

# Design of a Control Model for A 3-Phase Asynchronous Ac Motor

Ha Le Thi Thu <sup>(1)</sup> Nguyet Le Thi Minh <sup>(2)</sup>

<sup>(1)</sup> Faculty of Electrical Engineering, Thai Nguyen University of Technology, Vietnam

<sup>(2)</sup> Faculty of Electrical Engineering, College of economics and techniques Thai Nguyen, Vietnam

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## Abstract

During the industrialization and modernization of the country, automation plays an increasingly important role in production lines and industrial control systems. The application of Programmable Logic Controllers (PLCs) has become a popular trend due to its flexibility, high reliability, and easy scalability.

Three-phase asynchronous motors are widely used in industry because of their simple structure, durability, and high efficiency. In actual production, the need to reverse the motor's rotation direction frequently arises, especially in conveyor systems, lifting equipment, machine tools, etc. Therefore, the research and design of a PLC-based reversing control system for three-phase motors is extremely necessary and highly applicable.

Based on the above practical requirements, this paper focuses on researching PLC technology solutions to build an experimental control model for a three-phase asynchronous AC motor, meeting the criteria for stability and safety in operation.

A Programmable Logic Controller (PLC) is a specialized digital control device used in industry, developed to replace traditional relay logic control systems. The operating principle of a PLC is based on collecting signals from input devices, processing data according to predefined algorithms in memory, and outputting control signals to corresponding actuators.

In a three-phase asynchronous motor reversing system, the PLC acts as the central controller. The device receives control signals from function buttons (forward operation, reverse operation, and system stop). Based on the input signal state and the programmed logic structure, the PLC will output signals to activate or deactivate the power contactors, thereby changing the phase sequence and precisely controlling the motor's direction of rotation.

PLC applications offer numerous technical advantages over traditional methods, including: high operational reliability in harsh industrial environments; flexibility in configuring and expanding control algorithms; the ability to simultaneously integrate protection and safety interlock functions; and optimized hardware architecture by minimizing signal wiring.

## I. Overview of PLCs.

## II. Main equipment using model design



Figure 1: Equipment used in the model

The Mitsubishi FX3GA-24MR PLC belongs to the FX series of PLCs from Mitsubishi and is widely used in small and medium-sized automatic control systems. The Mitsubishi FX3GA-24MR is a programmable logic controller capable of receiving signals from input devices, processing them according to a programmed sequence, and outputting control signals to output devices such as contactors, intermediate relays, and indicator lights.

A three-phase asynchronous motor is an AC electric motor that operates on the principle of electromagnetic induction between the rotating magnetic field of the stator and the induced current in the rotor. This motor is widely used in industry due to its simple structure, durable operation, high efficiency, and reasonable cost. In this model, the three-phase asynchronous motor used is a 4K71B4 motor with a power of 0.55 kW, a frequency of 50 Hz, a rotational speed of 1390 rpm, and an efficiency of  $\eta$  70%.

The CHINT NXR-25 thermal overload relay is used to protect three-phase asynchronous motors from overload. The device has an adjustable current range from 17 to 25 A, is mounted directly after the contactor, and interrupts the control circuit when the current exceeds the permissible value.

The CHINT NXC-09 contactor is a switching device used to control three-phase asynchronous motors with a rated current of 9A. It has 3 main contacts and 2 auxiliary contacts (1 NO, 1 NC), suitable for motor control and protection circuits in industrial systems.

The LRS-60-24 switching power supply is used to convert 220V AC to 24V DC to supply the control circuit. With a power of 60W and a maximum output current of 2.5A, it ensures stable and safe power supply for devices such as PLCs, relays, and sensors.

The  $\varnothing$ 22 mm LED indicator lights are mounted on the panel of the electrical cabinet to display the system's operating status. The lights come in various colors such as red, yellow, and green to distinguish operating status, warnings, and faults, making it easy for operators to observe and troubleshoot.

