Design PLC on Induction Motors Using Star-Delta With Manual and Automatic Technique

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Abstract - This journal focuses on induction motor research by paying attention to motor starting. There are several types of motor starting circuits, one of which uses a star-delta circuit. This circuit has advantages, one of which is the connection method that is often used when starting a three-phase induction motor. The delta starting method can reduce power surges when the motor is in the starting position. For the investigation method, the motor can be controlled through several stages, one of which is manual and automatic control. The manual control system is a simple device because it does not have additional devices such as timers. However, manual devices have a weakness, namely the use of manual controls that are widely used with small power, such as lathes. Meanwhile, automatic control has the advantage that the operator's job is a little easier because they simply press a button, while the drawback is that the circuit is more complicated when compared to manual control.
Keywords: Control manual, automatic, star-delta circuit

I. INTRODUCTION

Electric motors are currently widely used, especially in industry. The type commonly used is the AC (alternating current) motor. There are two kinds of AC motor: synchronous and induction. Induction motors are often used in industry in Indonesia, which are 3-phase types. One of the advantages of this type is that it has a relatively affordable price compared to other types, so it is widely available in the market and requires little maintenance. In addition to the advantages, induction motors also have a weakness, namely the rotational performance. where the rotation is difficult to regulate and the starting current is quite high, with a range of 5 times to 6 times the nominal motor current. This 3-phase electric motor control circuit can use PLC. PLC itself has an abbreviation of Programmable Logic Controller, which simply means a control device that can do programming on a logic basis. In addition to the logic basis, a lot of programming can be done by PLCs, such as sequential, timing, counting, and arithmetic requirements that are used to design an automation system [1].

This journal discusses the solution of a motor that uses agitation with the Star-Delta method with automatic and manual techniques. The Star-Delta circuit is basically a manual control circuit and is included in the 3-phase type of electrical installation, mainly used in electrical machines [2]. In this journal, PLC media is also used. The way the technique works for a manual Start-Delta motor is to do it at start, run, and stop. Meanwhile, in the series of automatic techniques, the thing to do is to set a timer on the motor, which has a working method. When the timer has reached the setting time, the configuration automatically changes. With the above problems, the authors take the title "*Design PLC on Induction Motors Using Star-Delta With Manual And Automatic Technique*".

II. RESEARCH METHODS

Electric Motor

An electric motor is a machine capable of converting electrical energy into mechanical energy [3]. The electric motor itself has a fairly simple design where for now electric motors are widely used in industry. Electric motors are widely used both for household appliances and for factory machines. There are two types of electric motors, namely AC (alternating current) electric motors and DC (DC) electric motors [4]. There are two types of AC electric motors, namely synchronous motors and asynchronous motors, while DC motors have three types of DC motors, namely Shunt DC Motor, Series DC Motor, and Compound DC Motor.

Induction Motor

The journal focuses more on discussing induction motors. An induction motor is an electric motor classified as AC that has a working principle based on the induction of a magnetic field between the rotor and stator [5]. In this article, induction motors can be classified into two groups, namely 1-phase induction motors and 3-phase induction motors [6]. A single-phase induction motor is the type of motor that is mostly used for household appliances, such as fans, washing machines, etc. Because the single-phase induction motor has only one winding on the stator, which has operation by supplying 1 phase power. This 1-phase induction motor is the type to turn it on by requiring an

auxiliary device so that it can start. The 3-phase induction motor is the type of motor that is mostly used for industrial equipment, for example, such as water pumps, belt conveyors, compressors, and so on. Because the 3-phase induction motor has a fairly high power capability, a rotating magnetic field can be produced by supplying three very balanced phases. This 3-phase Induction Motor does not need a tool to help it start. Therefore, this motor can start by itself.

Advantages of Induction Motor

In this induction motor, there are many advantages that are obtained. This induction motor is often used in everyday life as well as in industry. This induction motor has advantages such as a very strong and simple construction, so this induction motor has minimal repairs, produces a more constant rotation than others, does not require other tools for starting or igniting the motor, has a price that is practically cheap and has a fairly high capability, has a fairly high efficiency in normal motor conditions, and does not have a brush, so that it produces a small friction loss. This induction motor also has some weaknesses, including the speed is difficult to control, the star current must go through 5 to 7 times for the nominal current.

