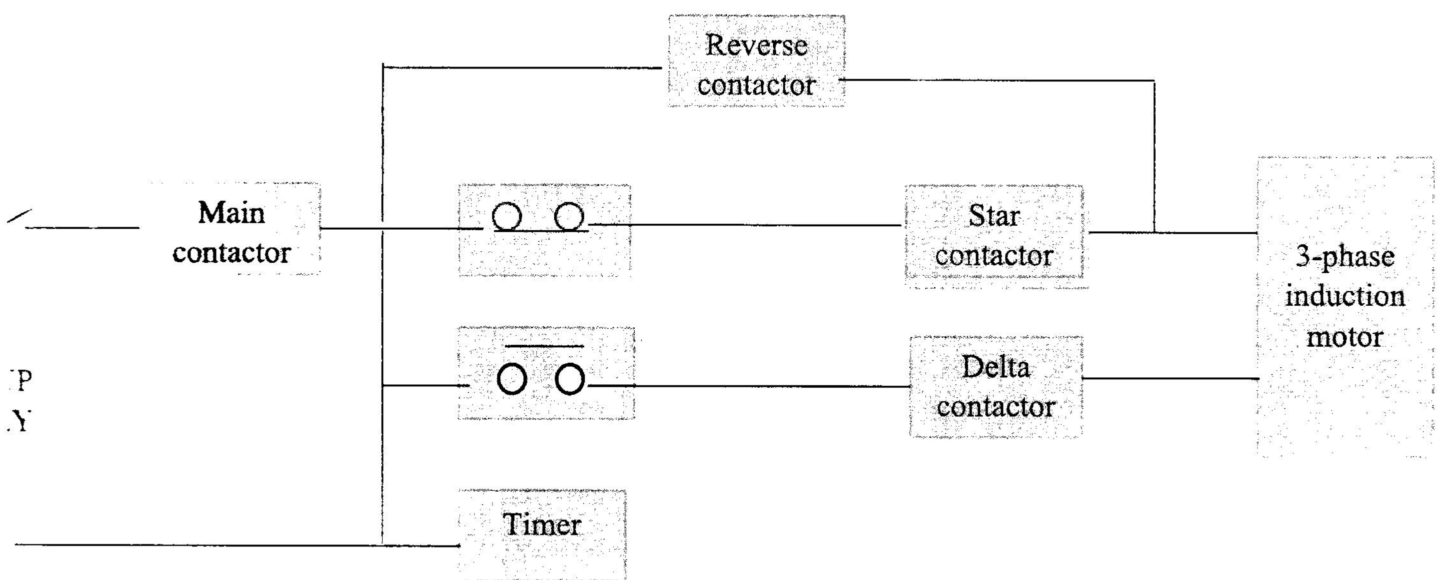

Fig.3.0 Fundamental block diagram of star delta starter

Electrical motors have been used in industries for quite a long period of time to convert electrical energy into mechanical energy. Three phase induction motors, also called asynchronous motors, are most extensively used motors in industries because of certain advantages like self starting, robust design, simple construction, less maintenance, efficient and comparatively low cost, though there is a problem of peak starting current associated with these motors. Peak starting current can be up to 5 to 7 times of full load current (flc) and sometimes it may become as high as 10 times of flc. However, the problem of peak starting current remains only for few seconds till the motor attains its speed, this problem may become severe especially with the motors above 10 HP. To deal with the problem of peak starting current or inrush current associated with three phase induction motors, many different starters having different mechanism and principle of operation are used. These Star-delta starters are used for motors ranges from 5 hp or 3.5 kW above. Star delta starters first configure windings of 3 phase motors in star thereby reduce voltage across each winding and then after few seconds these starters configure windings in delta and motors start run at full load voltage without any difficulty.

The magnitude of voltage induced in rotor conductors depends upon the magnetic flux linking with the rotor conductors and the Slip. Slip is the difference between the synchronous speed of the rotating magnetic flux produced from voltage applied to stator windings and the actual rotational speed of the rotor. At the moment of starting, Slip is maximum and decreases as the motor gains speed. Emf, therefore, induced in rotor conductors is high at starting as it is proportional to the Slip. Also magnitude of e.m.f. induced in rotor conductors will become high at the moment of starting, if full rated voltage i.e., line voltage is applied directly to the motor as the strength of the magnetic flux linking with rotor depends upon the voltage applied to the motor.

Because the impedance of rotor windings being short circuited is very low and voltage induced is very high across windings, the motor current becomes many times of full load current or flc during starting. This high current drawn by the motor may burn motor windings and / or may cause unwanted disturbances in the voltage supply regulation and hence affects other loads adversely connected to the same supply.

Three phase induction motors are, therefore, started through appropriate star-delta starters because star-delta starters reduce voltage or start motors at reduced voltage by first configuring windings in star connections to overcome problem of high current surge at starting.

3.1 Requirement Specification

Star-delta Starter Consists following units

Contactors (Main, Reverse, star and delta contactors) 3 No's (For Open State Starter) or 4 No's (Close Transient Starter).

Time relay (pull-in delayed) 1 No.

Three-pole thermal overcurrent release 1 No.

Fuse elements or automatic cut-outs for the main circuit 3 Nos.

Fuse element or automatic cut-out for the control circuit 1No.

CALCULATE SIZE OF CONTACTOR, FUSE, C.B, O/L OF STAR/DELTA STARTER

Implementation of this project involved strategical calculations of the electrical devices using national electrical codes (NEC) table, This helped in determining the appropriate values of time delay fuse, circuit breaker, thermal overload relay, main contactor, star contactor and delta contactor.

