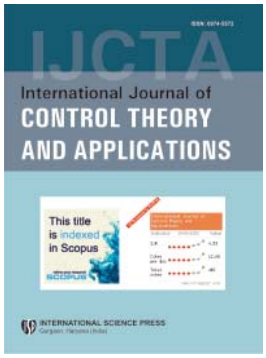

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PLC Based Star - Delta Starter for Three Phase Squirrel Cage Induction Motor

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Abstract: This Paper describes the importance of limiting the starting current and torque at starting of motor. There are different methods of starting of 3-phase Squirrel Cage Induction Motor. However, a star - delta method with programmable logic controller (PLC) is proposed in this paper to start the Induction Motor. In a squirrel cage induction motor, during starting time main & start contactors remain closed and complete the circuit. In Star connected mode, voltage applied is reduced to $1/\sqrt{3}$ of the line voltage across each winding, hence the starting current decreases. When motor attains a rotational speed approximately, say 90% of full rpm, and after few seconds, timer connected in starter disconnects star contactor first and then connects delta contactor. This helps the motor to start run at full load voltage without any difficulty. The process of management of time and controlling of contactors is the function of the PLC. Depending on PLC output, the contactors will get energised. In this paper the hardware set up of 3 phase star - delta starting of induction motor using PLC is proposed and implemented. The flexibility and efficient controllability of PLC helps in effective automation.

Keyword: *Star – Delta Starter, 3-phase squirrel cage induction motor, PLC.*

1. INTRODUCTION

Star/Delta starters are probably the most common reduced voltage starters in 50Hz power world. It is widely known as Wye/Delta starters at 60Hz frequency. They are used in an attempt to reduce the starting current applied to the motor during start as a means of reducing the supply voltage. In this paper, a hardware model is proposed. The main components are as described. The Star/Delta starter is designed by three contactors, a timer and a thermal overload. The contactors are smaller than the single contactor used in a Direct on Line (DOL) starter and they are controlling winding currents only [1]. The currents through the winding are $1/\sqrt{3}$ = 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. Fig.1 describes the basic arrangement and various components used in the model. The rotor of the induction motor has a short circuited secondary of the transformer. Therefore, if normal supply voltage is applied to a stationary motor, then similar to a transformer, a very large initial current is taken by the primary, for a short period of time [2]. This is because; during starting there is no back EMF, to oppose the initial rush-in of the current. So, Induction motors when connected “direct

on-line", draw 5 to 7 times the original full load current. At this time, it develops only 1.5 to 2.5 times the full-load torque [3]. This sudden initial drawing of current by an induction motor leads to heavy undesirable voltage dip which affects the other electrical machineries. Hence, any induction motor, whose rating above 25 kW to 40 kW should not be started direct on-line [4].

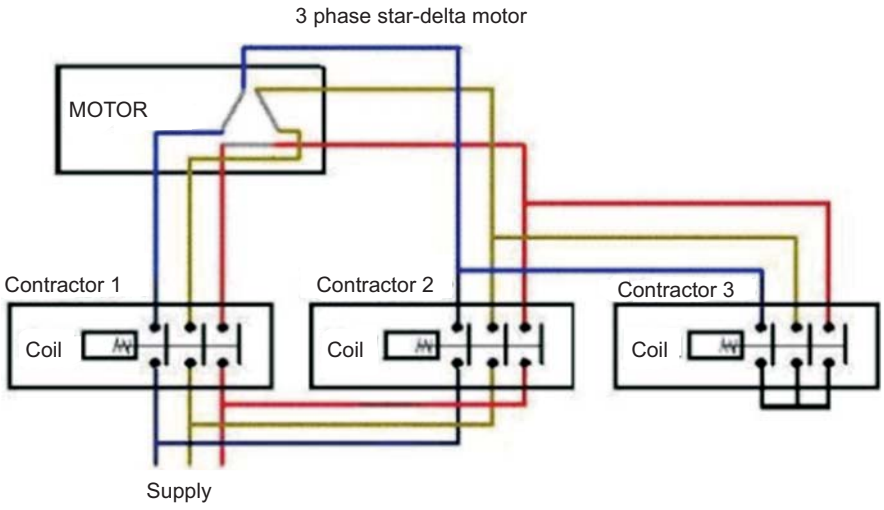

Figure 1: Main circuit diagram used for implementation with PLC

2. DESCRIPTION OF HARDWARE MODEL

The components used for the development of the setup are PLC (Delta company is used), 3 phase squirrel cage Induction motor, power supply, connecting wires, and contactors. The hardware model is depicted in Fig.2.