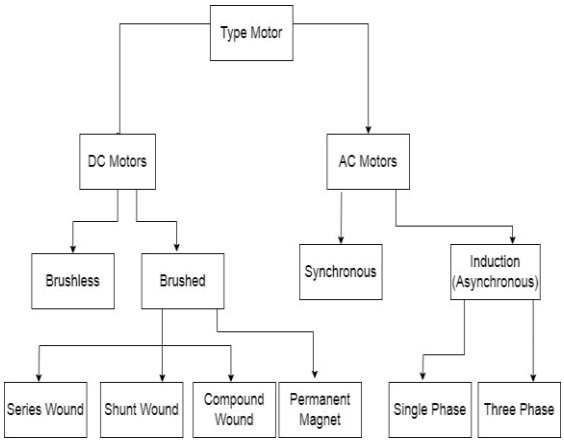

Figure 1. Classification of electric motors [7]

PLC (Programmable Logic Controller)

A PLC is an electronic device that controls the process of input and output signals (digital or analog) on a machine [8]. PLC stands for programmable logic controller, which has the ability to control programs that aim to analyze the input signal, which continues to adjust the output state according to what is desired by the user. The state of the input to the PLC can be stored in a memory where the PLC will give logical commands to the program by following the input state. The tools used at the input usually include photoelectric sensors, push buttons, and limit switches, which aim to create a signal to enter and go through the process to the PLC. In addition, the output device usually includes a switch in charge of turning on the indicator light and a relay that aims to drive a motor with the same goal of moving the output signal from a PLC. When explained in detail, PLC has the meaning of "programmable", which has the concept of being able to adjust according to needs. Logic has a concept of being able to provide work according to algorithms. A controller has a concept of the final result of logic and programs. PLC components include CPU (Central Processing Unit), Memory, Input/Output, and Power Supply [9].

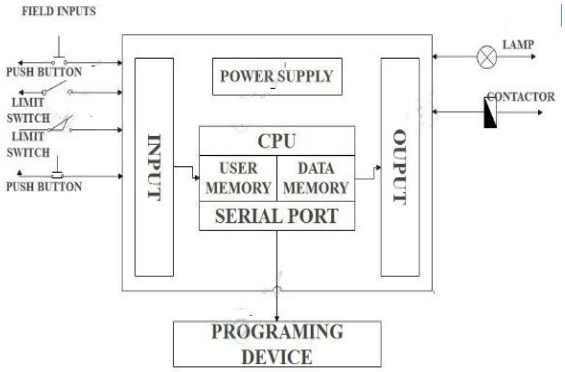

Figure 2. PLC parts

PLC type CP1E

PLC CP1E is a type of PLC that is prioritized by having a low price but still efficient by having input and output and being able to measure temperature. The types of PLC type CP1E as well as differentiators from other types of PLC include the following: the number of I/O (Input and Output), the scan time of the PLC CP1E, the capacity of the program, the type of output (relay), and the type of power used by the PLC (AC/DC). The CP1E PLC has many advantages in terms of ports or in terms of price. Therefore, in terms of ports, there are many types of CP1E PLCs, including: CP1E-E Type (Built-in USB ports), which has 5 ports, each of which has 5 ports. Each has different output and input values. The CP1E-N S1 Type (Built-in RS-232C, RS-458, and USB ports) has three ports, each with a different output and input value; the CP1E-N NA (Built-in RS-232C, RS-485, and USB ports) has four ports, each with a different output and input value. This PLC CP1E has a relatively cheap price, with prices ranging from Rp. 1,500,000 to Rp. 5,700,000. The price is from the lowest type to the highest type, which has its own advantages and disadvantages. The address used for the CP1E PLC starts from 0.00 by looking at the capacity of the CP1E type. For example, if it has 8 capacities, the input will be 0.00-0.07. while the output value starts from 100.00. For example, if the type has 8 DO, then the address starts from 100.00-100.07.