Calculate Size of each Part of star delta starter for The System Voltage 220V ,5HP Three Phase House hold Application Induction Motor. Code A. Motor efficiency 80%, Motor RPM 750, Power Factor 0.8. Overload Relay of Starter is Put before Motor.

CALCULATION OF MOTOR TORQUE AND CURRENT

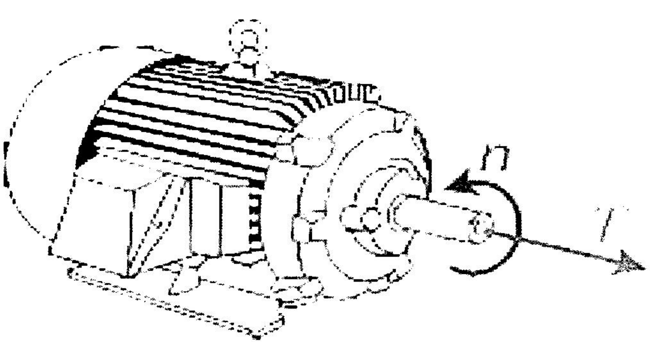

Fig.3.1 an induction motor

Basic Calculation of Motor Torque & Current of star /delta motor is as:

Motor Rated Torque (Full Load Torque) =5252xHP/RPM

Motor Rated Torque (Full Load Torque) =5252×5/750=35 lb-ft.

Motor Rated Torque (Full Load Torque) =9500xKW/RPM

- Motor Rated Torque (Full Load Torque) =9500x (5×0.746)/750 =47 Nm
- If Motor Capacity is less than 30 KW than Motor Starting Torque is 3xMotor Full Load Current or 2X Motor Full Load Current.
- Motor Starting Torque=3xMotor Full Load Current.
- Motor Starting Torque==3×47=142Nm.
- Motor Lock Rotor Current =1000xHPx figure from below Chart/1.732×415

Measuring the locked rotor current (in the rotor or stator) can be used to find the equivalent circuit components of an induction motor.

Locked Rotor Current

Code	Min	Max
A	1	3.14
B	3.15	3.54
C	3.55	3.99
D	4	4.49
E	4.5	4.99
F	5	2.59
G	2.6	6.29
H	6.3	7.09
I	7.1	7.99
K	8	8.99
L	9	9.99
M	10	11.19
N	11.2	12.49
P	12.5	13.99

R	14	15.99
S	16	17.99
T	18	19.99
U	20	22.39
V	22.4	

- As per above chart Minimum Locked Rotor Current =1000x5x1/1.732×415=7 Amp
- Maximum Locked Rotor Current =1000x5x3.14/1.732×415=22 Amp.
- Motor Full Load Current (Line) =KWx1000/1.732×415
- Motor Full Load Current (Line) = (5×0.746) x1000/1.732×415=6 Amp.
- Motor Full Load Current (Phase)=Motor Full Load Current (Line)/1.732
- Motor Full Load Current (Phase)==6/1.732=4Amp
- Motor Starting Current =6 to 7xFull Load Current.
- Motor Starting Current (Line)=7×6=45 Amp

SIZE OF FUSE

Table.3.1 Fuse as per NEC

Fuse as per NEC 430-52

Type of Motor	Time Delay Fuse	Non-Time Delay Fuse
Single Phase	300%	175%
3 Phase	300%	175%
Synchronous	300%	175%
Wound Rotor	150%	150%
Direct Current	150%	150%

- Maximum Size of Time Delay Fuse =300% x Full Load Line Current.
- Maximum Size of Time Delay Fuse =300%x6= 19 Amp.
- Maximum Size of Non Time Delay Fuse =175% x Full Load Line Current.
- Maximum Size of Non Time Delay Fuse=175%x6=11 Amp

SIZE OF CIRCUIT BREAKER

A circuit breaker is an automatically operated electrical switch that is designed to protect an electrical circuit from damage caused by excess current from an overload or short circuit. Fig.3.2 shows a typical miniature circuit breaker. Its basically function to interrupt current flow after a fault is detected.

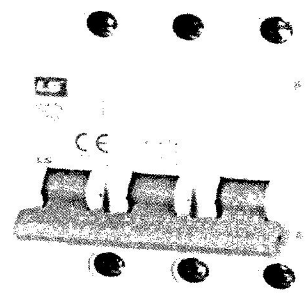

Fig 3.2 Miniature Circuit breaker

Table.3.2 Circuit breaker as per NEC 430-52

Circuit Breaker as per NEC 430-52

Type of Motor	Instantaneous Trip	Inverse Time
Single Phase	800%	250%
3 Phase	800%	250%
Synchronous	800%	250%
Wound Rotor	800%	150%
Direct Current	200%	150%

- Maximum Size of Instantaneous Trip Circuit Breaker =800% x Full Load Line Current.
- Maximum Size of Instantaneous Trip Circuit Breaker =800%x6= 52 Amp.
- Maximum Size of Inverse Trip Circuit Breaker =250% x Full Load Line Current.
- Maximum Size of Inverse Trip Circuit Breaker =250%x6= 16 Amp.

THERMAL OVER LOAD RELAY

Thermal overload relays are electromechanical protection devices for the main circuit. Fig.3.3 shows a typical overload relay. They provide reliable protection for motors in the event of overload or phase failure. The thermal overload relay can make up a compact starting solution together with contactors.

