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Three Phase Induction Motor Rotation Direction Control Using PLC Omron CP1E and HMI NB7W-TW00B

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Abstract
Rotation direction control on three-phase electric motors is very much needed in industry as driving machines such as mixers, grinders, conveyors, and transportation machines. This study proposes controlling the rotational direction of a three-phase induction motor automatically using an Programmable Logic Control (PLC) Omron CP1E which is connected to the Human Machine Interface (HMI) NB7W-TW00B. The HMI NB7W-TW00B provides timing instructions to the PLC to change the direction of rotation of the induction motor. To provide safe operation of the induction motor due to changes in the direction of rotation, the PLC control was given a delay of 1 to 4 seconds. The results show that a delay of 1 to 4 seconds provides a linear reduction in speed before the motor rotates in the opposite direction.
Keywords: Three Phase Induction Motor; PLC Omron CP1E; HMI NB7W-TW00B; Safe Operation; Rotation Direction Control;

Introduction
Three-phase induction motor is an electric motor that is commonly used in industry because the price is relatively cheap compared to other types of electric motors and low maintenance costs. Three-phase induction motors are used for conveyor driving machines and other equipment that requires alternating directions of rotation. Rotation direction control becomes an important requirement for this problem.

A sudden change in the direction of rotation of the induction motor can cause damage to the induction motor. This is because there is a rotating field that is opposite to the power supply while the motor is still rotating in the direction of the previous rotating field. This sudden change in the direction of rotation can also shorten the service life of the induction motor. To avoid this, it is necessary to give a time delay before the rotating field of the power supply is reversed.

Programmable Logic Control (PLC) is a control technology with logic principles to reduce maintenance costs and replace relay-based engine control systems. Currently, almost all industries, both small and large, that require process control for system operation are already using PLC for process control. PLC can be programmed to control the process or operation of the machine. Control program on the PLC to analyze the input signal and then adjust the output state according to the target to be achieved. PLC has advantages as a control device, which can be easily changed the control system circuit and is more flexible in the control circuit compared to relay-based control circuits. PLC has a principle like a computer so that if there is a disturbance in the control system, the operator can track the disturbance of the control circuit more easily. One of the most popular and easy to program PLCs for control system purposes is the PLC Omron CP1E.

The use of interface software such as Graphical User Interface (GUI) can provide convenience to the control system. Human Machine Interface (HMI) is a GUI-based interface that can be connected to a PLC to make it easier for operators to understand the work of the control system on the PLC. HMI provides a number of information related to the control process on the PLC. To be able to provide effective information, the HMI must be designed visually so that it is easier for the operator to deal with problems or controls needed for the process. The HMI NB7W-TW00B is a touchscreen HMI. HMI NB7W-TW00B is one type of HMI that can be connected to PLC Omron CP1E via serial communication using RS-232 cable.

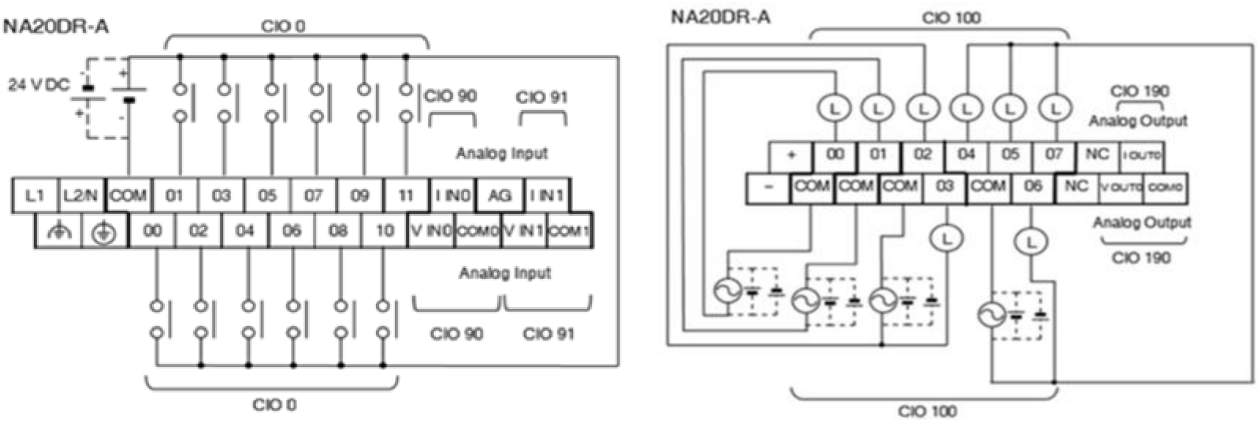
This study aims to realize a three-phase induction motor rotation direction control system using the Omron CP1E PLC which is equipped with an HMI NB7W-TW00B touchscreen interface. The presentation of this research includes the introduction in the first part, followed by a literature review in the second part, in parts three and four are the research methodology and results & discussion. The last part is the closing which contains the conclusion.