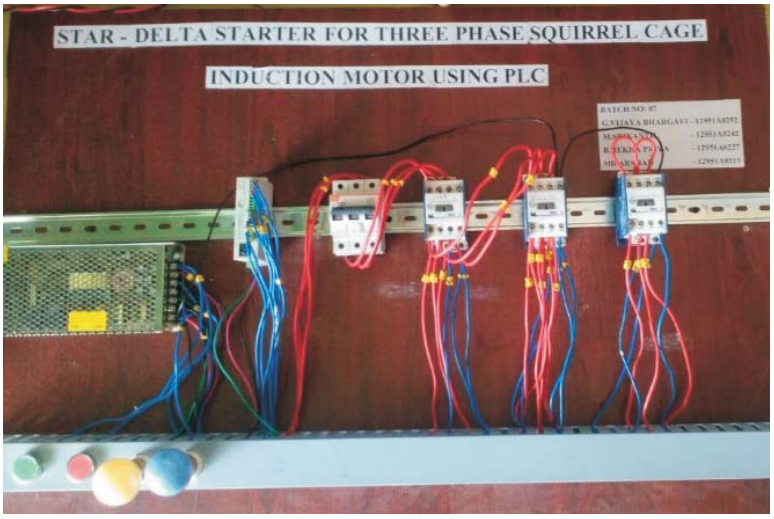

Figure 2: Hardware Setup with PLC

2.1. Delta PLC

The 2nd generation DVP-SS2 series slim type PLC keeps the basic sequential control functions from the DVP-SS series PLC with faster execution speed and enhanced real-time monitoring capability. The snapshot of PLC is shown in Fig.3. The technical specifications are as given below.

Power	:	20.4 to 28.8 VDC
Digital Inputs	:	8 inputs, 24 VDC sink or source
Digital Outputs	:	6 relay outputs
Output Rating	:	1.5A each output
Communication Port	:	RS-232

Figure 3: View of PLC used

The various steps are described herewith.

1. Input Scan, detects the state of all input devices that are connected to the PLC
2. Program Scan, executes the user created program logic
3. Output Scan, energizes or de-energize all output devices that are connected to the PLC.
4. Housekeeping, this step includes communications with programming terminals, internal diagnostics.

2.2. Three Phase Squirrel Cage Induction Motor

A 3 phase induction motor is very popularly used as they are rugged, have low price and easy to maintain. It consists of stator and rotor. In this setup, induction motor of 5HP, 440V, 6.8A, and 1450 rpm is used.

2.3. Contactors

Contactor is a basic component that functions as a switch rather they are advanced form of switches. They are commonly used to control motors and to perform opening/closing operations. Here the contactors are operated through PLCs. It consists of two contact parts- stationary and movable. Whole circuit is connected to the stationary part and the movable part consists of a coil. When the coil is energized the movable contacts are closed against the stationary contacts, and the circuit gets completed. Ordinary relays are normally used for low current but contactors are used for switching operations at higher values of currents. Three contactors of 4 poles, 9 Amp, 400 V are used in the hardware design. The coil specifications are 240 V, 50 Hz.

2.4. SMPS

Switched Mode Power Supply (SMPS) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from source, like mains power to a load, such as a personal computer. Voltage regulation is achieved by varying the ratio of ON-to-OFF time. The higher power conversion efficiency is an important advantage of a switched-mode power

supply. Switched mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight. Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weights are required. They are, however, more complicated; their switching currents can cause electrical noise problems, if not carefully suppressed and simple designs may have a poor power factor.

2.5. MCB

Miniature Circuit Breaker (MCB) is used widely in low voltage electrical networks instead of fuse. The operating mechanism of miniature circuit breaker provides the means of manual opening and closing operation of miniature circuit breaker. It has three positions "ON", "OFF" and "TRIPPED". The external switching latch can be in the "TRIPPED" position, if the MCB is tripped due to over-current. When manually switch off the MCB, the switching latch will be in "OFF" position. In close condition of MCB, the switch is positioned at "ON". By observing the positions of the switching latch, one can determine the condition of MCB whether it is closed, tripped or manually switched off.

