

MODIFICATION OF FORWARD AND REVERSE ELECTRIC MOTOR STARTERS

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ABSTRACT

Modification of forward and reverse Electric Motor Starters is designed to reduce the numbers of Electrical component used in conventional Electric Motor Starters. The modified forward and reverse Direct-On-Line Starter is designed to use one Contactor, one Start Push Button, one Stop Push Button, one Miniature Circuit Breaker, one Control Breaker, one Overload Relay and Three-Phase Selector Switch. The modified forward and reverse Star/Delta Starter is designed to be implemented with two Contactors, one Start Push Button, one Stop Push Button, one Timer Relay, one Miniature Circuit Breaker, one Control Breaker and one Three-Phase Selector Switch. The designed Circuit diagrams are then subjected to test by using a software called CADE-SIMU to simulate the circuit diagrams. The modification reduces the cost of number of Contactors and some other Electrical components used as well as reducing the cross-sectional area of the Electrical panel.

Keywords: Contactors; Overload Relay; Timer Relay; Forward and Reverse

1.1 Introduction

Electric Motor Starters incorporate some Electrical components with safety devices to start the operation of the Electric Motor. There are two major types of such Starters, namely, Direct-On-Line Starter and Star/Delta Starter. The Electric Motor is either connected as Star or Delta at the Electric Motor terminals when using the DOL Starter. The Star/Delta Starter is another type of Electric Motor Starter having three Contactors, one Overload Relay, one Timer Relay, one Miniature Circuit Breaker, one Control Breaker, Indicating lamps and Push Button Switches. The three Contactors are tagged as Main Contactor, Star Contactor and Delta Contactor. If the Timer Relay is set at ten seconds, the Main Contactor and the Star Contactor are energized simultaneously for ten seconds. After ten seconds the Star Contactor disengage to give way to the Delta Contactor and the Main Contactor to continue the operation of the Electric Motor (Ifiok, 2024). The Star/Delta Starter is for soft starting of the Electric Motor. Changing the direction of Three-Phase Induction motor is carried out by interchanging two of the three phases.

2.1 Brief review of similar work

Forward and reverse operation of Electric Motor DOL Starter is realized with two contactors (Uduak Okoa, 2024). One Contactor for forward movement while the other Contactor for the reverse movement. The Control and Power line diagrams are as shown in figure 1.0.

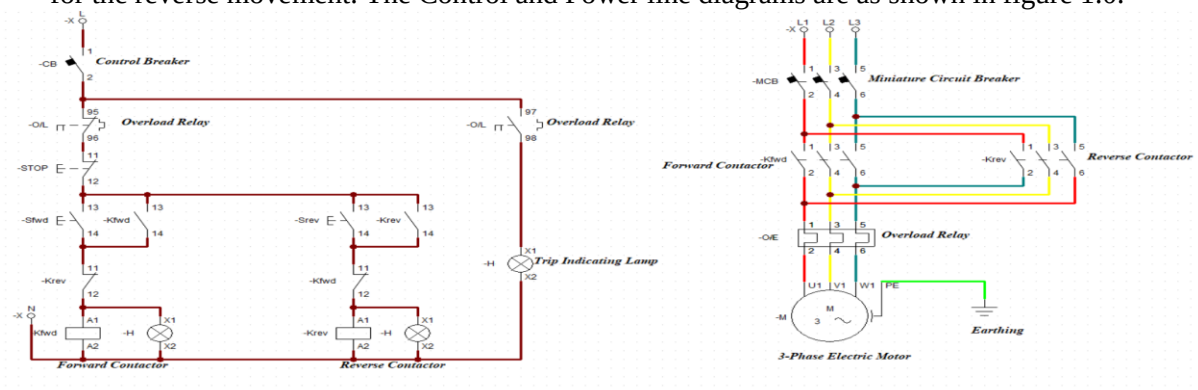


Figure 1.0: Forward and reverse Motor Starter

The software CADe-SIMU (CADe-SIMU Version 4.2, 2024) was used to draw and simulate the circuit diagrams. The result of the simulation for the forward operation is as shown in figure 1.1. If the forward Contactor is energized, the reverse Contactor remains open because the NC Contact from the forward Contactor which is connected in series with reverse Contactor coil is opened. Similarly, If the reverse Contactor is energized, the forward Contactor remains open because the NC Contact from the reverse Contactor which is connected in series with forward Contactor coil is opened. These operations were tested with the software and it works satisfactorily. The present research work is to use one Contactor, one Start Push Button and other electrical components to achieve the same aim.

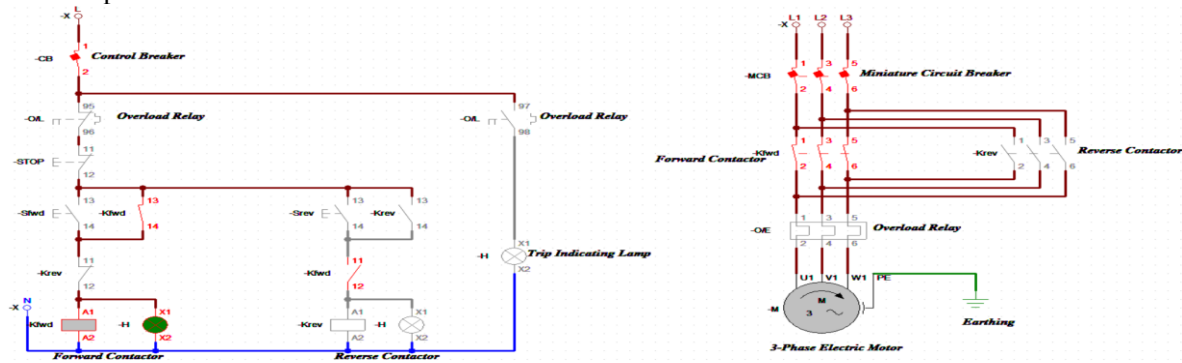


Figure 1.1: Forward and reverse Motor Starter (forward mode operation)
The result of the simulation for the reverse operation is as shown in figure 1.2