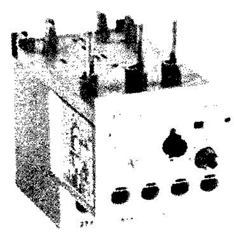

Fig.3.3 Thermal overload relay

- Thermal over Load Relay (Phase):
- Min Thermal Over Load Relay setting =70%xFull Load Current(Phase)
- Min Thermal Over Load Relay setting =70%x4= 3 Amp
- Max Thermal Over Load Relay setting =120%xFull Load Current(Phase)
- Max Thermal Over Load Relay setting =120%x4= 4 Amp
- Thermal over Load Relay (Phase):
- Thermal over Load Relay setting =100%xFull Load Current (Line).
- Thermal over Load Relay setting =100%x6= 6 Amp

(4) Size and Type of Contactor:

A contactor is an electrically-controlled switch used for switching an electrical power circuit. Fig 3.4 shows a contactor. A contactor is typically controlled by a circuit, which has a much lower power level than the switched circuit, such as a 24-volt coil electromagnet controlling a 230-volt motor switch.

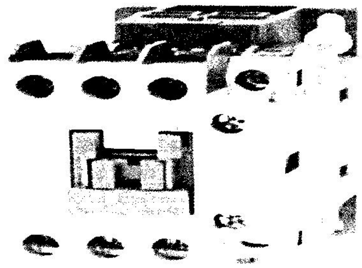

Fig.3.4 Contactor

Application	**Contactor**	**Making Cap**
Non-Inductive or Slightly Inductive ,Resistive Load	AC1	1.5
Slip Ring Motor	AC2	4
Squirrel Cage Motor	AC3	10
Rapid Start / Stop	AC4	12
Switching of Electrical Discharge Lamp	AC5a	3
Switching of Electrical Incandescent Lamp	AC5b	1.5
Switching of Transformer	AC6a	12
Switching of Capacitor Bank	AC6b	12
Slightly Inductive Load in Household or same type load	AC7a	1.5
Motor Load in Household Application	AC7b	8
Hermetic refrigerant Compressor Motor with Manual O/L Reset	AC8a	6
Hermetic refrigerant Compressor Motor with Auto O/L Reset	AC8b	6
Control of Restive & Solid State Load with opto coupler Isolation	AC12	6
Control of Restive Load and Solid State with T/C Isolation	AC13	10

Control of Small Electro Magnetic Load (<72VA)	AC14	6
Control of Small Electro Magnetic Load (>72VA)	AC15	10

- As per above Chart
- Type of Contactor= AC7b
- Size of Main Contactor = 100%X Full Load Current (Line).
- Size of Main Contactor =100%x6 = 6 Amp.
- Making/Breaking Capacity of Contactor= Value above Chart x Full Load Current (Line).

Making/Breaking Capacity of Contactor=8×6= 52 Amp.

3.2 Design

Circuit diagram

The star contactor serves to initially short the secondary terminal of the motor U2, V2, W2 for the start sequence during the initial run of the motor from standstill. This provides one third of DOL current to the motor, thus reducing the high inrush current inherent with large capacity motors at startup.

Controlling the interchanging star connection and delta connection of an AC induction motor is achieved by means of a star delta or wye delta control circuit. The control circuit consists of push button switches, auxiliary contacts and a timer. The system has two different circuits: the power circuit and control circuits as shown in fig.3.5 and 3.6 below.

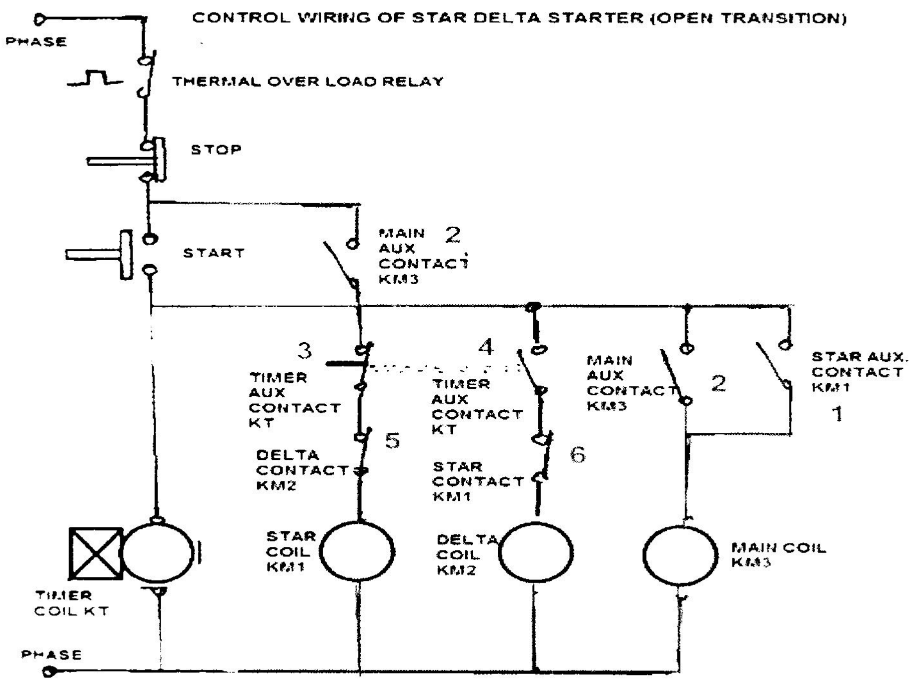

FIG. 3.5 Control Circuit of Star-Delta Starter (Open Transition)