3. WORKING PRINCIPLE OF STAR - DELTA STARTER USING CONTRACTOR AND TIMER

There are three states of star-delta starters: *a*. Star Connected State, *b*. Open State and *c*. Delta Connected State. During starting time, main and star contactors remain closed and complete the circuit. In star connected state, voltage applied is reduced to $1/\sqrt{3}$ of the line voltage across each winding. As and when motor attains close to the rated rotational speed, say about 90% of full rpm, after few seconds, timer connected in starter disconnects star contactor first and then connects in delta contactor. Between these two, star connected and delta connected states, circuit becomes open and motor neither remains in star nor in delta state. This is called open transition switching. In delta connected state, voltage applied to windings is equal to line voltage.

Items required to make star delta starter are three contactors (*i.e*. one main contactor, one star contactor and one delta contactor), Over Load Relay (OLR) timer, Fuse Switch Unit (FSU), 2 Pole MCB, Fuse, Start Push Button (NO), 3 Pole MCB, Stop Push Button (NC).

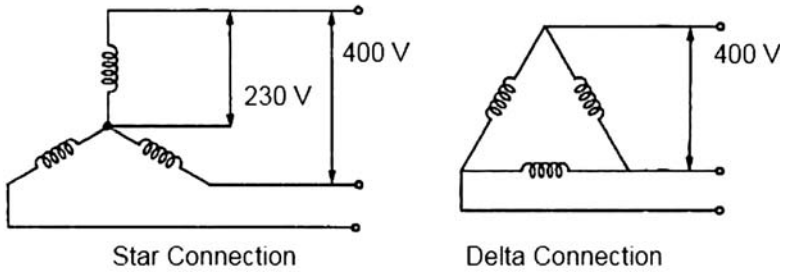

Figure 4: Basic star and delta connections

There are two contactors that are closed during run, often referred to as the main contactor and the delta contactor. These are AC3 rated at 58% of the current rating of the motor [5]. 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 of the motor rating. In operation, the main contactor (KM3) and the star contactor (KM1) are closed initially, and then after a period of time, the star contactor is opened, and then the delta contactor (KM2) is closed. The control of the contactors is by the timer (K1T) built into the starter. The star and delta are electrically interlocked and preferably mechanically interlocked as well. In effect, there are four states: OFF State. All Contactors are open star state. The main and the star contactors are closed and the delta contactor is open. The motor is connected in star and will produce one third of DOL torque at one third of DOL current open state. The main contactor 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 delta contactors are closed. The star contactor is open. The motor is connected to full line voltage and full power and torque are available. This type of operation is called open transition switching because there is an open state between the star state and the delta state.