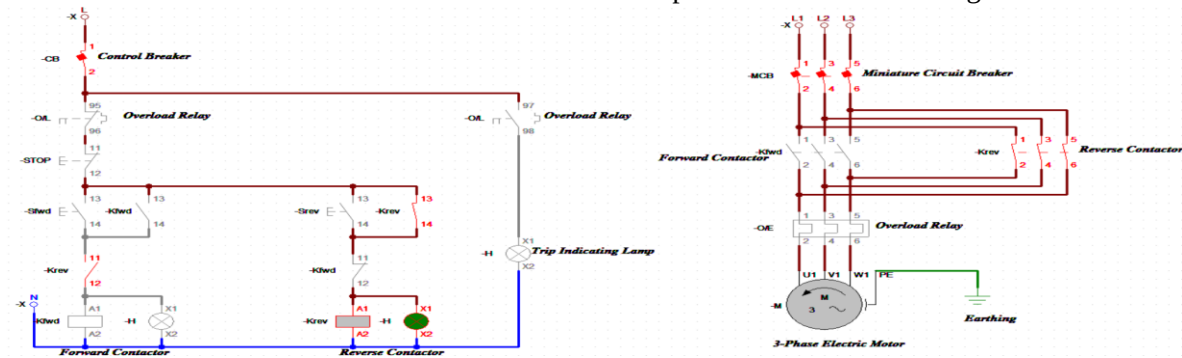


Figure 1.2: Forward and reverse Motor Starter (reverse mode operation)

The conventional Star/Delta Starter forward and reverse operation involves four contactors, one Overload Relay, one Timer Relay, one Miniature Circuit Breaker, one Control Breaker, Indicating Lamps and Push Button Switches. Use of Arduino Based Star/Delta Starter with forward and reverse control is equally another research work (Nigar Sultana, 2023). The Control and Power line diagrams are as shown in figure 1.3. The present research work is to use just two Contactors, one Start Push Button with other electrical components to realize the operation of the forward and reverse Star/Delta Starter. The starting torque and starting current in Delta connection is higher than that of Star connection (Jayswal, 2018).

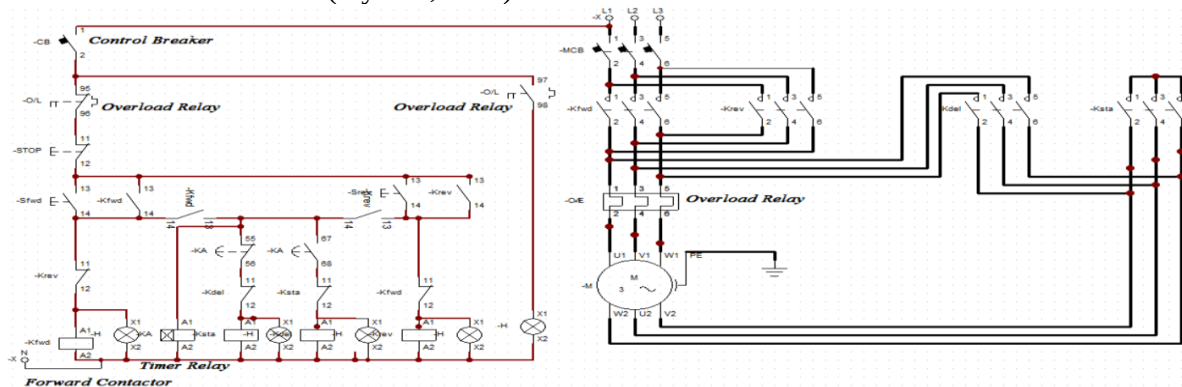


Figure 1.3: Control and Power line diagrams of forward and reverse Star/Delta Starter

The result of the simulation of the circuit diagram in forward Star mode is as shown in figure 1.4

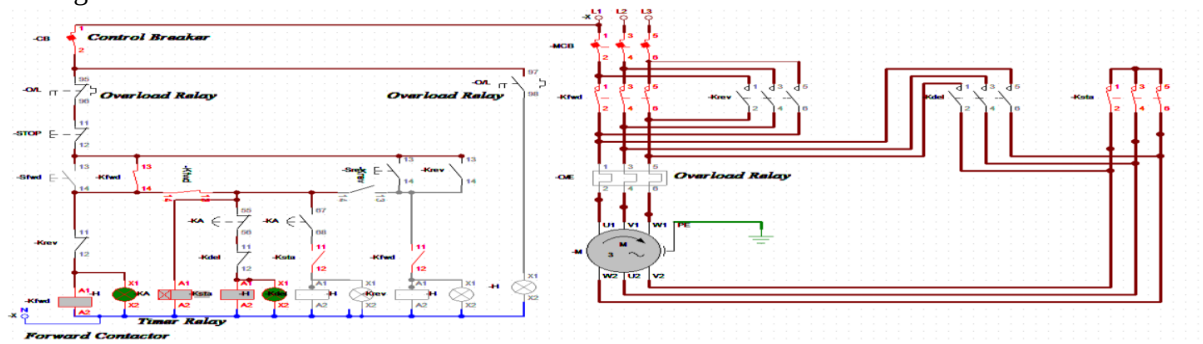


Figure 1.4: Control and Power line diagrams of forward and reverse Star/Delta Starter (forward Star mode)

The result of the simulation of the circuit diagram in forward Delta mode is as shown in figure 1.5

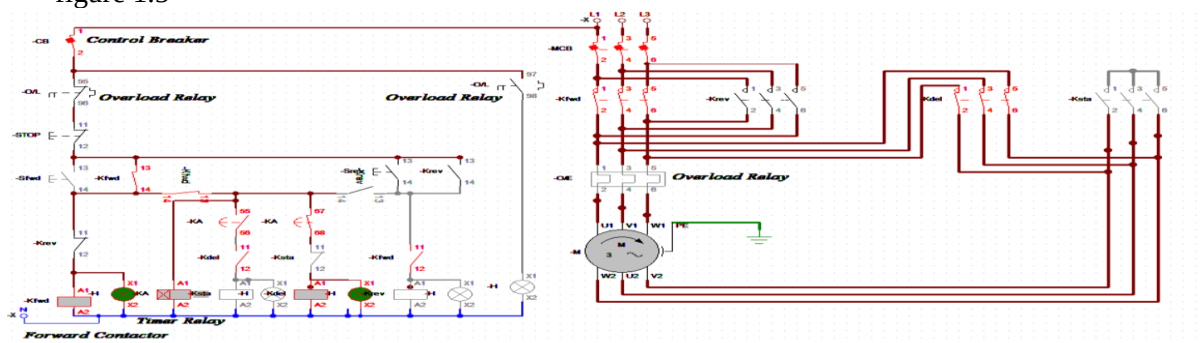


Figure 1.5: Control and Power line diagrams of forward and reverse Star/Delta Starter (forward Delta mode)

The result of the simulation of the circuit diagram in reverse Star mode is as shown in figure 1.6