Literature Review

The application of three-phase induction motors is quite a lot, among others: as an elevator/lift driver (DEVIANTO, 2021), as a generator (Alim et al., 2019), as a transferring driver on a green tire building machine (Hendarto & Triyana, 2014), as a driving force electric cars (Purwanto et al., 2011). The application of three-phase induction motors is quite a lot because of the relatively low price, easy operation and low maintenance costs (Nasution et al., 2020).

Three-phase induction motors are widely needed as drives that can be easily controlled for changes in rotation direction. Induction motor rotation direction control is widely applied to conveyor systems or conveyor belts (Syafrudin & Hasibuan, n.d.). Several studies on designing control of the direction of rotation of induction motors such as reverse starting of a three-phase induction motor based on an SMS controller using the Bascom programming language (Denis et al., 2013), three-phase motor control rotating right and left using arduino uno and bluetooth module HC-06 (Kurnianto, 2019), the circuit of turning the right and left of the forward reverse electric motor using a relay circuit (Wahyudi, 2020), design of a PLC-based star-delta connection three-phase induction motor rotation direction control system (Sihombing, 2008), realization of PLC Omron CP1E based three-phase induction motor control system (Rahmansyah & Satriadi, 2015), three-phase induction motor control using Arduino Mega based on Human Machine Interface (Mariani & Hastuti, 2020), and design of three-phase induction motor control and IoT-based monitoring system (Syahreja, 2018).

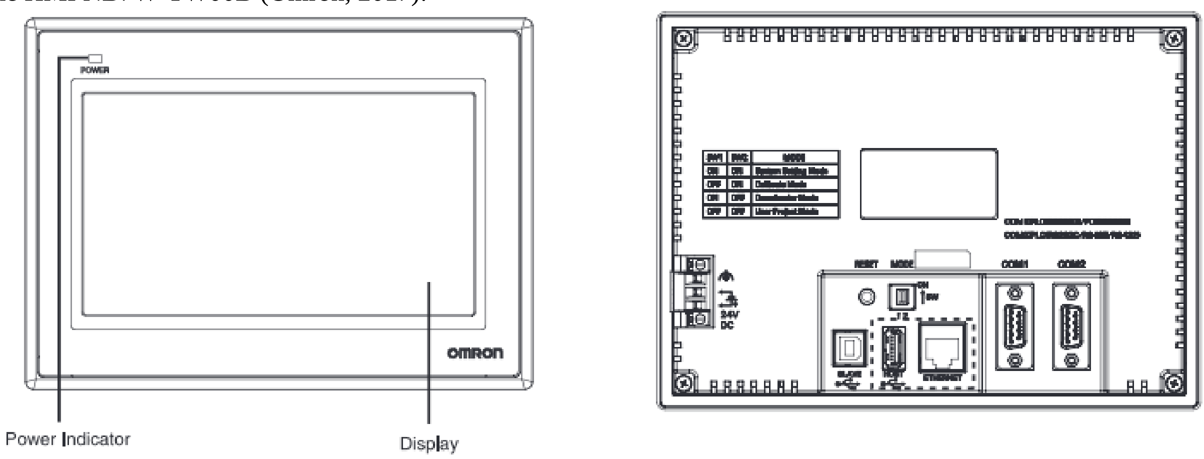
PLC is very popular from the beginning of its development because it can replace relay-based control functions. The relay-based control circuit has a complex circuit and requires a large cost to change the control function. PLC is widely used to control the direction of rotation on DC motors such as the design of the tool for controlling the direction of rotation of the DC motor power windows based on the Panasonic PLC using the Human Machine Interface. (Alfitri & Setiono, 2016), PLC application as a regulator of the direction of rotation of dc motors to drive PMS in miniature substations (Aripin & Moediyono, 2013). PLC which is quite popular and widely used is Omron PLC type CP1E. Figure 1(a) and (b) are the input and output wiring of the PLC Omron CP1E (Maulana, 2022).