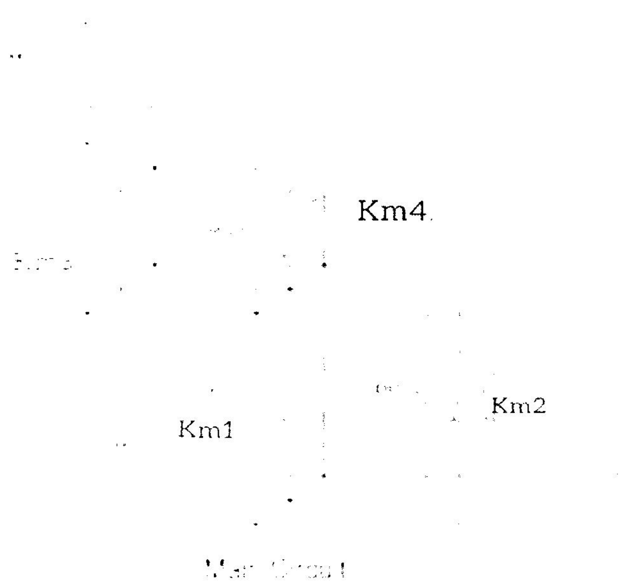

Fig 3.6 Power circuit of Star-Delta starter

Fig.3.7,3.8 and 3.9 show the design progress till it was fully completed

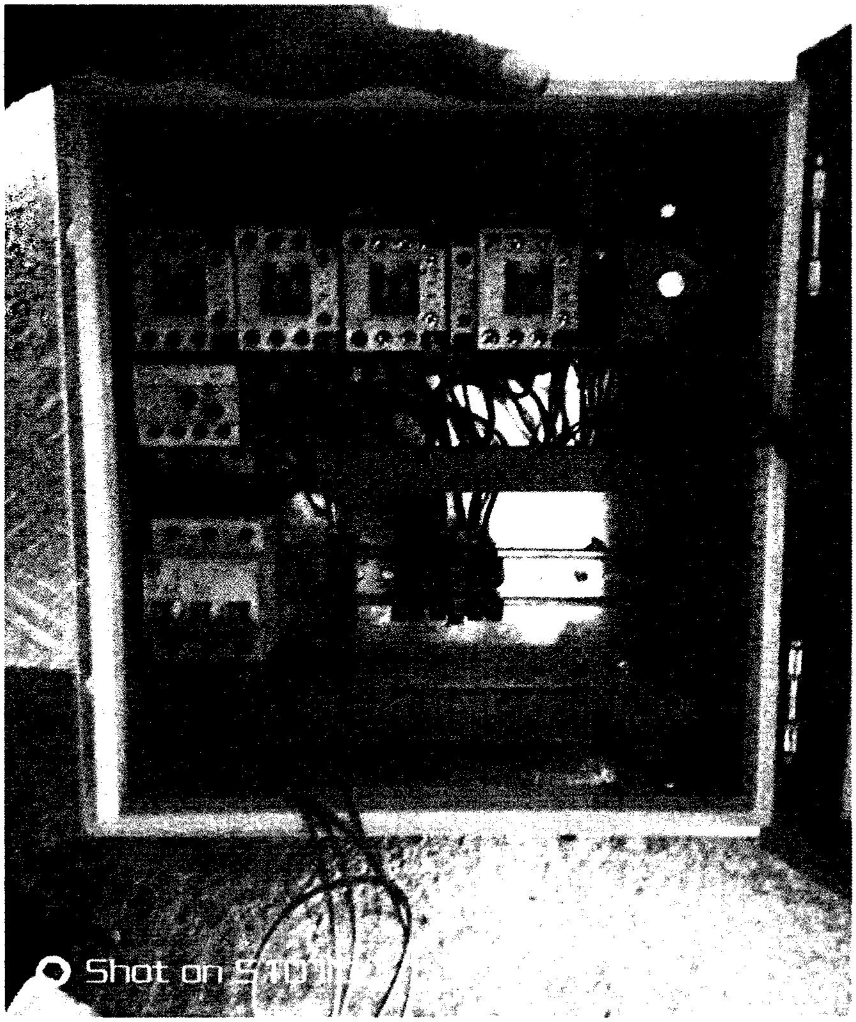

Fig.3.7 Design progress

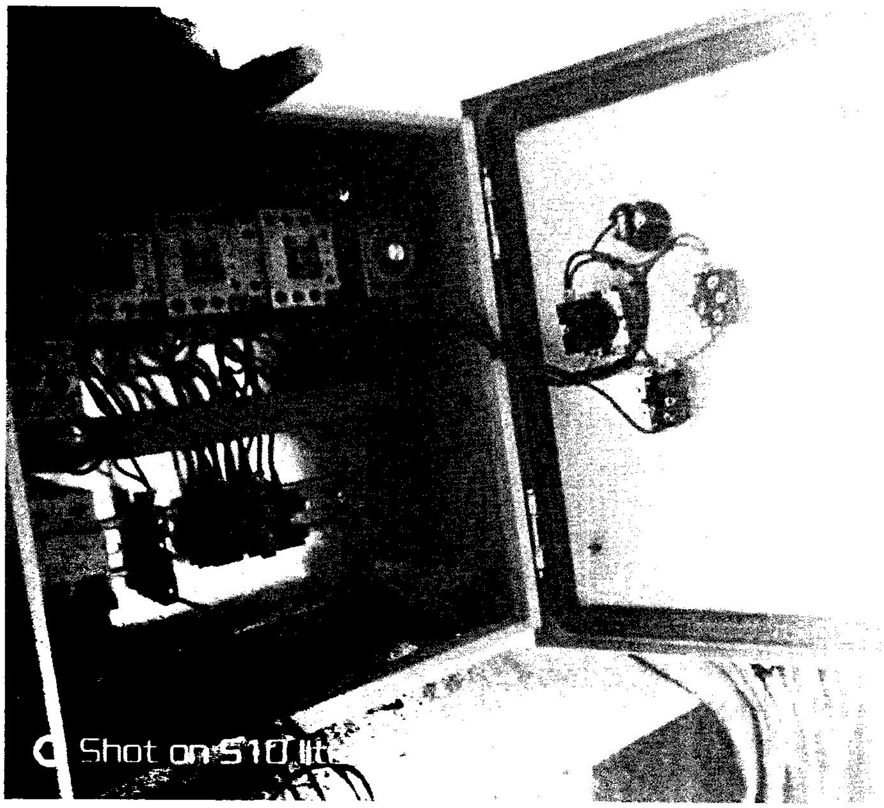

Fig.3.8 Design progress

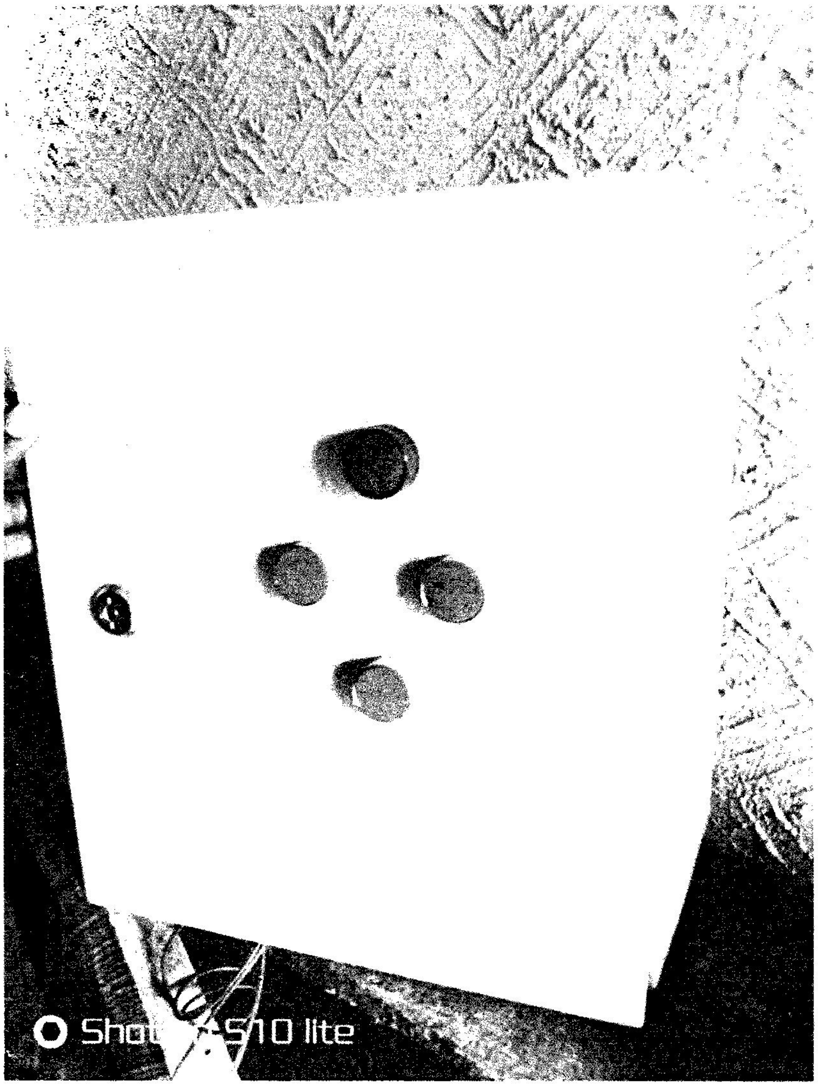

Fig.3.9 Design progress 3

CIRCUIT DESCRIPTION

The ON push button starts the circuit by initially energizing Star Contactor Coil (KM1) of star circuit and Timer Coil (KT) circuit. When Star Contactor Coil (KM1) energized, Star Main and Auxiliary contactor change its position from NO to NC.

When Star Auxiliary Contactor (1) (which is placed on Main Contactor coil circuit) become NO to NC it's complete The Circuit of Main contactor Coil (K[illegible]) so Main Contactor Coil energized and Main Contactor's Main and Auxiliary Contactor Chan; e its Position from NO to NC. This sequence happens in a friction of time.

After pushing the **ON** push button switch, the auxiliary contact of the main contactor coil (2) which is connected in parallel across the ON push button will become NO to NC, thereby providing a latch to hold the main contactor coil activated which eventually maintains the control circuit active even after releasing the ON push button switch.

When Star Main Contactor (KM1) closes Motor connects on STAR and it's connected in STAR until Time Delay Auxiliary contact KT (3) become NC to NO.

Once the time delay is reached its specified Time, the timer's auxiliary contacts (KT) (3) in Star Coil circuit will change its position from NC to NO and at the Same Time Auxiliary contactor (KT) in Delta Coil Circuit(4) change its Position from NO To NC so Delta coil energized and Delta Main Contactor becomes NO To NC. Now Motor terminal connection change from star to delta connection.

A normally close auxiliary contact from both star and delta contactors (5&6) are also placed opposite of both star and delta contactor coils, these interlock contacts serves as safety switches to prevent simultaneous activation of both star and delta contactor coils, so that one cannot be activated without the other deactivated first. Thus, the delta contactor coil cannot be active when the star contactor coil is active, and similarly, the star contactor coil cannot also be active while the delta contactor coil is active.