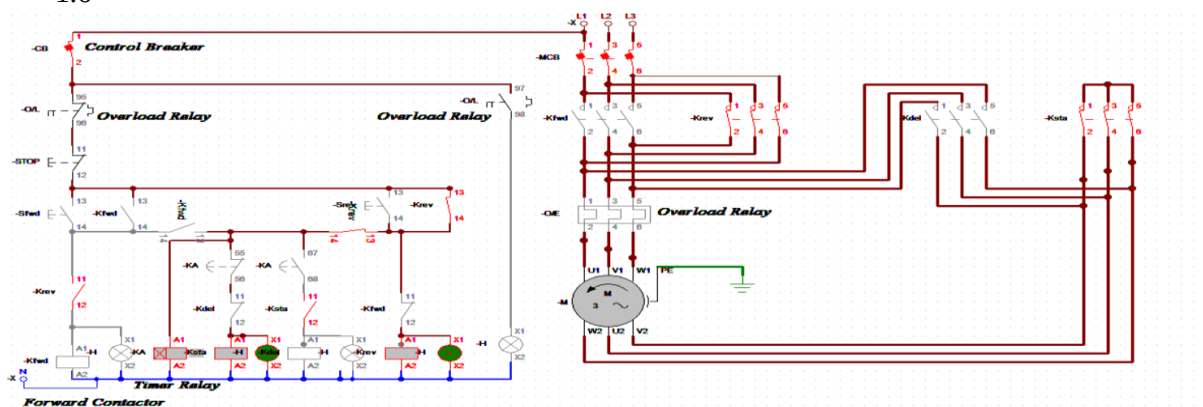


Figure 1.6: Control and Power line diagrams of forward and reverse Star/Delta Starter (reverse Star mode)

The result of the simulation of the circuit diagram in reverse Delta mode is as shown in figure 1.7

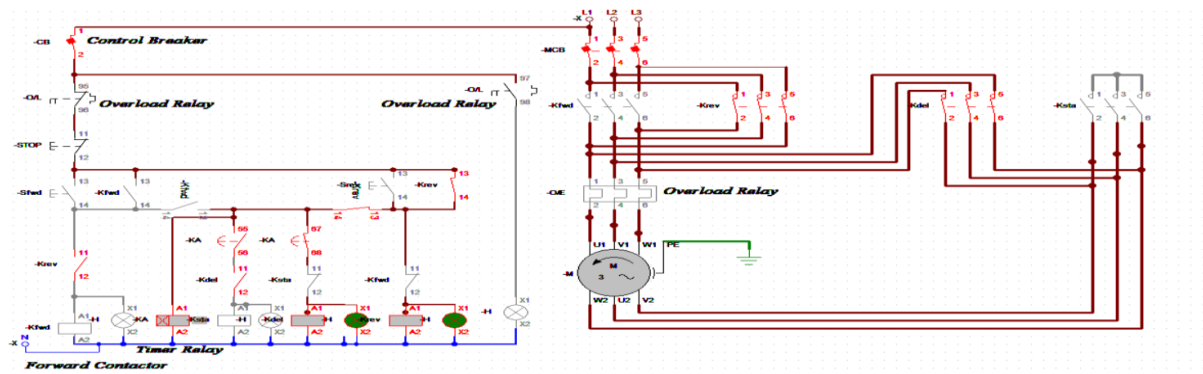


Figure 1.7: Control and Power line diagrams of forward and reverse Star/Delta Starter (reverse Delta mode)

Use of relays to realize the operation of Star/Delta Starter is another research work carried out by (Ayibapreya, October, 2022). This idea is practically not realizable on Electric Motors of high power capacity. Safety measures like Miniature Circuit Breaker and Overload Relay were excluded in the research work. The idea of Star connection and then Delta connection is to reduce the inrush starting current (Apoorva, June, 2017).

The connection involving three Contactors with other Electrical Components is as shown in figure 1.8.

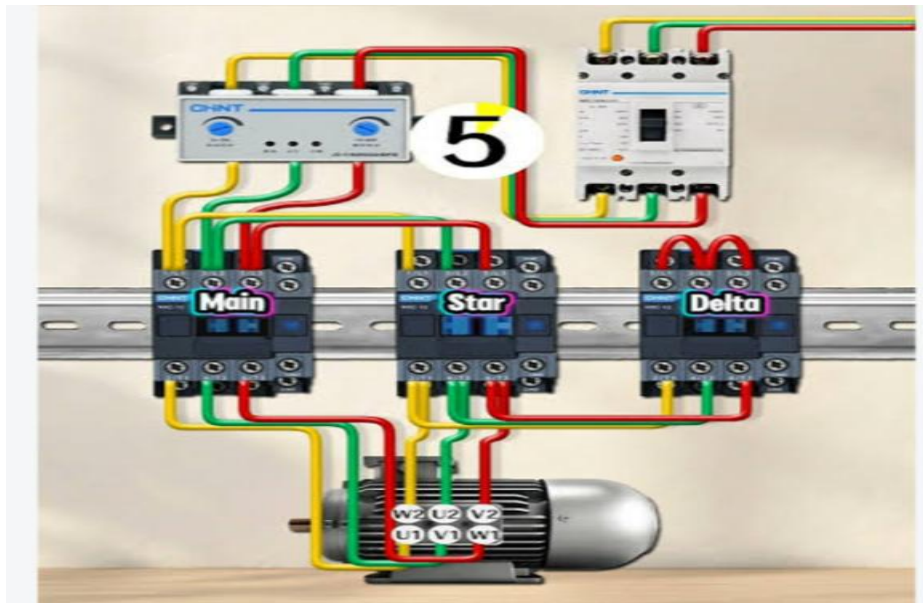


Figure 1.8: Star/Delta Starter

2.2 Problem Statement

Forward and reverse operation of Electric Motor in Industries is very vital in some product processing. The change of direction in three-phase induction Motor is realized by changing two of the phases. Hence there is need to make such changing more flexible and within the shortest period of time. Reducing the number of Electrical components will not only save cost but as well reduces the space within the Electrical panel.

2.3 Aim & Objective

The aim of this research work is to demonstrate implementation of Electric Motor Starters by reducing the numbers of Contactors involved.

3.1 Methodology

The conventional forward and reverse Starter incorporates two Contactors, one Overload Relay, one Miniature Circuit Breaker, one Control Breaker, two Start Push Buttons, one Stop Push Button and Indicating lamps. The modification is the utilization of such operation with just one Contactor, one Overload Relay, one Selector Switch, one Start Push Button, one Stop Push Button and Indicating Lamps. One contactor performs both the forward direction and the reverse direction. The change of direction is carried out on the Selector Switch. When changing the direction of the Electric Motor, the Operator must make sure the Stop Push Button on the Control Circuit is pressed.

The major reason for such step is to avoid arching within the Three-Phase Rotary Contacts. A position is OFF position while the remaining two positions are configured to change the sequence of the 3-Phase power supply.