(a) Wiring Input (b) Wiring Output

Figure 1. PLC Omron CP1E

HMI as a human and machine interface. HMI is designed as a visualization medium to make it easier for operators to operate the control system. HMI has a touch screen facility so that the operator can give instructions to the control system by pressing a button or inputting data through the GUI on the screen. HMI designs can use a microcontroller coupled with a TFT screen. One of the HMIs that support PLC Omron is the HMI NB7W-TW00B. Figure 2 is a display of the HMI NB7W-TW00B (Omron, 2017).



(a) Front view (b) Back view

Figure 2. HMI NB7W-TW00B

Materials & Methods

This study uses tools to create and test the control system under study. These tools are listed in Table 1. There are 5 tools such as a computer, multimeter, drill, combination pliers and screwdriver.

Table 1. Research tools

No	Tool's name	Amount	Remarks
1	Computer	1	The computer specifications are Intel Celeron, 4GB RAM and 1T HDD with windows 10 operating system. Computer to program PLC with CX-Programmmer software and HMI with NB-Designer software.
2	Multimeter	1	Voltage and current measuring device.
3	Drill	1	Tool for punching holes in acrylic boards where control equipment is placed
4	Combination pliers	1	Tool for stripping and cutting wires.
5	Screwdriver	1	Tools for wiring and fastening bolts.

The material requirements for realizing a three-phase induction motor rotation direction control system are tabled in Table 2.

Table 2. Research material

No	Material name	Amount	Remarks
1	1 phase MCB	1	Max current 6A, max voltage 400V, breaking capacity 6000 A.
2	3 phase MCB	1	Max current 16A, max voltage 400V, breaking capacity 6000 A.
3	Contactor	2	600V contact voltage, 32A contact current, 220V coil voltage, 50 Hz coil frequency.
4	Thermal Overload Relay (TOL)	1	Current 32A.
5	Cable	10 meters	Type NYAF 2.5 mm2.
6	Push Button	3	1. Stop button. 2. PB 1 start button. 3. PB 2 start button.
7	Indicator Light	4	1. Stop indicator. 2. Yellow indicator 2 pieces. 3. Red indicator 1 piece.
8	PLC Omron CP1E	1	This PLC has 12 inputs and 8 outputs.
9	DC Power Supply	1	24V power supply.
10	3-phase AC Power Supply	1	AC source for 3-phase Induction motor.
11	3-phase Induction Motor	1	Capacity 400/230 V, 0.45/0.78 A, 0.12 kW, cos phi 0.68, 1380 rpm, 50 Hz.
12	HMI NB7W-TW00B	1	GUI for control PLC
13	Acrylic Board 50cm x 50cm	1	Material for component base.

The research step begins with making a power circuit for a three-phase inductive motor, followed by making a rotation direction control circuit using a relay circuit. After the rotation direction control works as it should, it is continued by replacing the relay circuit with a PLC. PLC is programmed using CX programmer software. The programming language of the CX programmer is the diagram leader. Before being uploaded to the PLC, the leader control program in the direction of rotation is tested to determine if the program works according to the instructions given (clockwise or anti-clockwise rotation). The HMI is programmed to build a visualization of the rotation direction control system in a GUI format. The HMI is programmed using NB Designer. The HMI is connected to the PLC via RS323 serial communication. The operator can give instructions to the three-phase induction motor for the direction of rotation and setting the delay time for changing the direction of rotation through the HMI by touching the button on the HMI screen and inputting the numerical value for the desired delay time. The steps of this research are described in the research flow chart Figure 3.

The research flowchart at Figure 3 part A is the preparation and data collection stage and making a power circuit for a three-phase induction motor. Part B is to design a control circuit for the direction of rotation of an induction motor using a relay circuit. Part C is to design an induction motor rotation direction control circuit using PLC-HMI. Part D is a discussion of the results and conclusions.