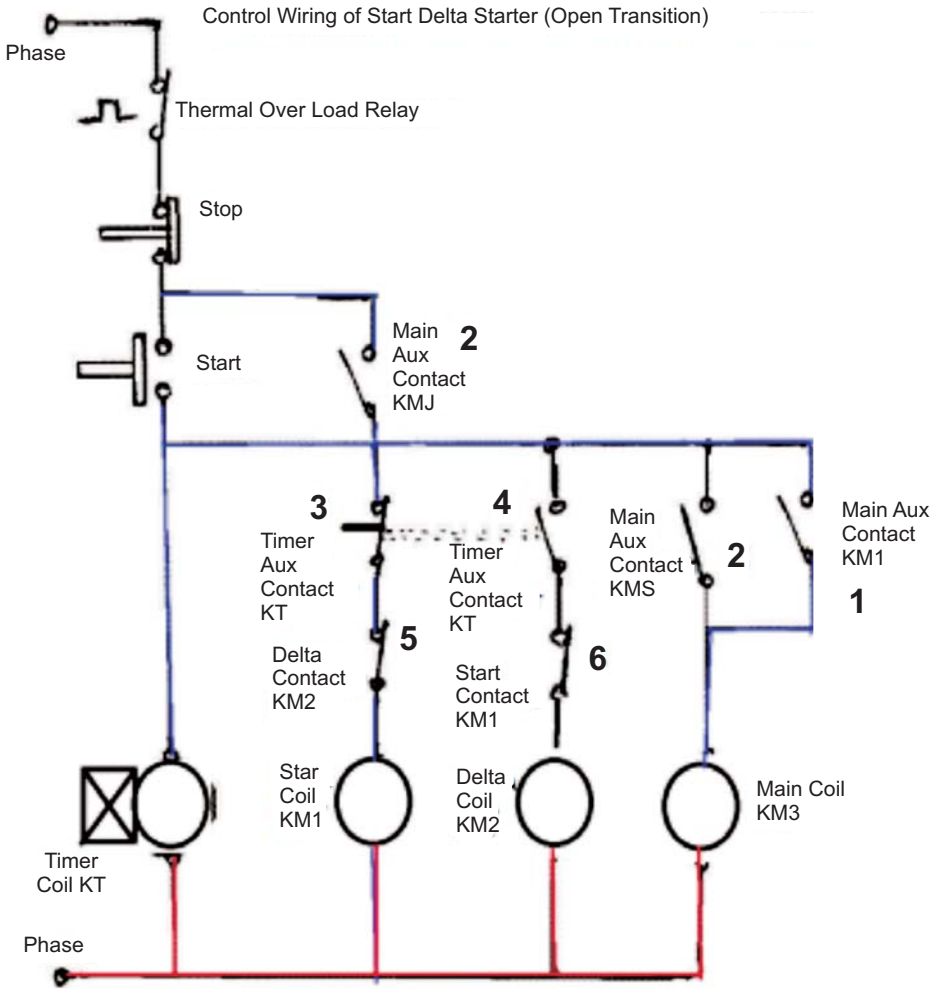

Figure 5: Control Diagram of star delta starting without PLC

4. STAR-DELTA STARTER WITH PLC

The working procedure is as explained below.

1. Connect the 24 V DC SMPS to three phase supply. A multi-meter is connected to measure the line current.
2. Connect the contactors to the stator windings of the induction motor. The windings connections can be plugged to the connection box on the induction motor. The stator must be WYE connected.
3. Connect the tacho-generator to the breaker control unit.
4. Make sure that the torque knob in the brake unit is at minimum, i.e., rotate all the way to the counter clock wise (CCW) direction.

5. Connect the NO and NC switches to the digital input module of the PLC. For each switch, connect one end to 24 V of SMPS, and connect other end to the corresponding input sockets on PLC Basic Unit.
6. Connect the PLC output from the PLC Basic Unit to the Contactor outputs of three contactors are Y0, Y1, and Y2. Connect A2- end of main contactor to zero volt on SMPS.