The conventional forward and reverse Star/Delta Starter involves four Contactors, one Overload Relay, one Timer Relay. This research work is to use just two Contactors, namely, Star Contactor and Delta Contactor. The forward and reverse operations are configured on the Selector Switch with three positions. The Selector Switch is as shown in figure 2.0.

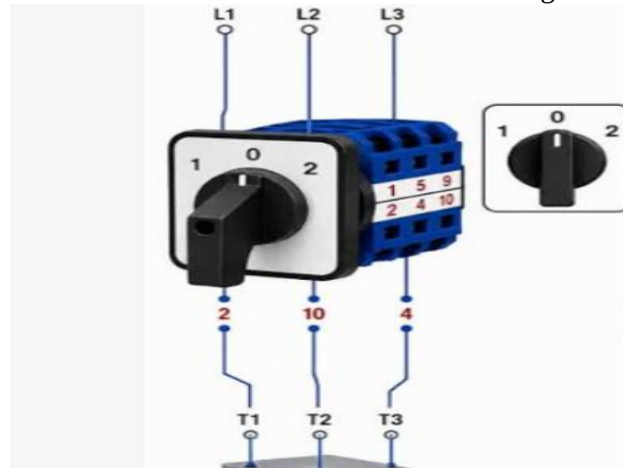


Figure 2.0: 3-Phase Selector Switch

4.1 Result

The results of modifications as carried out are as displayed as follows;

4.1.1 Modified forward and reverse DOL Starter

The operational mode of the modified forward and reverse Electric Motor Starter in forward direction is as shown in figure 2.1. When the Start Push Button is engaged as shown on the Control line diagram of figure 2.1 the Contactor is energized. The power supply to the Electric Motor terminal is obtained through the Three-Phase Selector Switch.

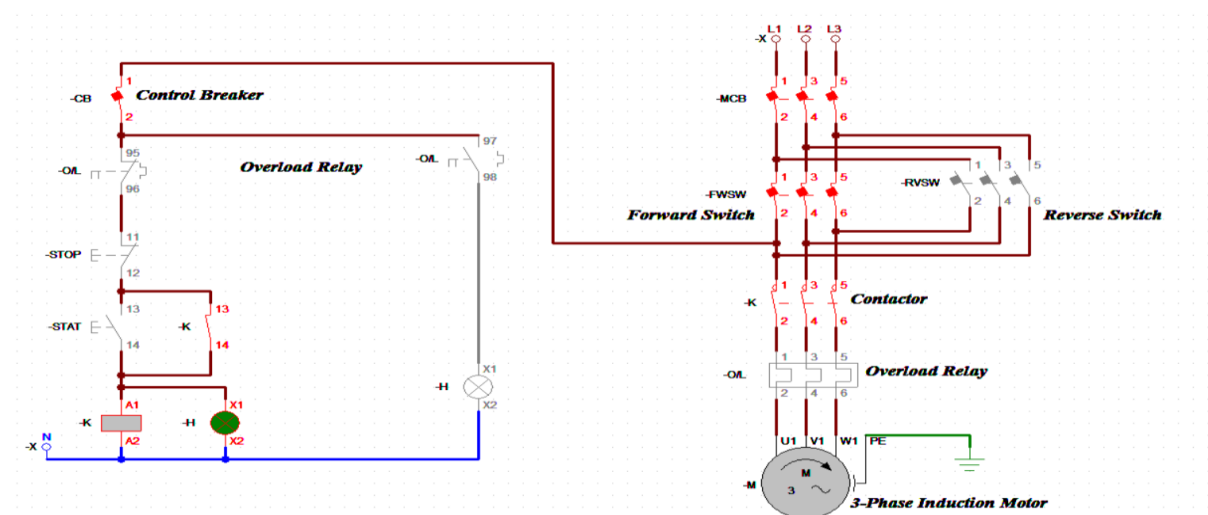


Figure 2.1: The operational mode of the Electric Motor in forward direction.

The operational mode of the modified Electric Motor Starter in reverse direction is as shown in figure 2.2.

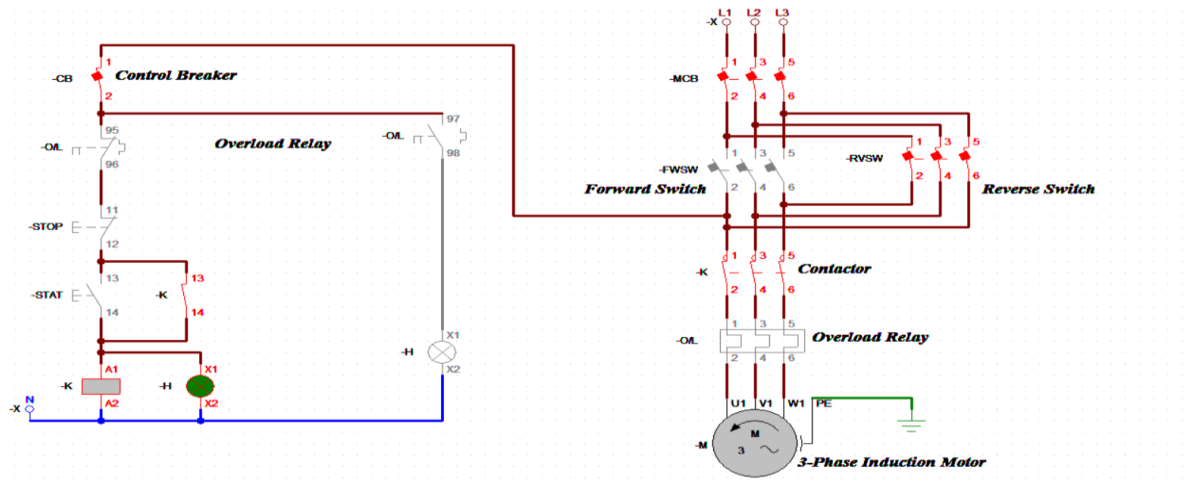


Figure 2.2: The operational mode of the modified Electric Motor Starter in reverse direction.

The diagram in figure 2.3 illustrates the connection of the Three-Phase Rotary Switch to implement the phase reversal.