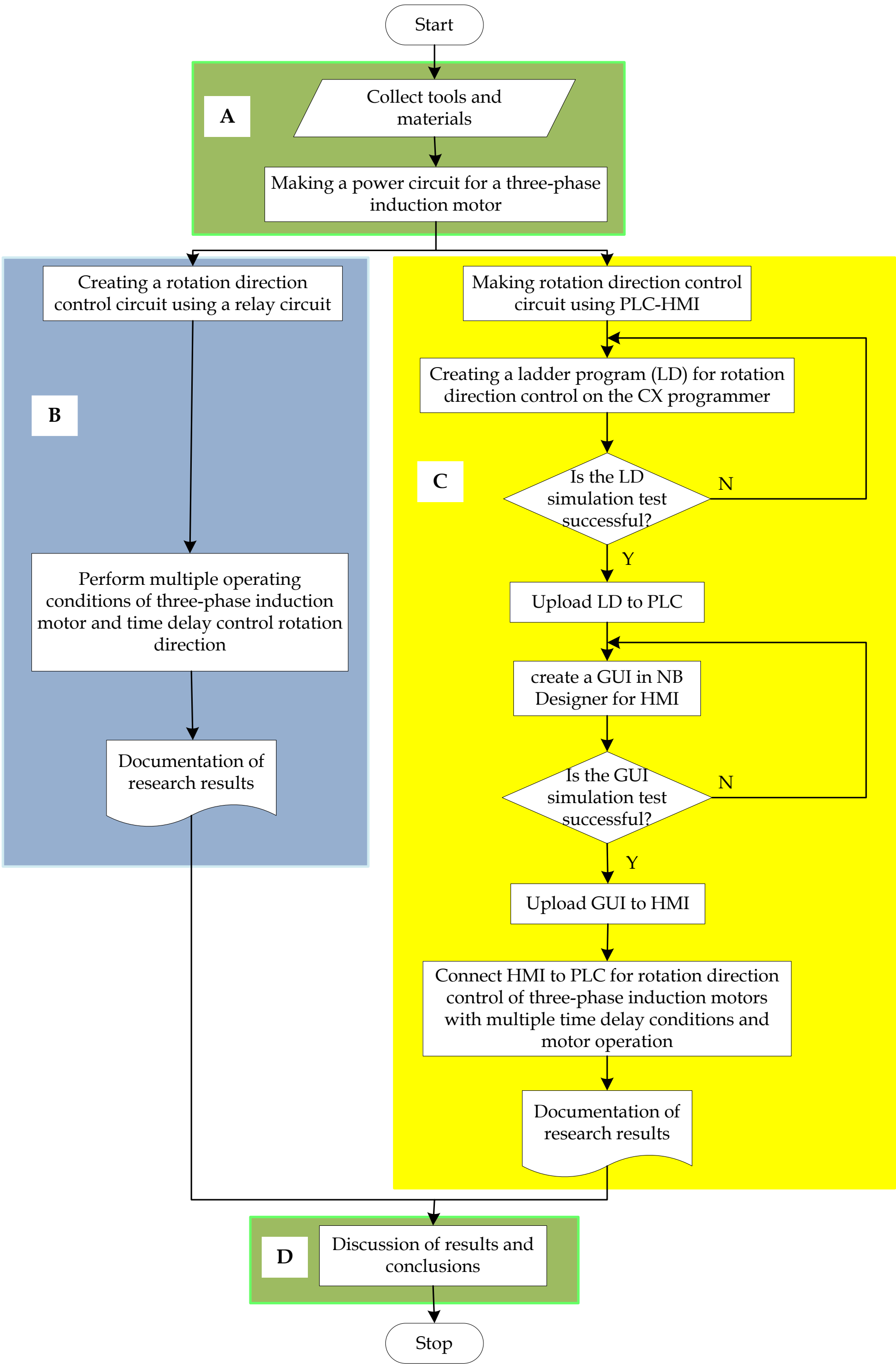


Figure 3. Research flow chart

Results and Discussion

The direction of rotation of a three-phase induction motor can be reversed by reversing one of the polarities of the incoming voltage to the motor. If the first contactor works in the order that the voltage R S T enters the motor sequentially R-U1, S-V1, and T-W1 then the motor rotates to the right (clockwise). If the second contactor works, then the polarity of the voltage R S T entering the motor is reversed to T S R, so that the order of the voltages entering the motor becomes T-U1, S-V1, and R-W1 and the motor rotates to the left (counterclockwise). Safety thermal overload relay is installed after the contactor to protect the motor from overload current. Figure 4 is a three-phase induction motor power circuit to control the direction of rotation.