### III. Design of power and control circuits

#### 3.1. System schematic diagram

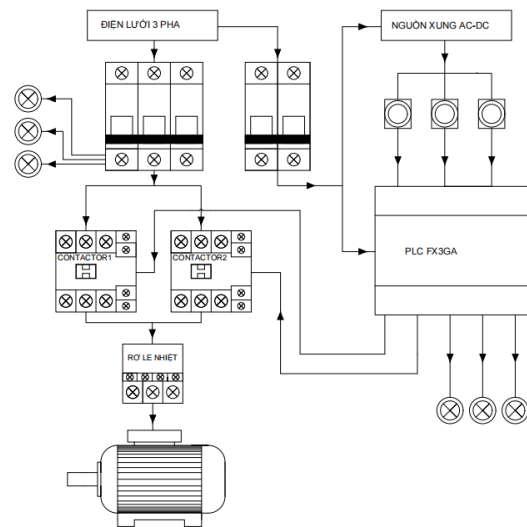


Figure 2. Operating principle of the model

The system is designed to control a three-phase AC motor via a PLC FX3GA programmable controller. Three-phase mains power is supplied to the system and distributed to both the power and control circuits. Specifically, the three-phase power, via a three-phase circuit breaker and phase status indicator lights, is distributed to the power circuit to supply the contactors and motor. The AC power, via a single-phase circuit breaker, is converted to DC voltage by an AC-DC switching power supply, providing power to the PLC and control devices. Control signals from push buttons are fed into the PLC inputs. After processing according to the designed control program, the PLC outputs signals to control the forward and reverse rotation of the contactor coils. When a contactor is activated, the main contacts close, allowing three-phase power to be supplied to the motor via a thermal relay. The motor will operate when the power circuit is closed and is protected from overload by the thermal relay. In case of overload, the thermal relay activates, interrupting the control circuit, causing the contactor to release and the motor to stop, ensuring system safety. Additionally, indicator lights controlled by the PLC display the system's operating status, such as forward/reverse rotation, stopped, or malfunction, allowing operators to easily monitor and control the system.

### 3.2. Power circuit diagram

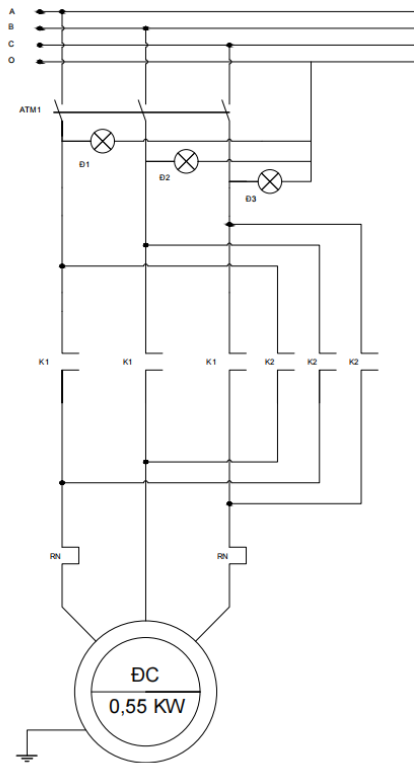


Figure 3. Power circuit diagram

The three-phase power supply A, B, C is fed into the circuit through circuit breaker ATM1. The circuit breaker's function is to switch the main power supply on and off and protect the power circuit in case of short circuits or overcurrents. After the circuit breaker, each phase is disconnected and connected to indicator lights D1, D2, and D3. When the corresponding phase is energized, the light illuminates, allowing the operator to easily identify whether the power supply is full or missing. The three-phase power is then passed through contactors K1 and K2 to power the motor. When contactor K1 is activated, its main contacts close, supplying the motor with three-phase power in the original phase sequence, causing the motor to rotate forward. When contactor K2 is activated, the two phases in the power circuit are reversed through the contacts of K2, changing the phase sequence supplied to the motor, causing the motor to rotate in reverse. The two contactors are interlocked to prevent simultaneous switching and short circuits. The current supplied to the motor passes through the thermal overload relay RN to protect against overload. When the motor is overloaded, the thermal overload relay activates, causing the motor to stop, ensuring the safety of the system and equipment.

### 3.3. Control circuit diagram

The AC power supply is provided to the system via circuit breaker ATM2, then fed into an AC-DC switching power supply to convert it to 24VDC for the PLC and control devices. The FX3GA PLC is powered at terminals L and N, and also uses an internal 24VDC power supply for the inputs. The control buttons, including forward, reverse, and stop buttons, are connected to the PLC's digital inputs. When the operator presses a button, a signal is sent to the PLC for processing according to the designed control program. Based on the control program, the PLC outputs signals to control the contactor coils K1 and K2, where K1 is used for forward rotation and K2 for reverse rotation of the motor. The program includes interlocking conditions to ensure that K1 and K2 cannot close simultaneously, preventing malfunctions in the power circuit. Additionally, the indicator lights DT, DN, and DD are controlled by PLC outputs to display the system's operating status, such as forward rotation, reverse rotation, or stop, allowing operators to easily observe and monitor the operation process.