The control circuit above also provides two interrupting contacts to shut down the motor. The OFF push button switch break the control circuit and the motor when necessary. The thermal overload contact is a protective device which automatically opens the STOP Control circuit in case when motor overload current is detected by the thermal overload relay, this is to prevent burning of the motor in case of excessive load beyond the rated capacity of the motor is detected by the thermal overload relay.

At some point during starting it is necessary to change from a star connected winding to a delta connected winding. Power and control circuits can be arranged to this in one of two ways – open transition or closed transition.

SIZE OF EACH PART OF STAR-DELTA STARTER

1. Size of Over Load Relay

For a star-delta starter there is a possibility to place the overload protection in two positions, in the line or in the windings.

Overload Relay in Line:

In the line is the same as just putting the overload before the motor as with a DOL starter.

The rating of Overload (In Line) = FLC of Motor.

Disadvantage: If the overload is set to FLC, then it is not protecting the motor while it is in delta (setting is x1.732 too high).

Overload Relay in Winding:

In the windings means that the overload is placed after the point where the wiring to the contactors are split into main and delta. The overload then always measures the current inside the windings.

The setting of Overload Relay (In Winding) =0.58 X FLC (line current).

Disadvantage: We must use separate short circuit and overload protections.

2. Size of Main and Delta Contractor

There are two contactors that are close during run, often referred to as the main contractor and the delta contactor. These are AC3 rated at 58% of the current rating of the motor.

Size of Main Contactor= IFL x 0.58

3 Size of Star Contractor

The third contactor is the star contactor and that only carries star current while the motor is connected in star. The current in star is 1/ √3= (58%) of the current in delta, so this contactor can be AC3 rated at one third (33%) of the motor rating.

Size of Star Contactor= IFL x 0.33

CHAPTER FOUR

4.0 Testing. Analysis of Result and Discussion

In implementing any electronics circuit, a circuit diagram is first obtained after which all components and materials needed for the circuit project are made available. The components are then assembled to construct a circuit and make sure that the circuit is operational as desired.

The electrical schematic diagram fig.4.1 is an illustration of a power circuit for a star delta motor controller used in every electrical industry involving industrial process automation control technology.

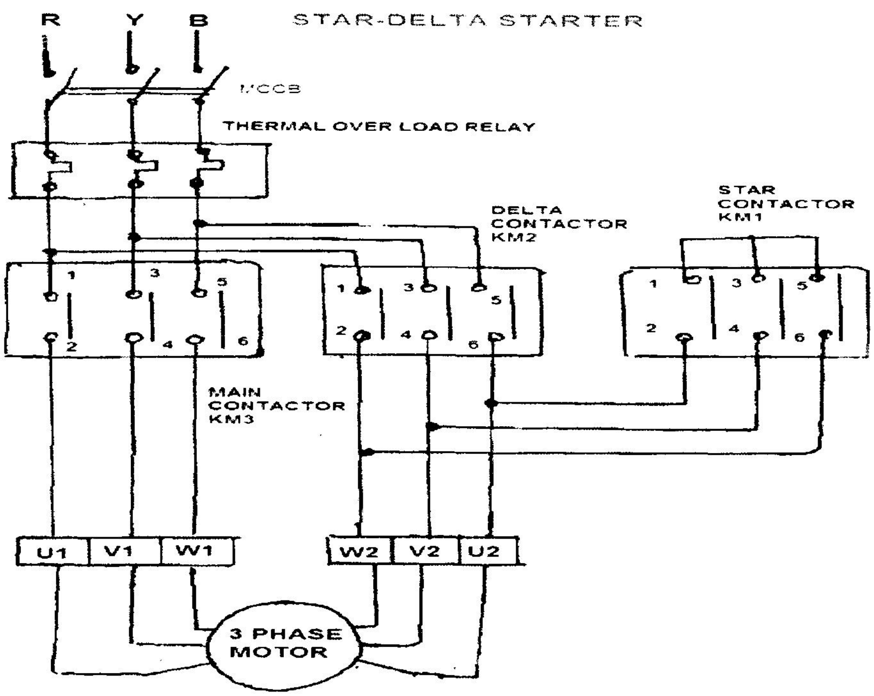

Fig.4.1 power circuit diagram

There are four magnetic contactors shown on the diagram above. The initial operating stage of the circuit is to firstly activate the main contactor together with the star contactor. The star contactor is a common starting device which provides the shorting of the motor's secondary terminal U2, V2, W2 during the startup run of the motor for both the forward and reverse function.

When the time has elapsed wherein the motor has finally gained momentum to attain sufficient holding inertia, the star contactor is released and the command transfers to the final motor run state, activating the forward delta contactor.

When the forward function is selected to run the motor, the main forward contactor and the star contactor are activated, once the elapsed time is reached, the star contactor releases and the delta forward contactor is activated while maintaining the main forward contactor energized during the entire operation of the motor.

Conversely, when the reverse function is selected to run the motor, the main reverse contactor and the star contactor are activated.

The power circuit diagram above illustrates the corresponding motor connection which follows an orderly wiring configuration conforming to a correct path of phase sequence appropriate for achieving a reduced high transient current spikes during the transition period when the motor connection is transferred from the star mode to the delta mode, this applies to forward function of the AC induction motor.

The forward (clockwise) and the reverse (counter-clockwise) motor rotation are both configured with appropriate motor connections that produces a minimal voltage difference between the phase voltage sequence and the transition voltage developed during the changeover duration from star to delta configuration.

DESCRIPTION OF OPEN TRANSITION SWITCHING

Open transition switching because there is an open state between the star state and the delta state.