Motor Starting Method

Starting the motor requires a Star-Delta circuit at the starting motor current. When starting, this is useful for reducing current surges and also torque when starting. The Starting Star-Delta has three contactors, namely Main Contactor, Star Contactor, and Delta Contactor [10]. The timer has a working method for switching from Star to Delta as well as an overload relay. Starting at the start, when the starting is connected in a star, the stator winding receives a voltage of 0.578 = (1/3) of the line voltage. Therefore, the current and also the resulting torque will be smaller than the DOL (Direct Online Starter). As it approaches normal speed, the state will switch to Delta-connected. This starting will do a good job when the motor is not under heavy load. The starting motor is a DOL that uses a motor with a power less than 5.5 KW (Kilo-Watt). Star-Delta itself uses 10–90 KW (Kilo-Watt). The voltage on the motor must pass through 2 windings on Star-Delta, with 1 winding on Star 380/3 220V while at Delta voltage, 1 winding of 380V.

How to Work and Understanding Star-Delta Circuit On Starting Motor

The Star-Delta circuit is a circuit that is usually used to operate three-phase motors [11]. In general, the following circuit can be used for single-phase or three-phase electricity. In its own use, it is often used for circuits that have 3 phases. Because a 3-phase electric circuit really requires a large enough power to initiate the movement. Therefore, a 3-phase electrical circuit is in dire need of a Star-Delta type circuit. The Star-Delta circuit itself has a very simple working principle and is quite easy to understand. Here's how the Star-Delta circuit works, namely:

- When the push button is pressed or in the on state, then the voltage is sourced from the MCB, which will flow to the coil.
- Then the contractor's magnetic coil (K1) is connected to the NO terminal on K1. Where later, the tension of the push button off will occur as a lock.
- Next, the timer for the circuit will receive an electric current from the coil terminal K1.
- The voltage at the initial NC comes from the coil, which is then continued to flow to the contactor magnetic coil (K3).
- Then contactor K1 drains the R-S-T voltage to the electromotor coil.
- Next, the K3 contractor connects the terminal for the first time.
- It is in this phase that the network will operate with the Star connection.
- After operating with a low voltage, the timer will make adjustments to make the current more stable.
- Then the NO terminal is connected to the magnetic coils K2 and K3 so that the R-S-T voltage operates for the electromotor coil.
- Then it is at this condition that this circuit connection moves from Star to Delta.
- Then when the push button off is pressed, what happens is that all current will be cut off and the electromotor will stop.

Star-Delta Circuit Advantages

The Star-Delta circuit has its own advantages both on the Star and Delta circuit. Here are the advantages of the connection method that is often used: One of the connection methods that are often used when turning on three-phase induction motors is the delta starting method, which can reduce power surges when the motor is in the starting position. Besides, the connection star has less insulation than the Delta connection, and for the Star connection, the neutral point can be ground. When using unbalanced loads, this can be added and performed to eliminate single phase in the Delta connection, but not in the 3-wire Star connection, which is used by the majority of induction motors.

III. RESULT AND DISCUSSION

Star-Delta Key Components

1. Push Button to OFF
2. Push Button to ON 1 to turn on the motor in the Star condition
3. Push button for ON 2 to start the motor in Delta (Triangle) condition
4. 3 pieces of magnetic contactor that function Main Contactor (KU), Contactor for Start connection (KS), Contactor for Delta connection (KD)
5. Multiple jumper cables
6. And other components such as panel boxes, cables, omega rails, ducks if you want to put them into the panel.

As for the following component specifications, such as for pushbutton ON 2, special specifications are needed where the pushbutton has 1 NO contact and 1 NC contact as shown below

For the main contactor (KU) requires 1 NC contact with notation 21-22 and 2 contacts NO with notation 13-14 and 43-44. Meanwhile, Delta (Triangle) contactors require 1 NO contact (13-14) and 1 NC contact (21-22).

Star-Delta Circuit Principles

1. Based on the circuit picture above, if pushbutton ON 1 is pressed for a moment then electric current will flow to the main contactor (KU)

while turning on the Star contactor (Star). In this condition, the 3-phase electric motor works in a star state.

2. If the time interval is sufficient to switch from the Star to Delta connection, then simply press the Push button ON 2 with a rather strong force because the Push button ON 2 has 2 roles at the same time which functions to disconnect and connect the electric current.
3. After enough time for the electric motor to turn on or if you want to turn off the circuit, simply press the OFF push button and the electric motor will stop. The Star-Delta series is equipped with interlock protection designed to overcome the possibility of "Human Error" due to negligence, namely when turning on the electric motor by pressing the ON 2 push button accidentally, the electric motor will not turn on while the ON 1 push button has not been pressed.