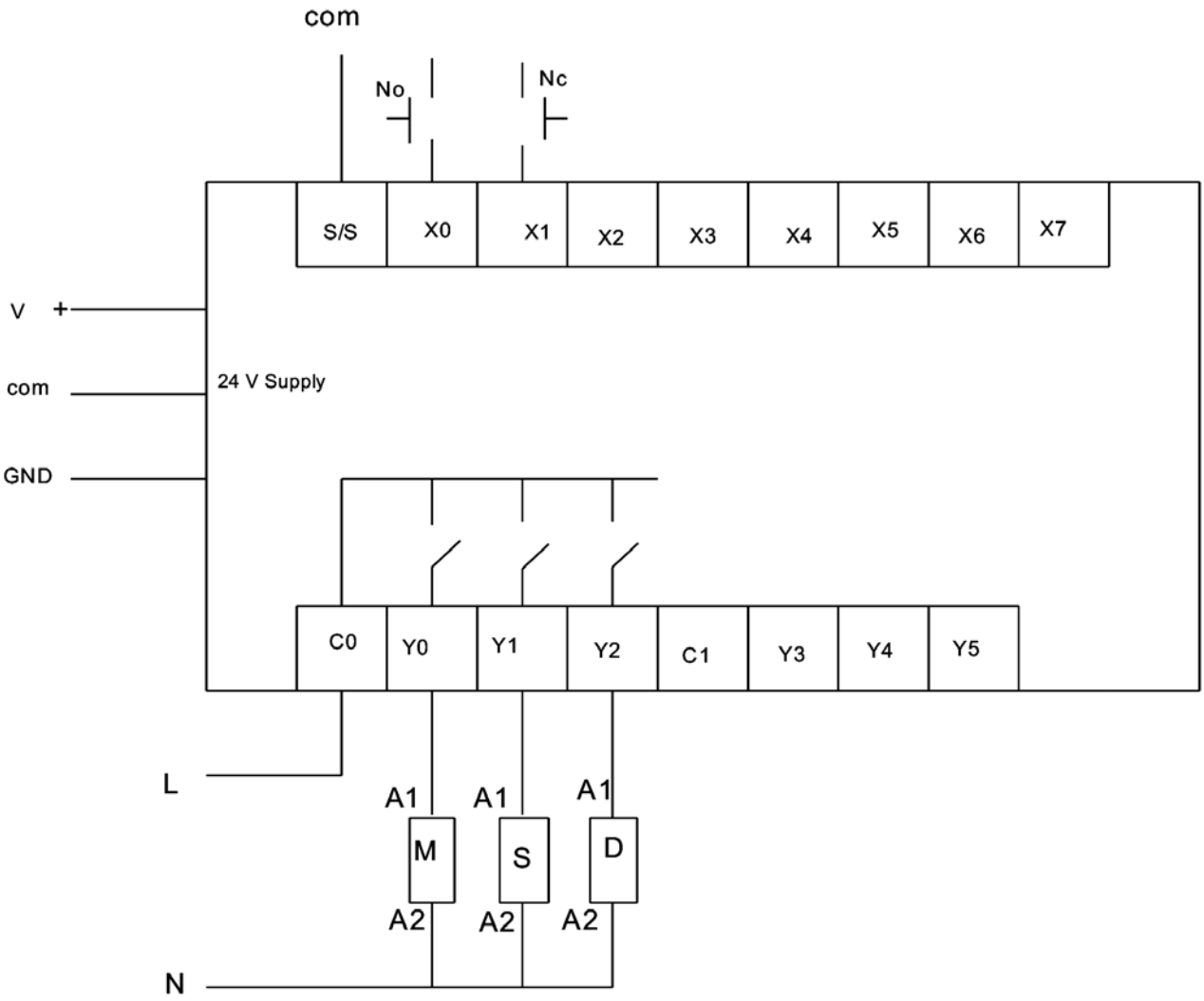

Figure 6: PLC input output connections

In the ladder logic, seen that X0 normally open (NO), X1 Normally opne (NO), timer, main (Y0). Star (Y1), Delta (Y2) contactors are used. WPLsoft is the software used for writing, simulating and running the program. In this software, F1 to F12 provides different functional keys and are present. By using this function keys we write the ladder logic program. In this function keys we used F1 shows normally open F2 Normally closed. F1 and F2 are input variables in this program. F6 has different types of functions like timer, counter, etc… Timer function has numbered with 96 in F6 key. F7 has output variables in this ladder logic. In this program Y0 Main, Y1 Star, Y2 Delta is outputs are connected to 3 Contactors of Main, Star, and Delta respectively. By compiling the program by default END line came. Here Y0 is latched with NO. By pressing No push button main contactor Y0 on while up to NC is pressed.