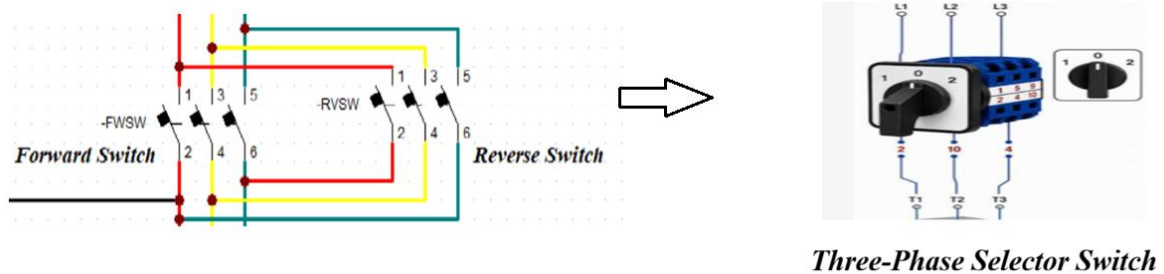


Figure 2.3: Diagram for the Three-Phase Selector Switch

The incorporation of Three-Phase Selector Switch for the modified Forward and reverse DOL is as shown in figure 2.4. the Selector Switch has three positions. Position labelled as '0' is the OFF position. Position labelled as '1' is to be connected power supply as Red, Yellow and Blue. This position '1' is for forward direction. Position labelled as '2' is to be connected to power supply as Red, Blue and Yellow. This position '2' is for the reverse direction.

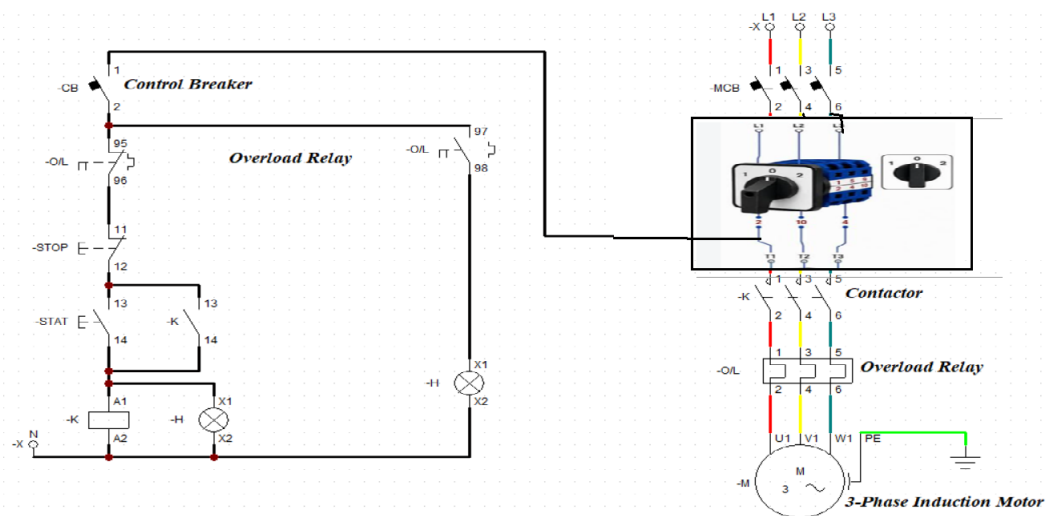


Figure 2.4: Use of Three-Phase Selector Switch for the modified Starter.

Safety

The safety measure when using the Selector Switch is to tap supply to the Control Breaker from the Contactor Main Contact. With this type of connection, the Contactor will only be energized via the Start Push Button when the Selector Switch is ON. The Main Circuit Breaker and the Overload Relay if well selected will protect the entire Circuit against any envisaged short circuit that might occur when the 3-Phase Selector Switch is operated.

4.1.2 Modified forward and reverse Star/Delta Starter

The control line diagram for the Modified Forward and reverse Star/Delta Starter is as shown in figure 2.5. The NC Contact and NO Contact of the Timer Relay are connected to the Star Contactor and Delta Contactor respectively to avoid operating the two contactors at the same time.

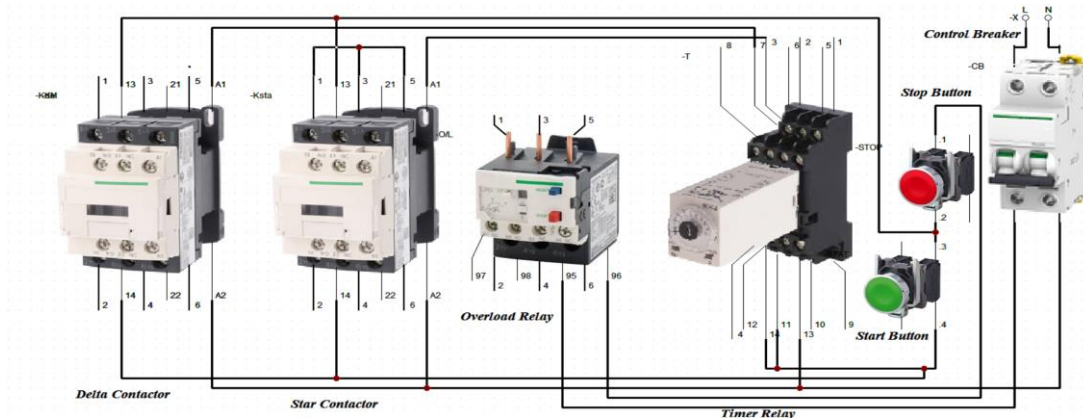


Figure 2.5: Control line diagram for the Modified Forward and reverse Star/Delta Starter

The operation of the control line diagram for the Modified Forward and reverse Star/Delta Starter in Star mode is as shown in figure 2.6. The Normally Close (NC) Contact of the Timer Relay labelled as terminal '3' is linked to the Star Contactor while the Normally Open Contact (NO) of the Timer Relay labelled '7' is linked to the Delta Contactor.

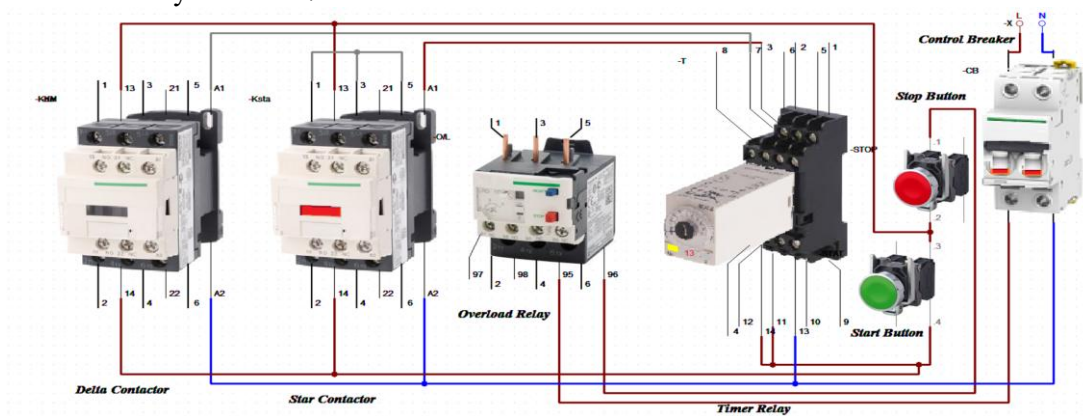


Figure 2.6: Control line diagram for the Modified Forward and reverse Star/Delta Starter (Star mode operation or simulation)

The operation or simulation of the control line diagram for the Modified Forward and reverse Star/Delta Starter in Delta mode is as shown in figure 2.7. The Normally Open (NO) Contact of the Timer Relay labelled as terminal '7' is now supplying current to the Delta Contactor. Under normal condition the NC and NO Contacts of the Timer Relay are neither close nor open simultaneously. That is, when the NO Contact is closed the NC Contact is opened.