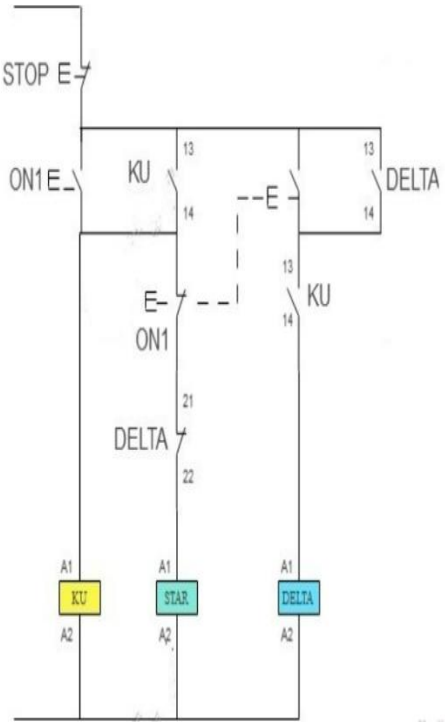

Figure 3. Desain wiring circuit manual star-delta circuit

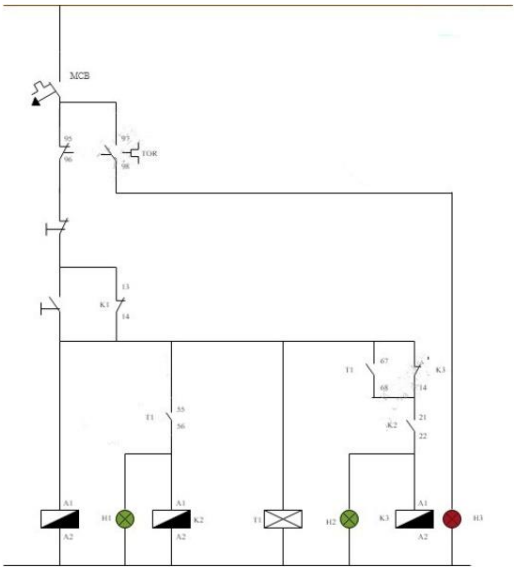

Figure 4. Desain wiring circuit automatic star-delta circuit

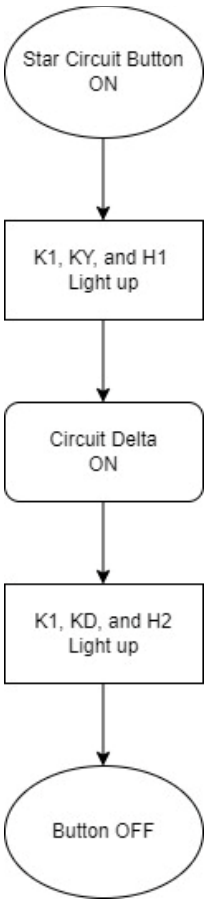

Figure 5. Flowchart of the working principle of star-delta manual

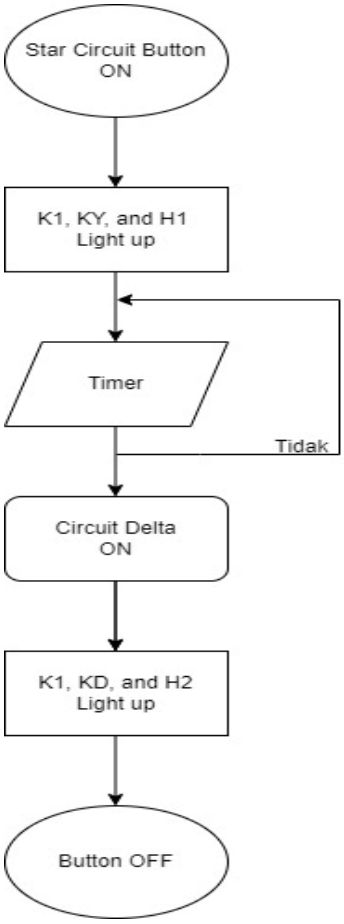

Figure 6. Flowchart of the working principle of automatic star-delta

Manual and Automatic Star-Delta Diagram Ladder

This chapter focuses on the explanation of automatic and manual star delta circuits in cx programmers and cx designers. In this series, the star to delta transfer is manual or you could say it is a change using the action of the user.