4.1. Star- Delta ladder logic program

Figure 7: Star delta ladder logic program using PLC

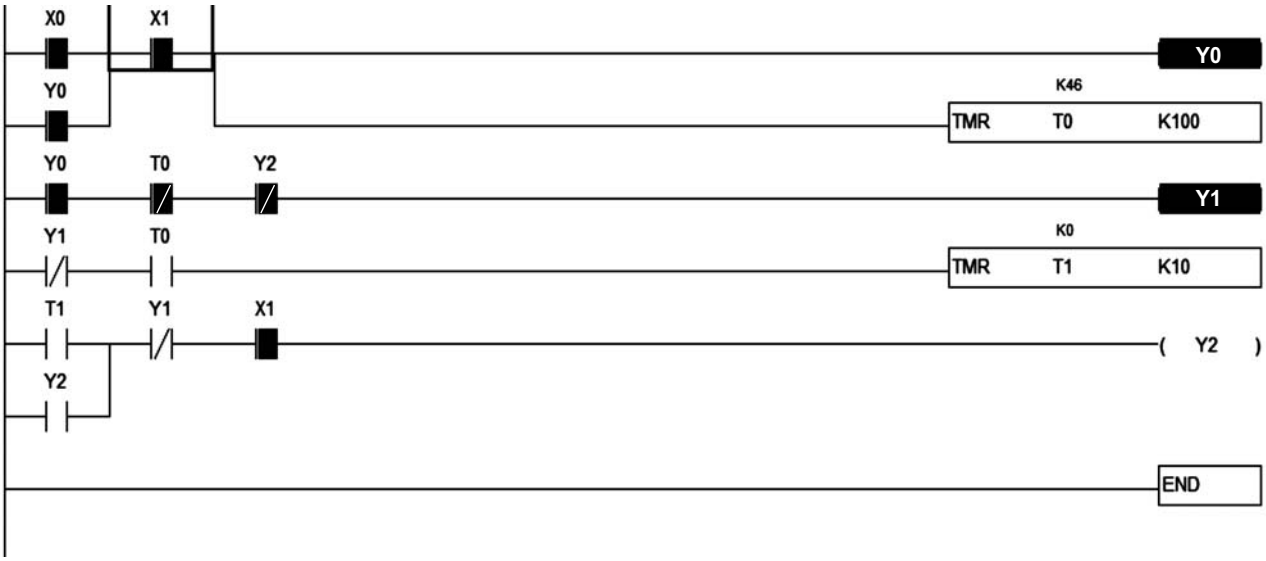

Figure 8: When motor is running condition in star

Now dump the program into PLC debugging program. Go to online mode, RUN the program as seen in Fig 7. In this, green color indicates that they are ON. Timer 0 is running *k*72 shows the num of milliseconds it has run.Y0 is on at a time Y1 is also on.

After timer 0 operation complete for 10 sec Y1 star is open at a timer 1 is ON and starts counting time for delay 1sec, can seen in Fig.9.

After the given delay time, *k*1 sec, motor gets 80% of rated speed after that timer open motor is running in delta mode. *i.e.*; Y2 delta contactor makes ON. It can be seen in Fig 10.