In open transition the power is disconnected from the motor while the winding are reconfigured via external switching.

When a motor is driven by the supply, either at full speed or at part speed, there is a rotating magnetic field in the stator. This field is rotating at line frequency. The flux from the stator field induces a current in the rotor and this in turn results in a rotor magnetic field.

When the motor is disconnected from the supply (open transition) there is a spinning rotor within the stator and the rotor has a magnetic field. Due to the low impedance of the rotor circuit, the time constant is quite long and the action of the spinning rotor field within the stator is that of a generator which generates voltage at a frequency determined by the speed of the rotor

Open transition starting is the easiest to implement in terms of cost and circuitry and if the timing of the changeover is good, this method can work well. In practice though it is difficult to set the necessary timing to operate correctly and disconnection/reconnection of the supply can cause significant voltage/current transients.

In open transition there are four states:

1. **OFF State**: All Contactors are open.
2. **Star State:** The Main [KM3] and the Star [KM1] contactors are closed and the delta [KM2] contactor is open. The motor is connected in star and will produce one third of DOL torque at one third of DOL current.
3. **Open State:** This type of operation is called open transition switching because there is an open state between the star state and the delta state. The Main contractor is closed and the Delta and Star contactors are open. There is voltage on one end of the motor windings, but the other end is open so no current can flow. The motor has a spinning rotor and behaves like a generator.

Delta State: The Main and the Delta contactors are closed. The Star contactor is open. The motor is connected to full line voltage and full power and torque are available

4.1 Testing

This project was tested at a saw mill where 3-phase power supply and an induction motor were available, It worked has designed when tested with three phase power supply.

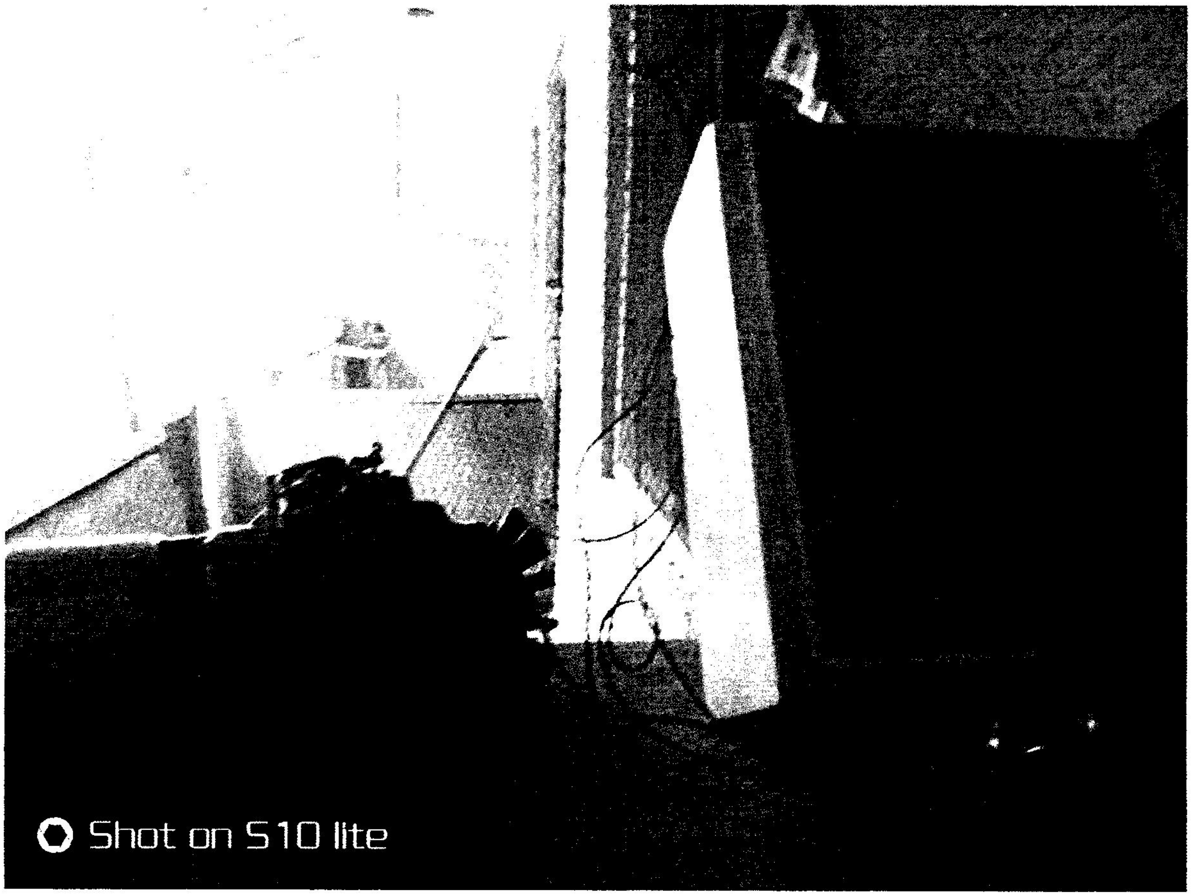

Fig. 4.2 Testing the starter with an induction motor

4.2 Design

Interesting features of my design are discussed below

After carefully selecting the values needed the automatic star delta starter with reverse function was designed and implemented using the schematic diagrams fig.4.6.