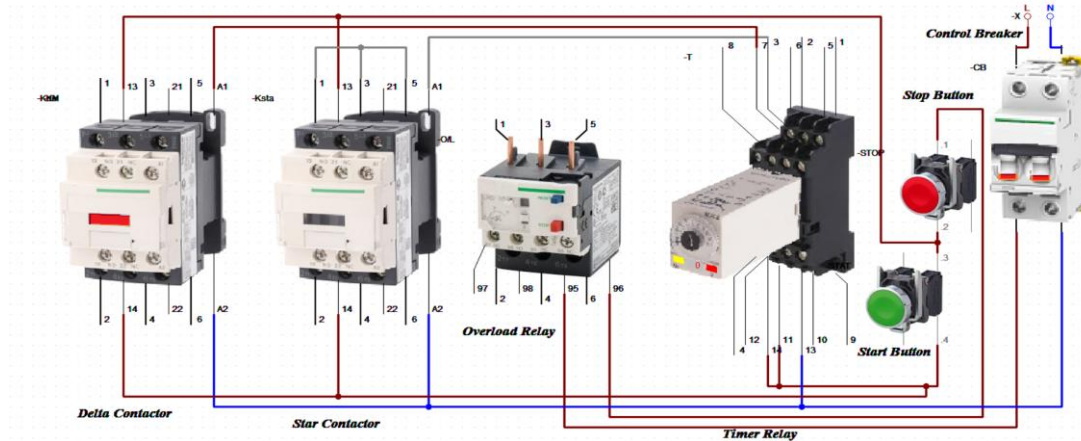


Figure 2.7: Control line diagram for the Modified Forward and reverse Star/Delta Starter (Delta mode operation or simulation)

The complete line diagrams for the modified Star/Delta Starter is as shown in figure 2.8. This design as shown in figure 2.8 do not need additional interlocking Contacts because the normally open and normally close contacts of the Timer Relay are connected respectively to the Star and Delta Contactor Coils.

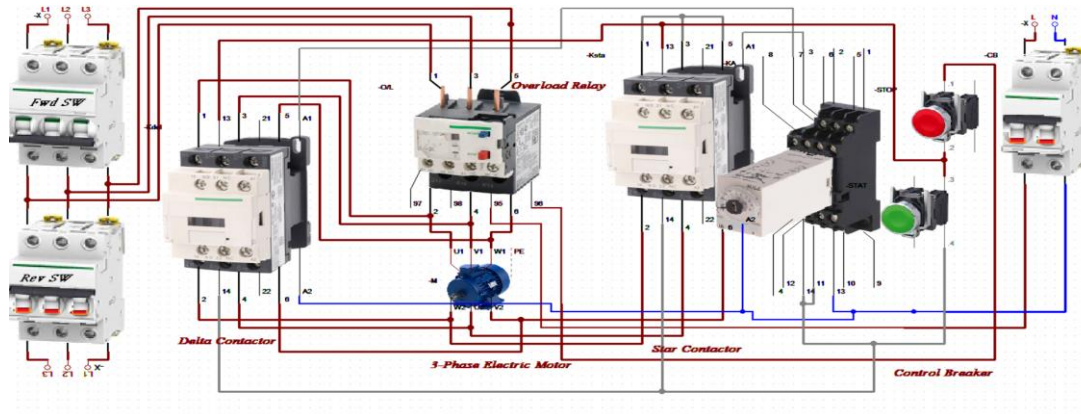


Figure 2.8: Complete line diagrams for the modified Star/Delta Starter

The operation or simulation of the motor as Star connected Motor in forward direction is as shown in figure 2.9. Current now flows through the NC Contact of the Timer Relay to the Star Contactor Coil. The Star Contactor is now energized to convey power supply to the Electric Motor. The Star Contactor remains ON for the period at which the Timer Relay is set. After the period the NC Contact open while the NO Contact of the Timer Relay close to convey current to the Delta Contactor Coil.

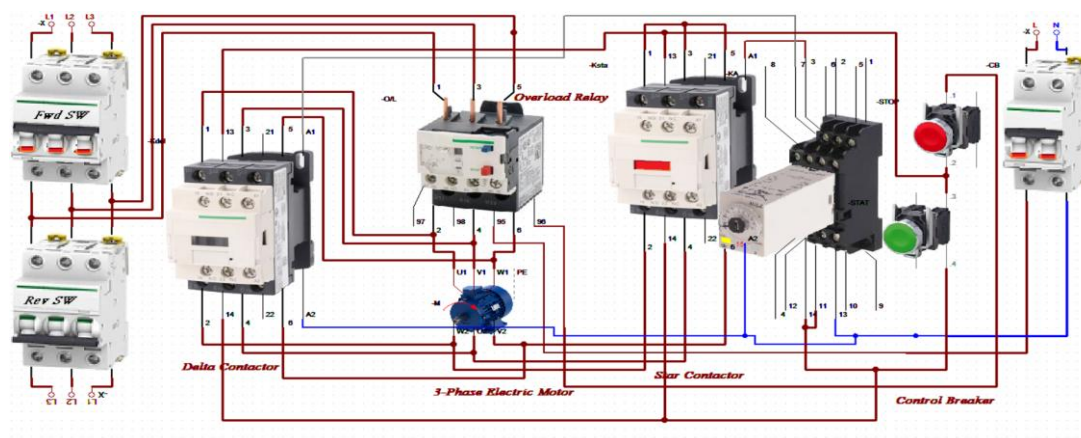


Figure 2.9: The operation or simulation of the motor as Star connected Motor in forward direction.

The operation or simulation of the motor as Delta connected Motor in forward direction is as shown in figure 2.10. Current now flows through the NO Contact of the Timer Relay to the Delta Contactor Coil. The Delta Contactor is now energized to convey power supply to the Electric Motor.