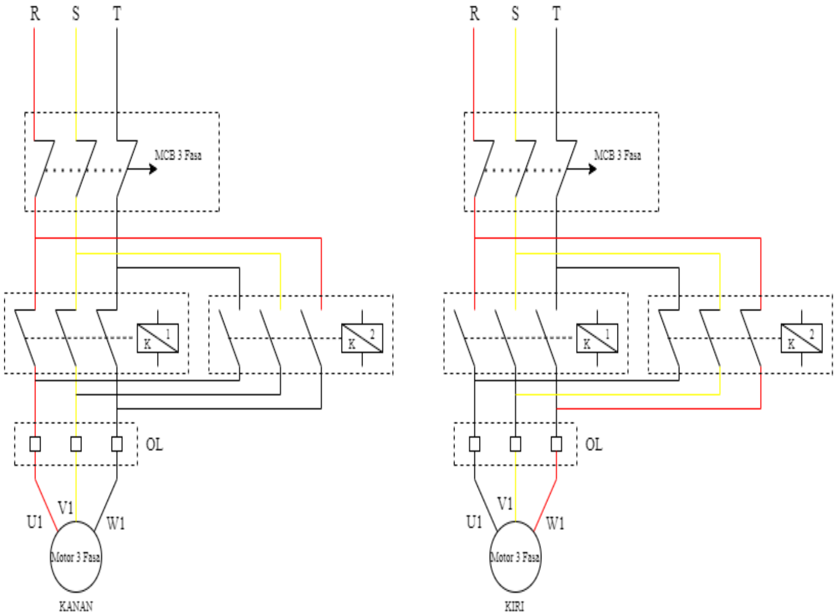


Figure 4. Three-phase induction motor power circuit for rotation direction control

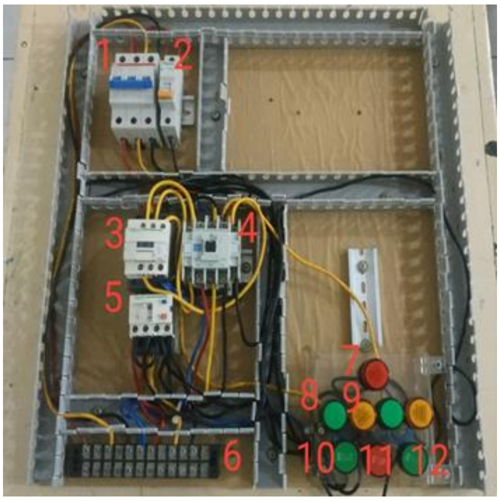


Figure 5. Physical form of a three-phase induction motor power circuit for rotation direction control

The description in Figure 5 is as follows: no. 1 is a 3 phase MCB, no. 2 is a 1 phase MCB, no. 3 is the first contactor, no. 4 is the second contactor, no. 5 is Thermal Overload Relay, no. 6 is the in terminal for 3-phase power supply and the out terminal for three-phase induction motor, no. 7 is an emergency indicator, no. 8 is the rotation indicator to the right (clockwise), no. 9 is the rotation indicator to the left (counterclockwise), no. 10 is the first pushbutton (pushbutton start then right rotation of the relay circuit), no. 11 is the second pushbutton (pushbutton for left rotation of the relay circuit), and no. 12 is the third pushbutton (pushbutton for three-phase induction motor stop).

