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Automatic Sequential Operations of Three Phase Electrical Induction Motors – Power, Control, Command and Wiring Circuits

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Abstract. Automatic sequential three-phase induction motors starting have a wide range of applications in various types of electrical installations on board. The following are some common applications of sequential electric motor starting: group starter panel - engine room pumps, central heating circulation pumps, chilled water pumps, and others. This paper presents in detail the power, control and automation schemes for the sequential starting of electric motors on board ships, the CAD simulation of normal and emergency operating modes, as well as the practical implementation of the experimental laboratory stand.

Keywords: automatic sequential starting; PLC; control; motor starter, protection.

1. Introduction

A sequential motor starting circuit is an electrical circuit designed to control the operation of motors in a sequential manner. The circuit is usually composed of a combination of control devices such as manual motor starter or miniature circuit breaker, contactors, PLC or numerical relays, and sensors. It prevents simultaneous starting of electric motors and ensures that each motor operates in a specific sequence for a specific purpose. A sequential motor starting circuit is an electrical circuit designed to control the operation of motors in a sequential manner. The circuit is usually composed of a combination of control devices such as power contactors, timers, relays and sensors. It prevents simultaneous starting of electric motors and ensures that each motor operates in a specific sequence for a specific purpose.

In this work, the experimental laboratory stand was realized for the automatic sequential starting of two motors in the first phase of different active powers and finally for two identical 1.1 kW motors at rated voltage of 400 V.

Sequential starting of two or more electric motors has a wide range of applications in different industries including the marine industry.

In on-board electrical installations we can mention:

- Pump systems: In pump drive systems, sequential motor control circuits are used to control the flow of liquids or gases. The control circuit energizes each pump sequentially to ensure smooth and efficient fluid flow.

- HVAC Systems: HVAC (heating, ventilation and air conditioning) systems require precise control of multiple components, including electric motors. Sequential motor control circuits are used to ensure that each motor is operated in the correct sequence to achieve optimum performance.

2. CAD Simulation of Automatic Sequence Operations

This automatic sequential control of two induction motors with timer and motor-starter has two circuits. They are:

Power circuit

Control circuit

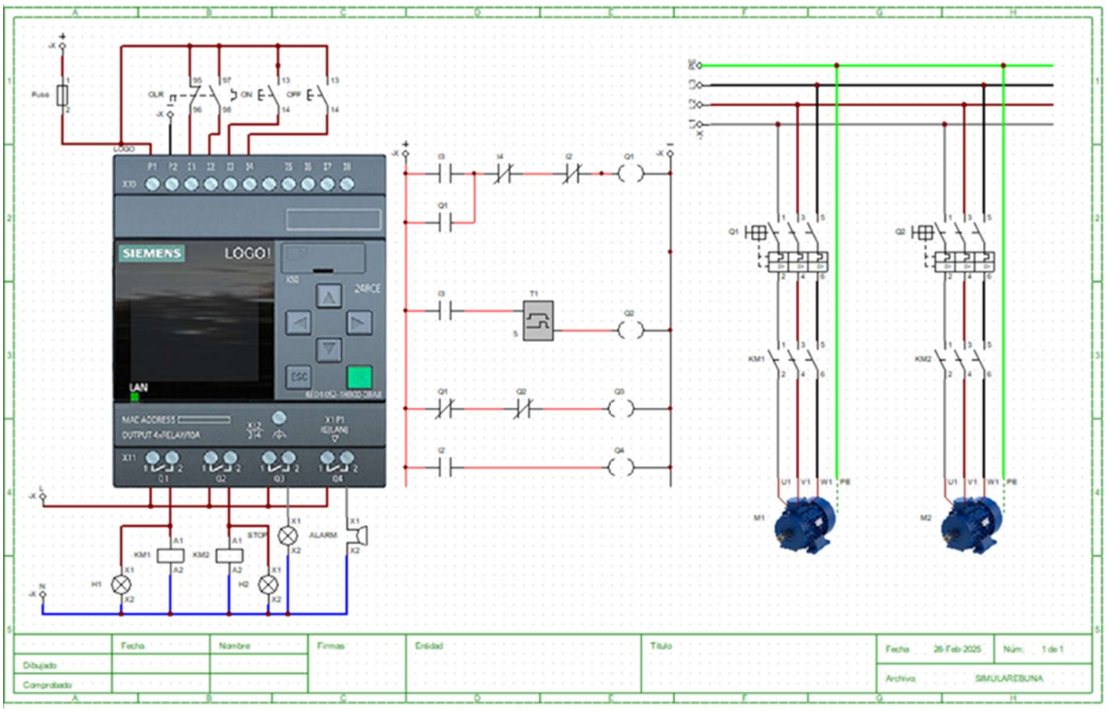

Figure 1. Power and control circuit using motor starters

This is an electromechanical as well as programmable logic control which is used to control two three-phase motors safely and efficiently. The control system comprises automatic start-up, shut-down, overload protection, as well as operation indicators.

Components and their roles are:

1. Programmable Logic Controller (PLC) - Siemens LOGO!

The PLC Siemens LOGO! 24RCE is the central device which accepts input signals, executes logic operations in accordance with its inbuilt program, and controls the output in response.

It is constructed with inputs to receive signals (for example, start, stop and overload) and output to energize contactors as well as lamps.

Components of the circuit are:

Power Circuit

Motor starters - Provide added protection for motors against long-duration overcurrent.

Contactors (KM1, KM2):
Electromechanical switches driven by PLC outputs (Q1, Q2).
They supply power to motors when energized by closing power contacts.
Motors (M1, M2):
Induction motors driven by a three-phase electric supply.
Commenced or ended by contactor switching.
Control Circuit
Power On Switch
Triggers the specified input in the Siemens LOGO!, which in turn activates the motor through PLC logic.
Stop Button (OFF):
It shuts off by providing a disable instruction to the PLC.
Sends a protection signal to the PLC input to stop the motor in order to prevent overheating.