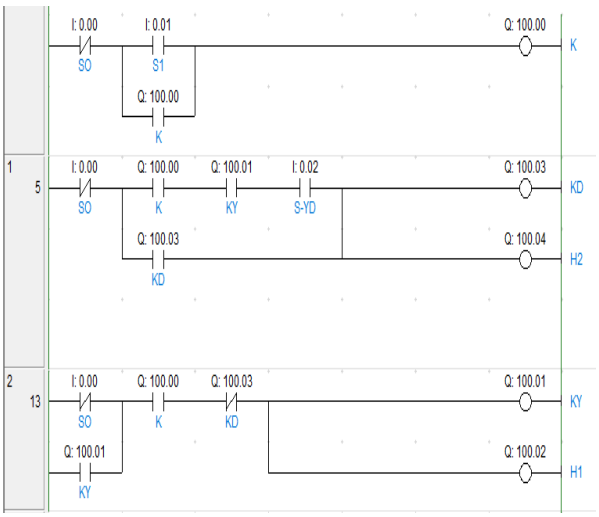

Figure 7. Deain ladder star-delta manual

The picture above is the arrangement of the circuit in the manual star delta in the cx programmer. The following table addresses the manual star delta circuit in the cx programmer.

Table 1. Manual star-delta addressing table

NO	COMPONENT NAME	ADDRESSING
1	PUSH BUTTON STOP	0.00
2	PUSH BUTTON START	0.01
3	PUSH BUTTON MANUAL	0.02
4	CONTACTOR	100.00
5	CONTACTOR STAR	100.01
6	LAMPU INDICATOR STAR	100.02
7	CONTACTOR DELTA	100.03
8	LAMP INDICATOR DELTA	100.04

How Manual Star-Delta Circuit Works

1. When the push button start is pressed, the contactor will lock, then the contactor contact will also directly turn on the star contactor and the star indicator light.
2. When the star contactor and the star indicator light are on, the star contactor will automatically lock the contacts of the star contactor.
3. When we want to change the circuit to delta then we have to press the manual push button then the delta contactor and the delta indicator light will automatically turn on, and the delta contactor will lock the contacts from the delta contactor and the star contactor will automatically turn off so the Star delta will automatically.

In this circuit, the star to delta transfer is automatic or you could say it is a turn using a timer.

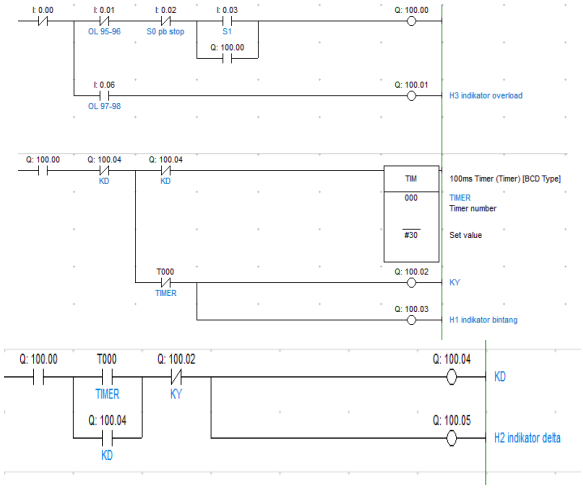

Figure 8. Deain ladder automatic star-delta

The picture above is the arrangement of the circuit on the automatic star delta in the cx programmer. The

following table addresses the automatic star delta circuit in the cx programmer:

Table 2. Automatic star-delta addressing table

NO	NAMA KOMPONEN	PENGALAMATAN
1	MCB	0.00
2	CONTACT OL 95-96	0.01
3	CONTACT OL 97-98	0.06
4	PUSH BUTTON STOP	0.02
5	PUSH BUTTON START	0.03
6	CONTACTOR	100.00
7	LAMP INDICATOR OL	100.01
8	CONTACOR STAR	100.02
9	LAMP INDICATOR STAR	100.03
10	TIMER	TIM 000 #30
11	CONTACTOR DELTA	100.04
12	LAMP INDICATOR DELTA	100.05

How Automatic Star-Delta Circuit Works

When the push button start is pressed, the contact of the contactor will lock the push button start. After that the star contactor, star indicator light, and timer will light up and the timer will count down for 3 seconds. When the timer has been counting down for 3 seconds, it will automatically turn on the delta contactor and the delta indicator light, and will turn off the star contactor.