The ladder diagram designed in the CX programmer software is shown in Figures 6 and 7. The program logic of the ladder diagram is simulated to obtain the appropriate rotation direction control. The first pushbutton starts the active motor coil, then the active time delay calculates the delay time to zero seconds, followed by the first active contactor coin to turn the induction motor to the right (clockwise). Figure 8 is the program logic of the ladder diagram that functions properly after the second pushbutton is given a high condition so that the coil for rotation of the motor to the left is active to turn the motor in the direction of rotation to the left (counterclockwise). Figure 9 is the simulation result of the third pushbutton given a high condition so that the motor coil stops active to turn off the operation of the three-phase induction motor. After the simulation of the ladder diagram to control the direction of rotation of the three-phase induction motor is successful, then the program is uploaded to the PLC using a serial cable.

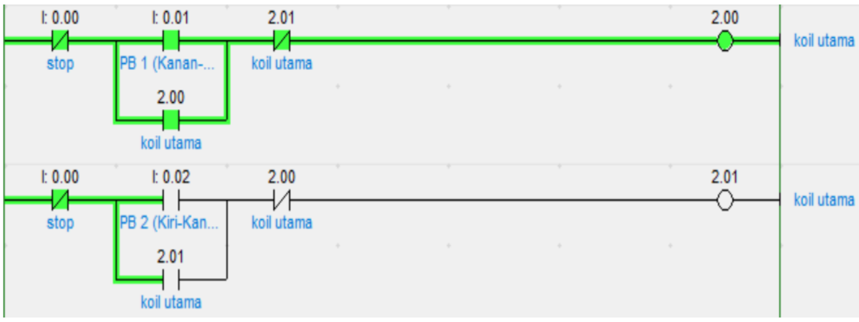


Figure 6. Simulation of the first pushbutton given high condition

Figure 7. After the time delay is met the induction motor rotates to the right

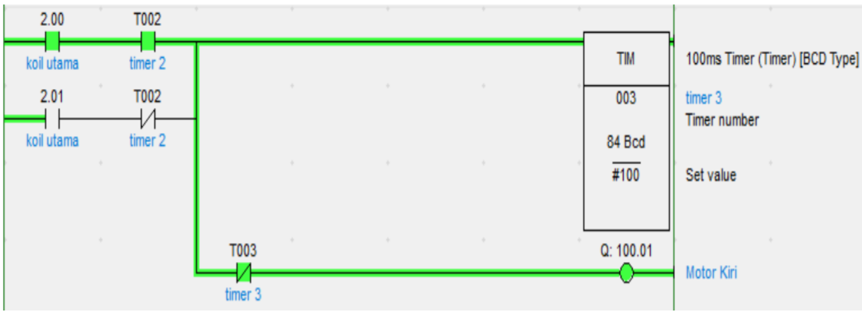


Figure 8. After the time delay is met the induction motor rotates to the left

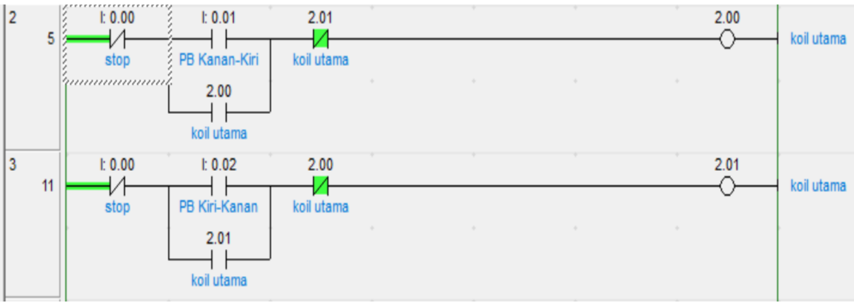


Figure 9. The third push button is given a high condition to stop the operation of the three-phase induction motor