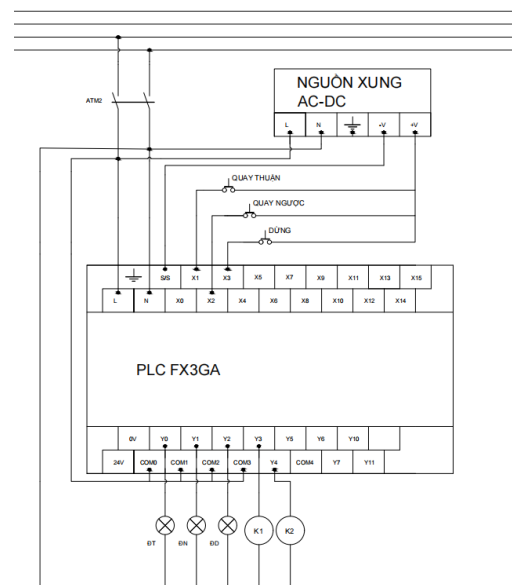


Figure 4. Control circuit diagram

### 3.4. Working principle of power circuit combined with control circuit

The three-phase power supply A, B, C is fed into the system through circuit breaker ATM1. This circuit breaker is responsible for switching the main power supply and protecting the power circuit in case of a short circuit. After the circuit breaker, lights D1, D2, and D3 are connected to each phase to indicate the power status, allowing operators to

easily detect whether a phase is on or off. The three-phase power is then passed through contactors K1 and K2 to supply the motor. K1 supplies power in the initial phase sequence for forward rotation, while K2 reverses the two phases to change the motor's direction of rotation. The two contactors are interlocked to ensure they cannot be switched simultaneously, preventing short circuits between phases. The current supplied to the motor passes through thermal overload relay RN. When the motor operates at a current exceeding the permissible limit, the thermal relay activates, interrupting the circuit and stopping the motor to ensure equipment safety.

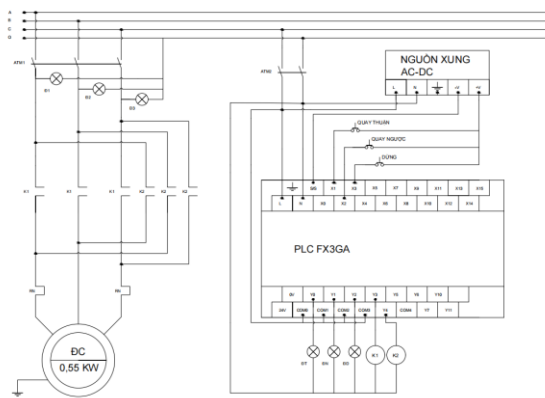


Figure 5. Power circuit and control circuit diagrams.

The control circuit is powered via the ATM2 circuit breaker and an AC-DC switching power supply, converting AC voltage to 24VDC to supply the FX3GA PLC and control elements. Forward, reverse, and stop push buttons are connected to the PLC's digital inputs. When the operator performs a task, the PLC receives the signal, processes it according to the designed control program, and outputs control signals to the outputs. The PLC outputs control the contactor coils K1 and K2 corresponding to the motor's direction of rotation, and also control the status indicator lights DT, DN, and DD to display the system's operating status. Thanks to PLC control, the system ensures accurate, safe, flexible operation and is easily expandable or program-modified as needed.

#### IV. Design the control program

The control program is designed to perform forward and reverse rotation control of the motor with time delay and ensure safe interlocking. When the forward rotation start button (X001) is pressed, if the stop button (X003) is not activated, the timer T0 has reached the set value K100 and the motor is not in reverse rotation (M1 = 0), the PLC will activate the intermediate bit M0 and maintain this state through the self-holding contact. Similarly, when the

reverse rotation start button (X002) is pressed, if the stop button is not activated, the timer T0 has reached the set value K100 and the motor is not in forward rotation (M0 = 0), the intermediate bit M1 is activated and self-holding, ensuring that only one direction of rotation is allowed at a time.