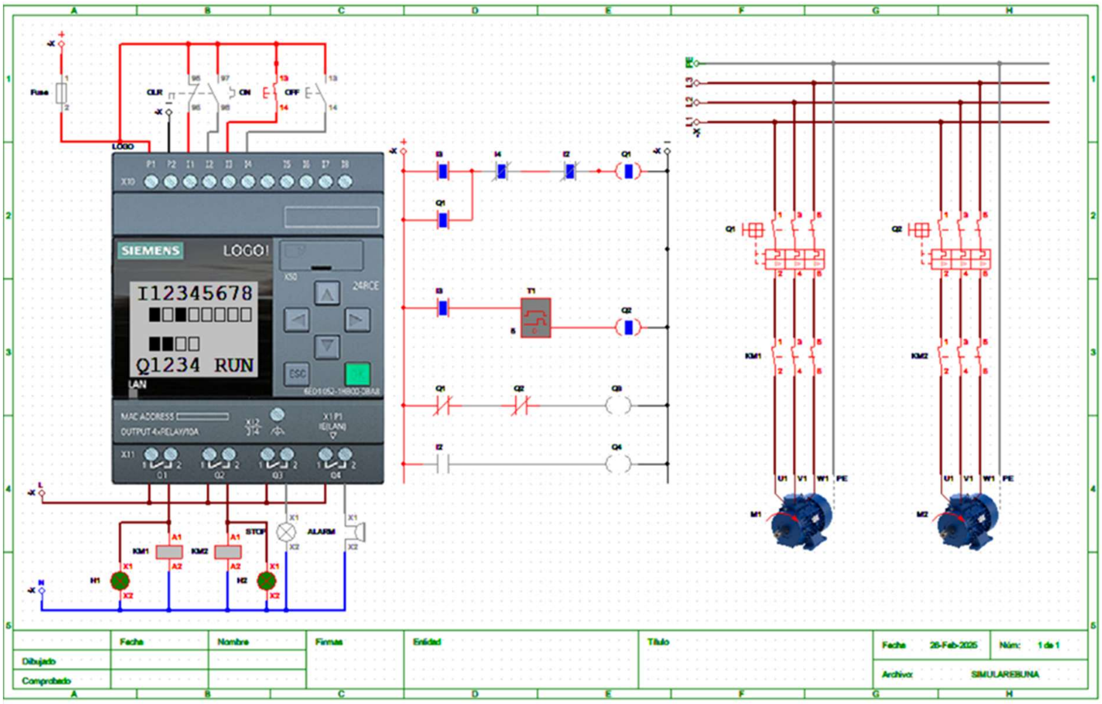

Figure 2. CAD simulation of sequential starting of two electric motors

Indication and Signalling (figure 2)
STOP Lamp (H1): Glows when the engine is switched off or the motors are at idle.
ALARM Signal: Initiated by PLC output (for instance, X1) to indicate abnormality, particularly during overloading conditions.
Operational Logic
Beginning Operations:
The operator presses the ON button.
The LOGO! PLC accepts and handles this input.
If the internal conditions of logic are fulfilled, the PLC powers the output relays.
Output relays power the contactor coils (KM1/KM2)
The energized coils close the main contacts of the contactor, connecting the motors (M1/M2) with the three-phase power supply.

Stating Operation:

The OFF button is activated to give a signal to the PLC.

The PLC shuts off output relays automatically. Contactor coils are de-energized, and main contacts open. Motors are stopped, coasting to the safe stop.

Fault conditions (figure 3)

In the event of thermal overloading (excessive current consumption), the relay energizes an input to the LOGO!.

The LOGO! switches off the output contactors (KM1/KM2), decouples motors, and stops their operation in an instant.

Simultaneously, an alarm output signal is generated which signals the operators through visual or audio alarms.

Operational Overview

Typically: PLC input → internal logic → output energized → contactor coil energized → motor comes online

Stop condition: Operator presses OFF, PLC receives input, output relay is de-energized, contactors open, motor stops.

Alarm status: Overheat detected, PLC automatically shuts off output, opens contactors, energizes alarm signals.

Automatic, reliable, and cost-effective control of twin three-phase motors with inbuilt safeguarding features and clear-cut signalling is provided by the outline design through the use of PLC-based automation and electromechanical switches.

Power and Control Configuration:

Power Circuit

The motors (M1 and M2) shown are three-phase induction motors, which are generally used in industrial applications wherein highly reliable power transmission is needed.