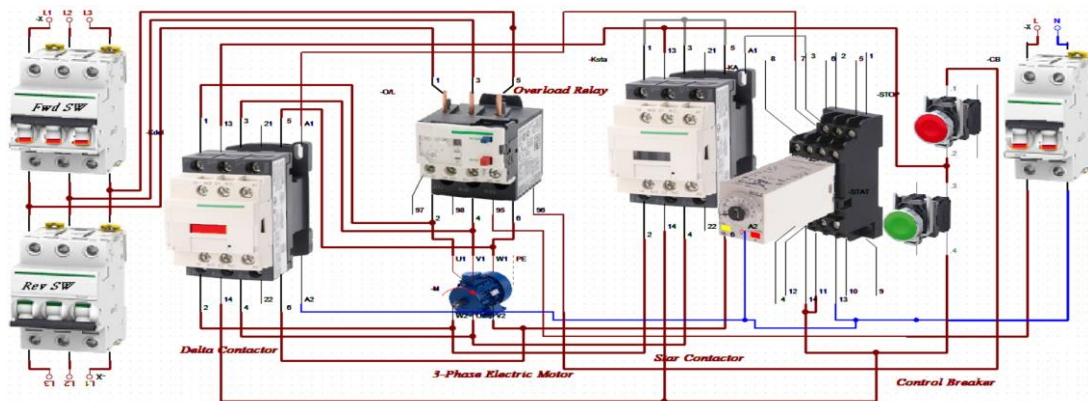


Figure 2.10: The operation or simulation of the motor as Delta connected Motor in forward direction.

The operation or simulation of the motor as Star connected Motor in reverse direction is as shown in figure 2.11. The Star Contactor is now energized to convey power supply to the Electric Motor.

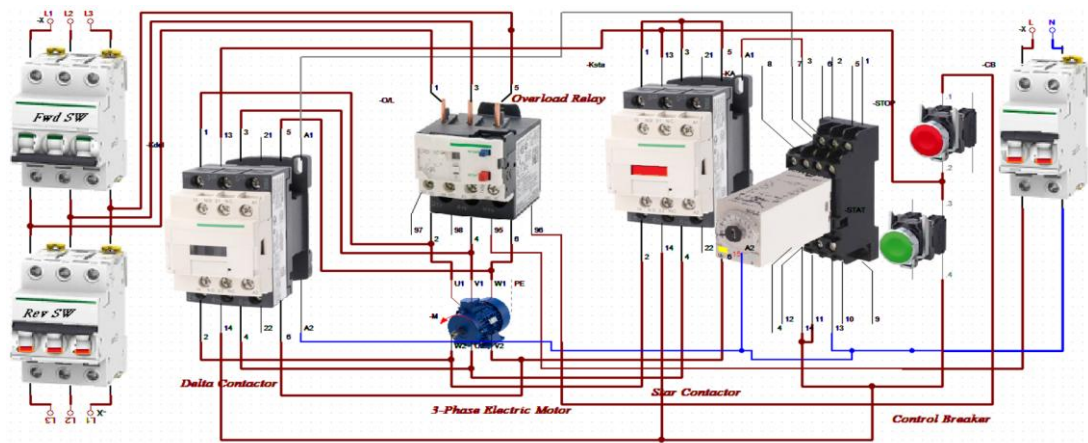


Figure 2.11: The operation or simulation of the motor as Star connected Motor in reverse direction.

The operation or simulation of the motor as Delta connected Motor in reverse direction is as shown in figure 2.12. The Delta Contactor is now energized to convey power supply to the Electric Motor.

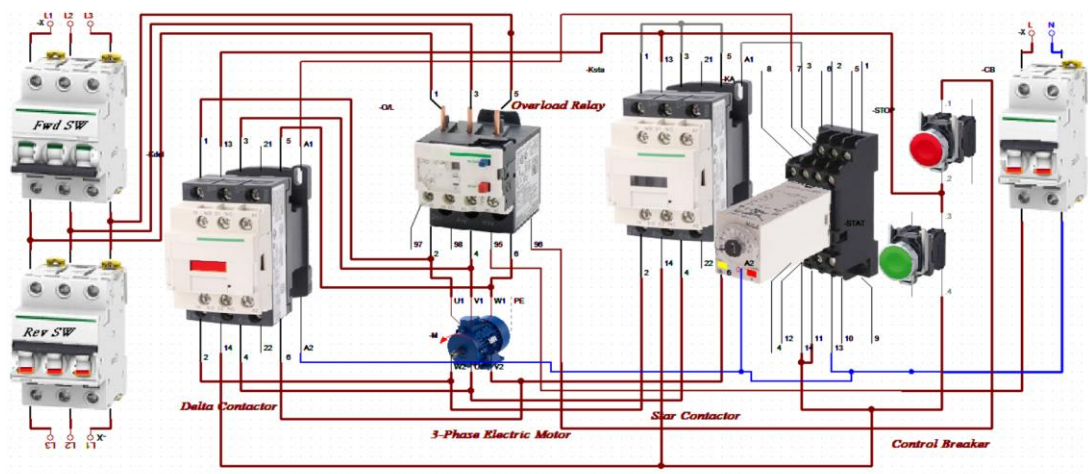


Figure 2.12: The operation or simulation of the motor as Delta connected Motor in reverse direction.

The Selector Switch as shown in figure 2.13 can be utilized to replace the two Miniature Circuit Breakers as used in figure 2.12.

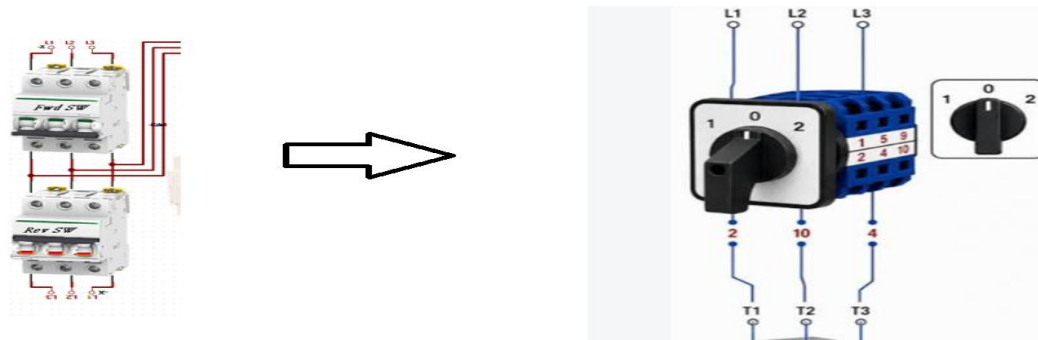


Figure 2.13: Three-Phase Selector Switch

The circuit diagram in figure 2.14 depicts incorporation of Three-Phase Selector Switch. The position (0) is OFF, the position (1) is connected to power supply as Red, Yellow and Blue. At this position '1' the Electric Motor is rotating in clockwise direction. The position (2) is connected to power supply as Red, Blue and Yellow. At position '2' the Electric Motor rotates in anti-clockwise direction.