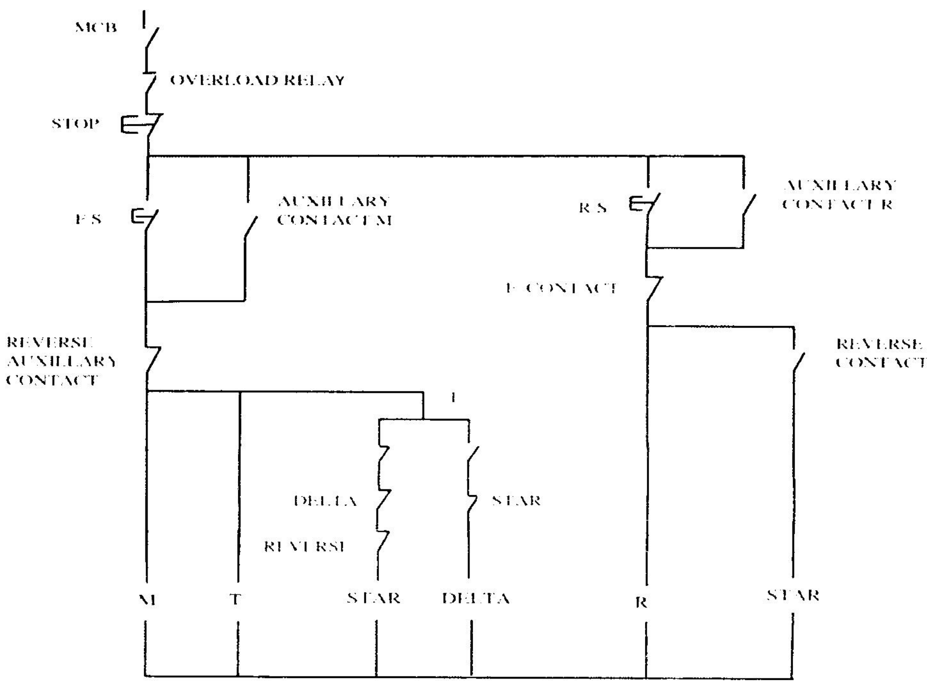

Fig. 4.3 Control circuit

An automatic star delta starter with reverse capability was implemented thereby improving on the conventional automatic star delta starter through iterative approach was applied in arriving at the desired result, however reverse function was added thereby widening its area of use or application

4.3 project management

This section of the project explained how the project was accomplished within the period of November 2018 to January 2019, as illustrated by using the Gantt chart in figure

	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK
LITERATURE REVIEW								
TASK 1								
TASK 2								
TASK 3								
TASK 4								
TASK 5								

Table 4.1 Gantt chart

TASK 1 – Gathering of materials for the project

TASK 2 – Design of project circuit

TASK 3 – Acquisition of components

TASK 4 – Construction and implementation of the project

TASK 5 – Testing and casing of the project.

CHAPTER FIVE

5.0 Conclusion and Recommendation

The delta configuration for the forward or clockwise motor rotational direction is achieved with the motor configuration U1-V2-L1, V1-W2-L2, W1-U2-L3 which provides a relatively reduced high inrush transient current during the transition period upon switching of the magnetic contactors from star (wye) to delta motor connection.

Similarly, the delta configuration for the reverse or counter-clockwise motor rotational direction is achieved with the motor configuration V1-U2-L1, U1-W2-L2, W1-V2-L3 which is also the most appropriate configuration for the purpose of providing a suitable reduction of high inrush transient current during the transition period when the magnetic contactors transfers the motor's wiring connection from star mode to delta mode.

The interchanging control for the star to delta and the command selection for choosing between forward or reverse run for the power circuit illustrated above is achieved by means of a corresponding forward reverse star delta control circuit.

I recommend that star delta starter, the motor connection must have 6 cables from control panel and 6 terminals at induction motor. Star delta starter only works when the application is light loaded during the start. If the motor is too heavily loaded, there will not be enough torque to accelerate the motor up to speed before switching over to the delta position.

5.1 Contribution to knowledge

This project has broadened my knowledge on the use of electrical devices/components, also buttressing my theoretical knowledge and this makes me to appreciate the theoretical knowledge imparted to us in the class room more. I was able to intimate myself with the tools used in the electrical workshop.

5.2 Limitations

The limitation of this project is that it can only be applied to motors where the six leads or terminals can be accessed. Also the supply voltage must be the same as the rated motor voltage for delta connection.

5.3 Future works

The possible future enhancement is to make it applicable to motors where the six terminals are not accessible.

when the starting current is reduced to approximately one third of the rated current, the starting torque is also reduced, an improvement can be made by letting the motor maintain its torque speed at the start without reducing.

5.4 Critical appraisal

In the course of this project there were series of challenges encountered, not all plans were executed smoothly during the project development.

I was not able to get all the components and the devices on time and this caused a little delay and even after obtaining the required devices one of the it was bad so I had to return it and get it replaced, After the completion of the project I decided to test it but to my surprise it didn't work as it ought to, the fault was traced and fixed but it cost me a lot of money because I had to travel from ekiti state to lagos state for the correction.

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Appendix A

BILL OF ENGINEERING MATERIALS AND EVALUAT ON

S N	COMPONENTS	QUANTITY	NIT	PRICE
1	MCB 3POL3	1	#4000	#4000
2	MCB 1POLE	1	#2500	#2500
3	CONTACTOR 12AMP	3	#4000	#12000
4	CONTACTOR 9AMP	1	#3000	#3000
5	TIMER RELAY	1	#1500	#1500
6	THERMAL OVERLOAD RELAY	1	#3500	#3500
7	CABLE	1	#1200	#1200

8	START PUSH BUTTON	1	#500	
9	STOP PUSH BUTTON	1	#500	
10	LAMP	1	#500	
11	ENCLOSURE	1	#9000	
		TOTAL	#41200	