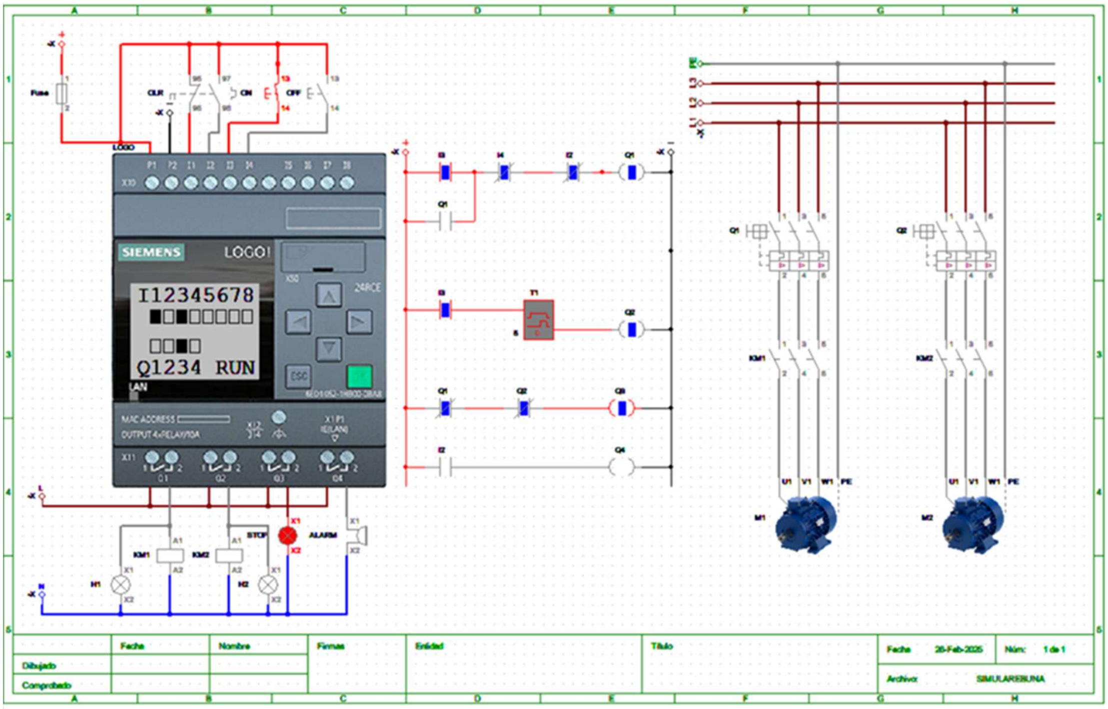

Figure 3. CAD simulation of the electrical scheme in case of a fault (overload or short-circuit)

The motors are energized by a three-phase alternating supply (L1, L2, L3) through the use of electromechanical contactors (KM1 and KM2), the coils of which are driven by the control.

They are part of the motor circuits to protect the motors from excessive currents, thereby cooling the motors in order to prevent the motor windings from getting damaged.

3. Steps required to implement a sequential motor starting system using a LOGO! PLC

The Siemens LOGO! 12/24V Programmable Logic Controller (PLC) is a compact, modular and easy-to-use automation device for small and medium control applications.

It operates on a 12V/24V DC power supply and is widely used in industrial automation, home automation and laboratory experimentation

To practically create the control scheme, the following steps are taken:

- Wiring the PLC power supply
- Wiring the inputs
- Wiring the outputs
- Wiring a ladder diagram
- Wiring the laptop and PLC
- Wiring the logic diagram

The LOGO! PLC is powered by 24 V DC from a rectifier V1. The PLC is mounted on module A1, where the phase is on terminal M+ and the neutral is on terminal M. For larger schemes with more inputs and outputs, an additional module is mounted, for example, module A2 (figure 4).