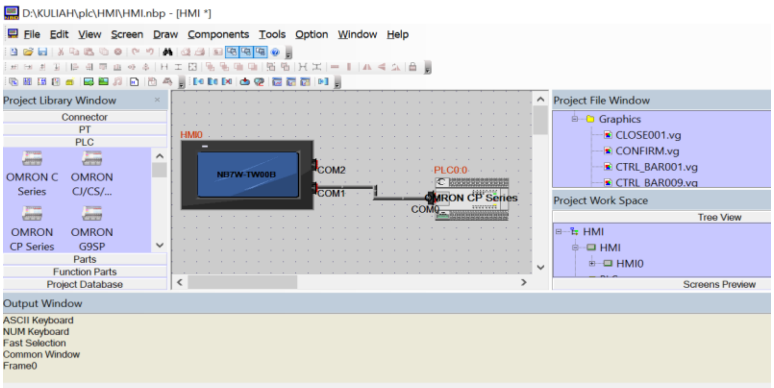


Figure 10. Setting the HMI connection to the PLC

The HMI connection to the PLC is set up in the NB Designer software so that the PLC Omron CP1E recognizes the instructions given by the NB7W-TW00B HMI. Figure 10 is the setting of HMI to PLC in NB Designer software. Set the address for each input/output and the input delay time of the NB7W-TW00B is adjusted to the address on the ladder diagram. The first pushbutton with address 0.01, the second pushbutton with address 0.02, and the third pushbutton with address 0.00 to stop or reset the program. The timer set is assigned the address TIM 001 for the delay in the direction of rotation to the right, TIM 003 for the delay in the direction of rotation to the left. The coil output is 100.00 for the direction of rotation to the right (first contactor) and 100.01 for the direction of rotation to the left (second contactor).

The complete hardware of the PLC-HMI control system for controlling the direction of rotation of a three-phase induction motor is shown in Figure 11. Numbers 1 to 12 in Figure 11 have the same description as Figure 5. Numbers 13 to 17 can be described as follows: no. 13 is the delay indicator, no. 14 is the right-left pushbutton, no. 15 is pushbutton stop, no. 16 is the left-right pushbutton, and no. 17 is the HMI NB7W-TW00B.

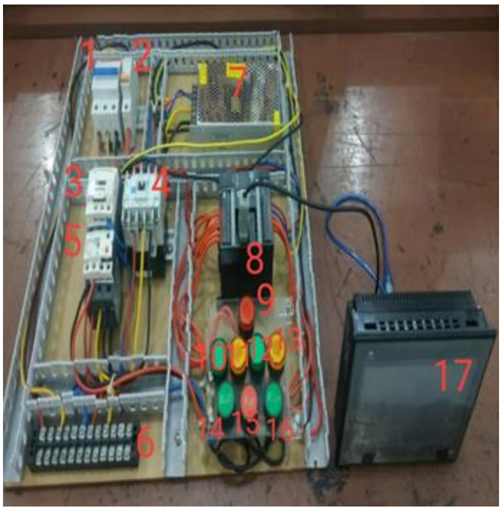


Figure 11. PLC-HMI control system for three-phase induction motor rotation direction control

The results of controlling the direction of rotation of a three-phase induction motor using a relay circuit are shown in Table 3. The results of measuring voltage, current and rotational speed in the right and left directions have the same results.

Table 3. The results of the control of the direction of rotation of the three-phase induction motor by the relay circuit

Rotation Direction	Phase Voltage (V)	Max. Current (A)	Steady Current (A)	Rotation Speed (rpm)
Right (Clockwise)	218	0,69	0,45	1300
Left (Counter Clockwise)	2018	0,69	0,45	1300

Measurement of the performance of an induction motor using a PLC–HMI can be tabled in Table 4. Simulations can be performed by inputting delay and start times in the GUI on the touchscreen HMI NB7W-TW00B as shown in Figure 12. Operators can set varying delay times to test the performance of the direction control of rotation of the PLC-HMI. Table 4 shows some variations of changes in delay time from 1 to 4 seconds. Motor operation is set 10 seconds before the direction of rotation is reversed. The results of the induction motor speed measurement for the left and right directions, such as one second delay time is 1000 and 1100 rpm, two second delay time is 500 and 700 rpm, three second delay time is 200 and 350 rpm, four second delay time is 50 and 50 rpm. This result shows that the best time delay before the induction motor rotation direction is reversed is 4 seconds. This is because at a time delay of 4 seconds the reversed direction of rotation of the motor does not give a shock to the motor due to the resistance of the rotating field from the source.