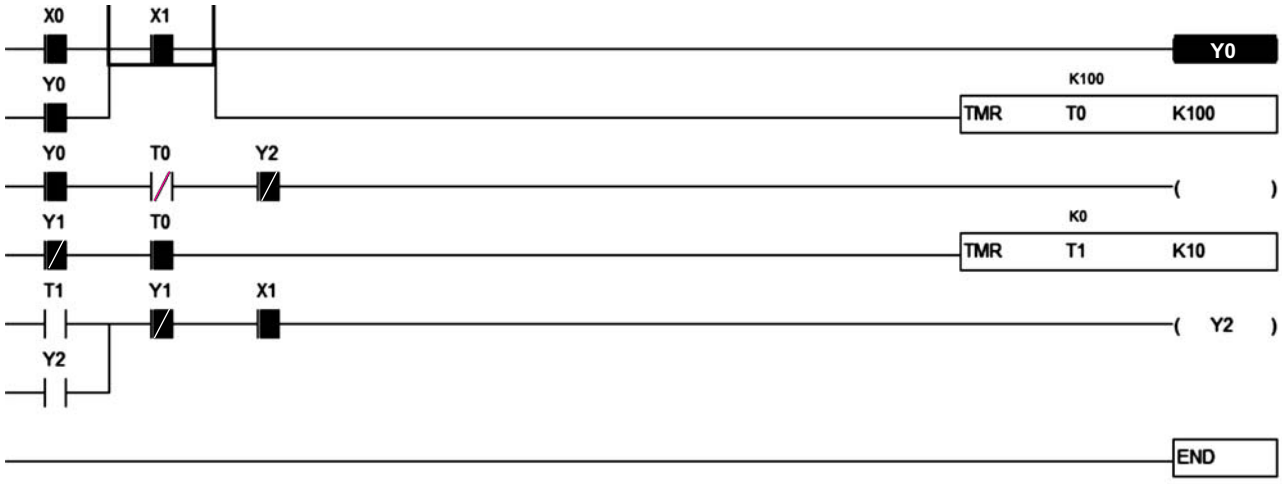

Figure 9: Timer 1 start

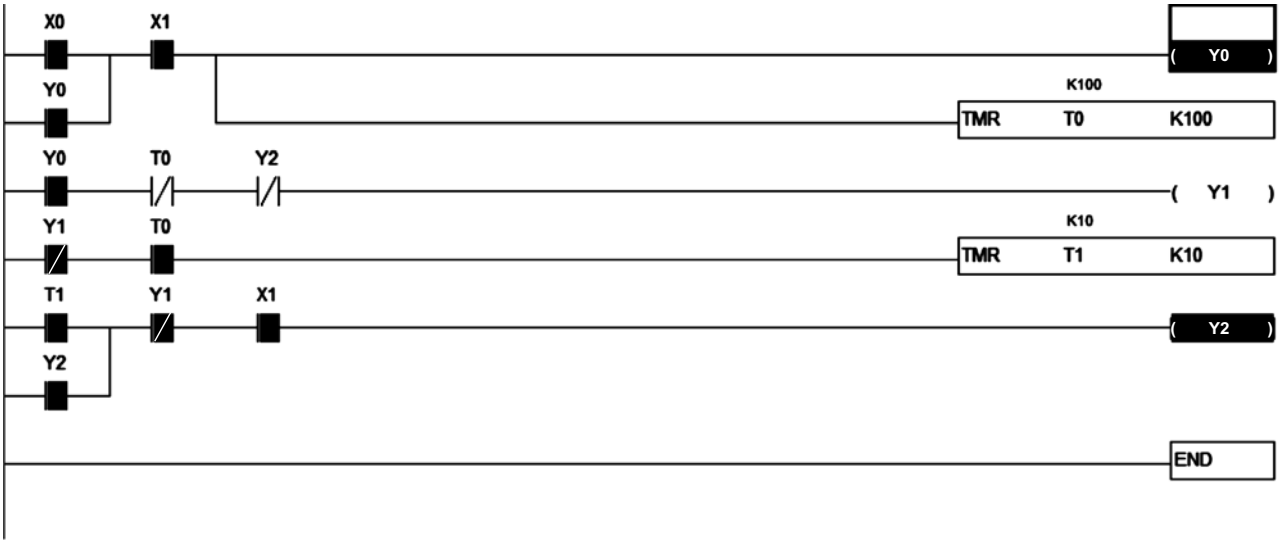

Figure 10: Motor is connected to delta connection

Figure 11: Motor is in OFF

The above fig. 11 shows the when motor is OFF. Motor is running in Delta mode the inrush currents are reduced.X1 normally closed push button is pressed Motor stops running. All contactors are OFF.

5. MOTOR STARTING CHARACTERISTICS OF STAR - DELTA STARTER

The characteristics of star to delta starter characteristics are shown in Fig.12. From the characteristics, it is concluded that:

1. Available starting current: 33% of full load current.
2. Peak starting current: 1.3 to 2.6 full load current.
3. Peak starting torque: 33% full load torque.

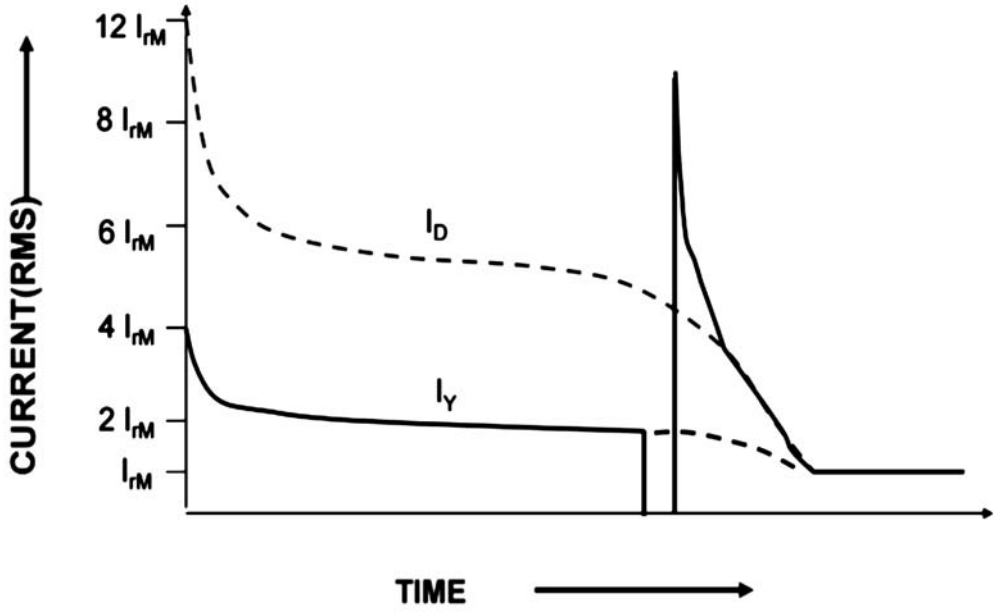

Figure 12: Motor starting characteristics of star-delta starter

6. CONCLUSION

A star to delta starter for three phase induction motor is discussed and implemented with PLCs. A prototype hardware model is built and programmed using ladder programming. By this user friendly starter, more effectively the starting parameters can be controlled of three phase induction motor. The time of contactors to open and close is controlled using timer in the ladder diagram program. It is found that a great flexibility is available in PLC programming as any sort of changes can be done through only changing the prescribed commands in the ladder diagram. Thus PLC has proved to be universal controller and utilized for enhanced automation technology.

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