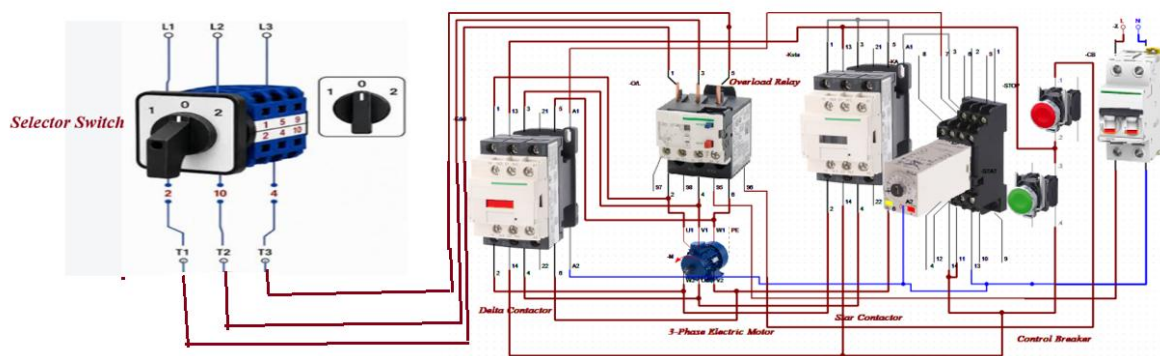


Figure 2.14: Incorporation of the Three-Phase Selector Switch on the modified Star/Delta Starter forward and reverse

4.1.3 Comparative Analysis

The comparative Analysis between the conventional Circuit diagrams and the modified Circuit diagrams for the two type of Starters are as estimated on Table 1.1. The estimated cost was obtained at market survey Kaduna on 30th September, 2026.

Table 1.1 (Kaduna)

Name of Starter	Materials required for the Conventional Circuit diagrams	Materials required for the Modified Circuit diagrams	Estimated Cost of Materials for the conventional Circuit	Estimated Cost of Materials for the Modified Circuit
Forward and reverse Direct-On-Line	(1) Two Contactors (2) Two Start Push Buttons (3) One Stop Push Button (4) Interlocking Contacts (5) One Overload Relay (6) One Miniature Circuit Breaker (7) One Control Breaker	(1) One Contactor (2) One Start Push Button (3) One Stop Push Button (4) 3-Phase Selector Switch. (5) One Overload Relay (6) One Miniature Circuit Breaker (7) One Control Breaker	(1) N2000 (2) N1000 (3) N500 (4) N1000 (5) N1500 (6) N2000 (7) N1500 Total N9500	(1) N1000 (2) N500 (3) N500 (4) N1500 (5) N1500 (6) N2000 (7) N1500 Total N8500

Name of Starter	Materials required for the Conventional Circuit diagrams	Materials required for the Modified Circuit diagrams	Estimated Cost of Materials for the conventional Circuit	Estimated Cost of Materials for the Modified Circuit
Forward and reverse Star/Delta	(1) Four Contactor s (2) One Overload Relay (3) Two Start Push Buttons (4) One Stop Push Button (5) One Timer Relay (6) Interlocking Contacts (7) One Control Breaker (8) One Miniature Circuit Breaker	(1) Two Contactors (2) One Overload Relay (3) One Start Push Button (4) One Stop Push Button (5) One Timer Relay (6) 3-Phase Rotary Switch. (7) One Control Breaker (8) One Miniature Circuit Breaker.	(1) N4000 (2) N1500 (3) N1000 (4) N500 (5) N1500 (6) N1000 (7) N1500 (8) N2000 Total N13000	(1) N2000 (2) N1500 (3) N500 (4) N500 (5) N1500 (6) N1500 (7) N1500 (8) N2000 Total N11000

The circuit diagram in figure 2.15 further demonstrates the reduction of space and numbers of Electrical components between the conventional Star/Delta Starter forward/reverse and the modified Starter.

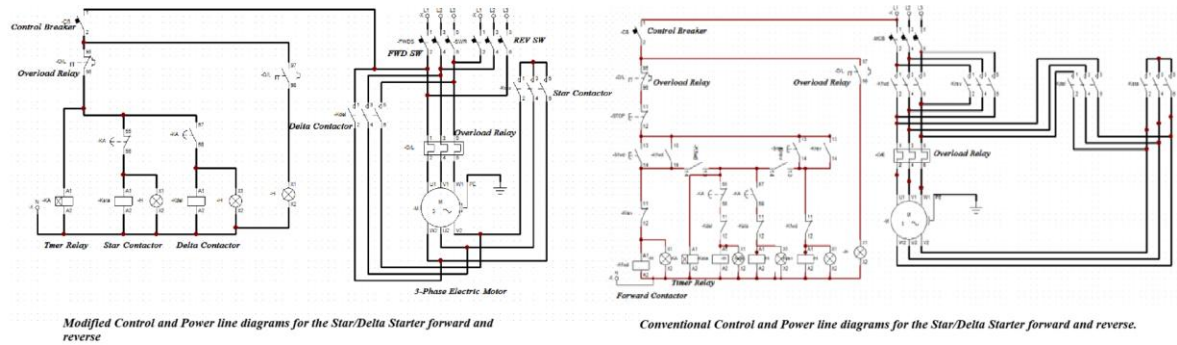


Figure 2.15: Modified and conventional forward and reverse Star/Delta Starter.

4.2 Conclusion

The research work provides another circuit connection schemes to realize the operation of Electric Motor Starters in Industries. The numbers of contactors used in conventional method was reduced. Where it involves two Contactors and two Start Push Buttons for the forward and reverse operations, one Start Push Button and one Contactor with other Electrical components were used. The four Contactors and two Start Push Buttons required for the forward and reverse Star/Delta Starter was equally reduced to two Contactor and one Start Push Button. This has greatly reduced the cost of numbers of Contactors in conventional method as well as reducing the space in the Electrical panel. The four Contactors for the conventional Star/Delta was equally reduced to two Contactors as well. The use of software CADe-SIMU shows the effective performances of the modified Electric Motor Starters. The only limitation with the modification for the forward and reverse DOL is the absence of indicating signal if the Electric Motor is in forward direction or reverse direction.

4.3 REFERENCES

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