Figure 12. The operator can input the delay time before pressing the pushbutton start on the screen

Table 4. The results of the control of the direction of rotation of the three-phase induction motor by the PLC-HMI

Rotation Direction	delay/ operation time (s)	Phase Voltage (V)	Max. Current (A)	Steady Current (A)	Rotation Speed (rpm)
Right	10	218	0,7	0,45	1350
Delay time	1	0	0	0	1100
Left	10	218	0,75	0,46	1350
Delay time	1	0	0	0	1000
Right	10	218	0,7	0,45	1350
Delay time	2	0	0	0	700
Left	10	218	0,75	0,46	1350
Delay time	2	0	0	0	500
Right	10	218	0,69	9,45	1350
Delay time	3	0	0	0	350
Left	10	218	0,69	0,45	1350
Delay time	3	0	0	0	200
Right	10	218	0,69	0,45	1350
Delay time	4	0	0	0	50
Left	10	218	0,69	0,45	1350
Delay time	4	0	0	0	50

The graph in Figure 13 shows a decrease in motor speed for changes in time delay before the rotating field from the power supply to the motor is changed by PLC-HMI control. Linear speed decrease with increasing delay time. The graph in Figure 11 shows the time delay above 4 seconds is the safest time delay to reverse the direction of a three-phase induction motor.

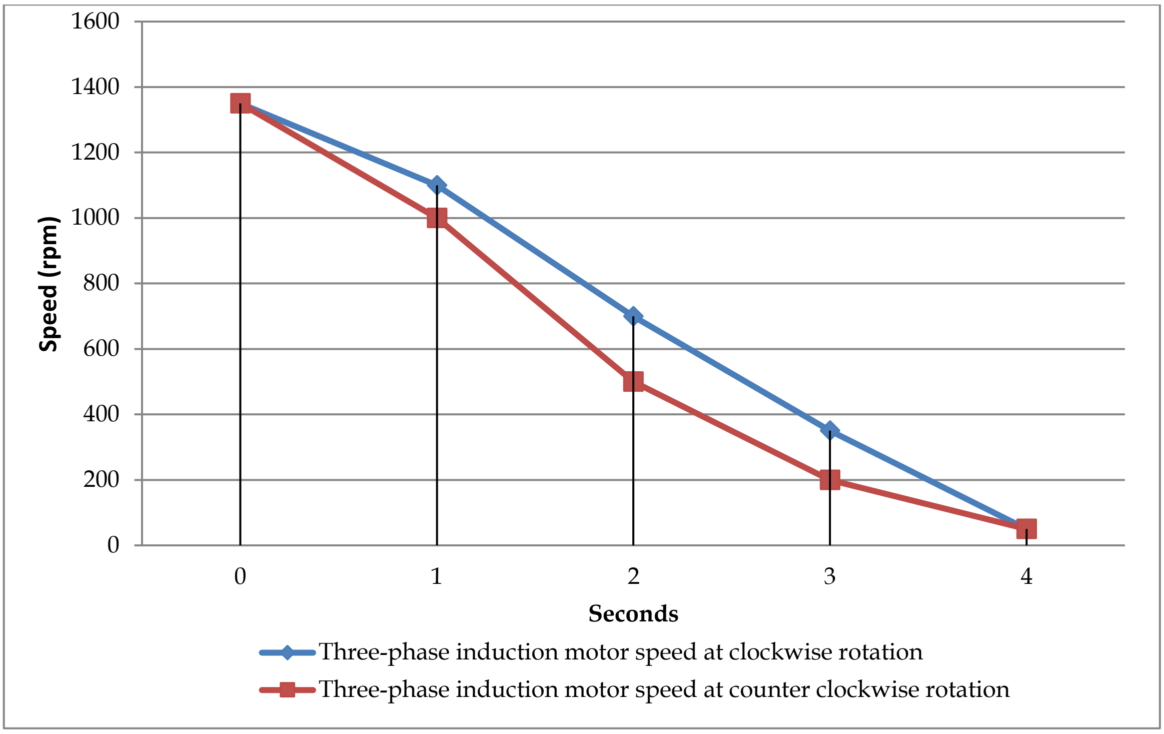


Figure 13. The graph of the relationship between the rotational speed of a three-phase induction motor and delay time

Conclusions

HMI NB7W-TW00B as an interface on PLC Omron CP1E control system to control the rotation direction of a three-phase induction motor. Setting the time delay for changing the direction of rotation and operating instructions for the three-phase induction motor can be done easily using the GUI on the HMI NB7W-TW00B via the touchscreen. The results showed that the best time delay setting to control changes in the rotation direction of a three-phase induction motor was greater than 4 seconds.

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