CX Star-Delta Designer Manual and Auto

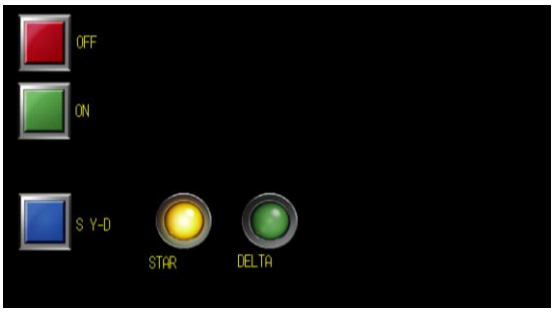

Figure 9. When the star turns on manual method

Figure 10. When delta is On

When the push button start is pressed, the star indicator light will light up, indicating that the star contactor is lit. When the manual push button is pressed, the delta indicator light will light up, indicating that the contactor of the delta is lit, and the star indicator light will automatically turn off after the delta indicator light is on.

Figure 11. At the time automatic star

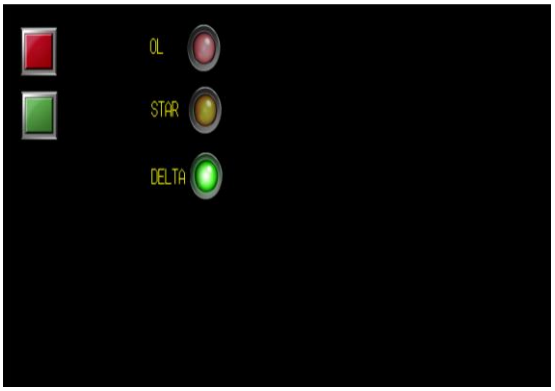

Figure 12. At the time auto delta

When the push button start is pressed it will turn on the star indicator light and also turn on the timer that has been set to count down for 3 seconds. After the timer counts down for 3 seconds, the delta indicator light will turn on and the star indicator light will automatically turn off after the delta indicator lights up.

A Table of Test Results That Show The Weaknesses/Strengths Of Each Design

In electric engine control, several types can be classified, which can be seen from the motor instigation method as follows [12]:

1. DOL (Direct On Line)
2. Star-delta
3. Soft Starter
4. Variable Frequency Drivers

In this paper, we discuss the star-delta method by controlling it manually and automatically. Here are the advantages and disadvantages of each design[13,14,15].

Table 3. The weaknesses/strengths of each design

Manual		**Automatic**	
Strengths	Weaknesses	Strengths	Weaknesses
There is a push button to turn the star to delta circuit on.	To turn on need to press the button to start.	The operator's work is a little lighter because they simply press a button.	The circuit is more complicated than the manual.
There is no need to use additional timer components to run the circuit.	The operator who operates it must exert a strong force.	More efficient and economical than manual circuit.	The need for more maintenance than manual.
The manual star-delta circuit is simpler.	The use of manual control is widely used with small power for example lathes.	Can be applied in the automotive industry.	An additional component is required, namely the timer.

IV. CONCLUSIONS

In this study there are several conclusions obtained, namely by using manual and automatic circuits there are several advantages and disadvantages, one of which is when using a manual it is simpler and the drawback is that it is only used in small power so it is not suitable to be applied in industry. While the advantages of the automatic circuit that the operator is easier because it is enough to press the start and turn off button, while the disadvantage is that the automatic circuit is more complicated when compared to manual.

In addition, PLC CP1E is a type of PLC that prioritizes low prices but is still efficient by having input/output and being able to measure temperature. The Star-Delta starter motor uses 10 until 90 KW (Kilo-Watt).

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