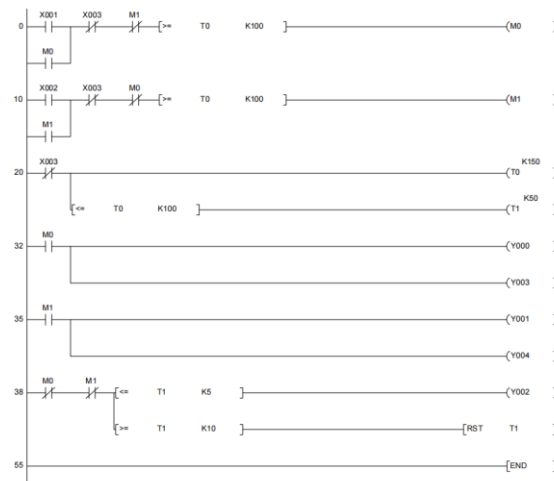


Figure 6. Control program diagram

When the stop button X003 is activated, the PLC interrupts the control state and simultaneously activates timer T0 with the preset value K150 to create a safe delay before allowing the motor contactor to close. After the delay time reaches K100, when the forward rotation button is pressed, the system activates the forward rotation state (M0 = 1). The PLC will then allow outputs Y000 and Y003 to close to control the contactor and the corresponding indicator light for forward rotation mode. Conversely, if the system is in reverse rotation state (M1 = 1), the PLC will activate outputs Y001 and Y004 to control the contactor and the indicator light for reverse rotation mode.

In addition, the program uses timer T1 to create a blinking circuit to indicate the stop state. When both intermediate bits M0 and M1 are inactive, for a time interval of timer T0 ≤ 5 seconds, timer T1 starts counting. During the timer interval T1 ≤ 0.5 seconds, output Y002 is turned on. When T1 ≥ K1 seconds, timer T1 is reset and the cycle repeats, causing Y002 to blink in sync with T1's cycle. The blinking light finishes the set value K100.

Output Y003 is controlled via interlock between M0 and M1 to indicate the system's stop state when there is no forward or reverse rotation command.

In addition, the program uses an interlock condition between M0 and M1 to ensure that when a forward or reverse rotation command is given, the system cannot be in two states simultaneously.

Thanks to the use of intermediate bits, timers, and logic interlocks, the program ensures that the motor only rotates in one direction at a time, with a reasonable delay when changing states, thereby improving the safety and reliability of the system.

### V. System testing and evaluation

After completing the design of the power circuit, control circuit, and PLC programming, the system is tested to verify the correctness of the program and the practical functionality of the model. The testing process involves powering the system and checking the operating status of the phase indicator lights, control power, and PLC input/output signals.

After a delay time set by the timer, when the forward rotation button is pressed, the PLC receives the input signal and activates the corresponding intermediate bit. The contactor controlling the motor to rotate in the forward direction closes, the motor operates stably, and the status indicator lights function correctly as designed. When the reverse rotation button is pressed, the system only allows operation when the forward rotation mode has been disconnected, ensuring safe interlocking between the two rotation directions.

During testing, when the stop button was pressed, the motor stopped operating and the system returned to a safe state. The control outputs and indicator lights accurately reflected the motor's operating status. The test results showed that the PLC program operated correctly as required, ensuring the motor rotated in only one direction at a time, with a reasonable delay when switching states, and meeting the requirements for safe operation.

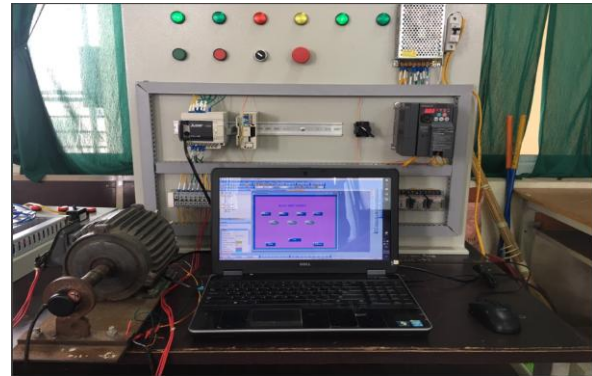


Figure 7. System model

### VI. Conclusion:

Test results show that the motor control system using the FX3GA PLC operates correctly according to design requirements. When power is supplied, the phase indicator lights fully display the three-phase power status, and the PLC and control circuit operate stably. When the forward or reverse rotation control button is pressed, the PLC receives and processes the signal accurately, the contactors are activated in the correct sequence, the motor rotates in the selected direction and operates stably, without the simultaneous closing of two contactors.

During operation, when a stop command is executed, the motor stops and the system returns to a safe state. The delay time when switching between the two rotation modes is ensured to be correct according to the value set in the program, contributing to limiting the starting current and enhancing the safety of the system. The status indicator lights accurately reflect the motor's operating mode, making it easy for the operator to monitor.

Through practical testing, the system has proven stable, fully meeting the requirements for control function, safety, and reliability, making it suitable for use in teaching and small-power motor control models.

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