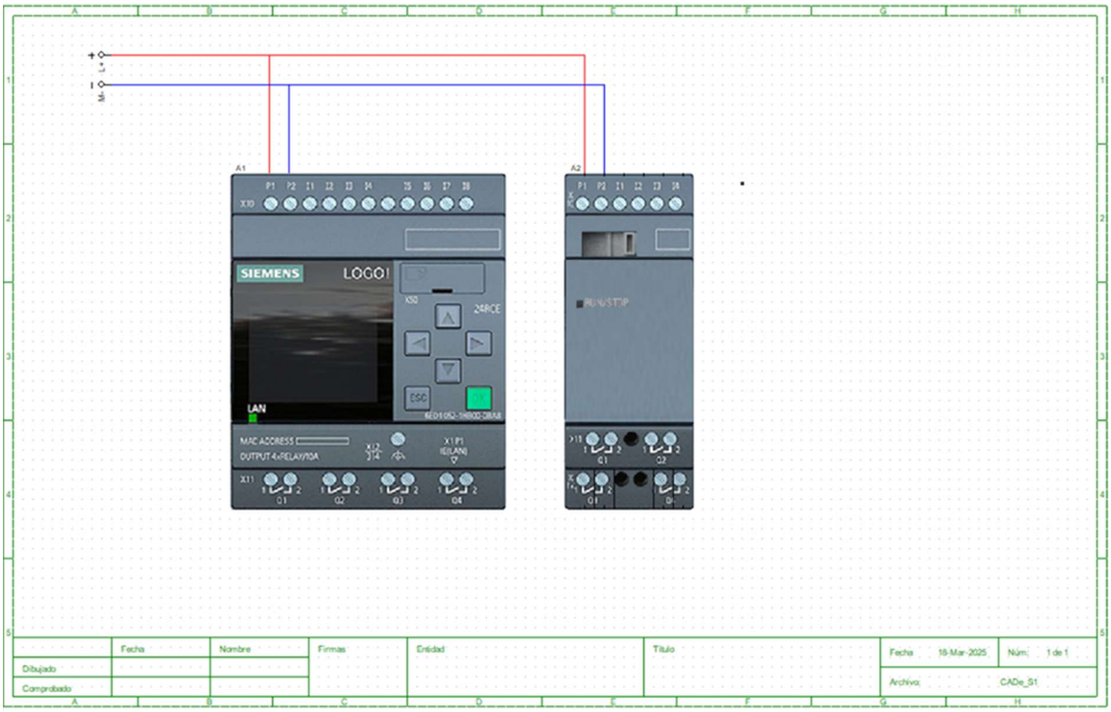

Figure 4. Power supply diagram for LOGO and the related module

The powering of the inputs and outputs of a PLC LOGO (programmable logic controller) is essential for the operation of the automated system.

In this configuration, the inputs are powered from a 24V voltage supply.

Figure 5 and Figure 6 show the connection diagrams of the PLC inputs and outputs

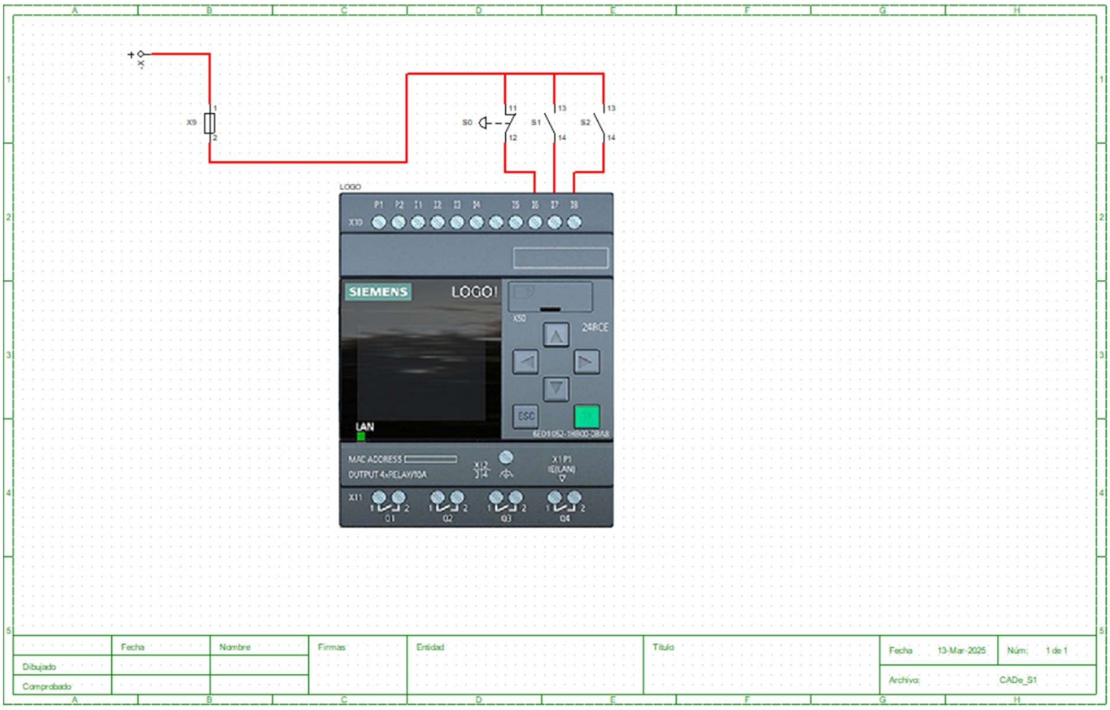

Figure 5. LOGO Inputs Wiring Diagram

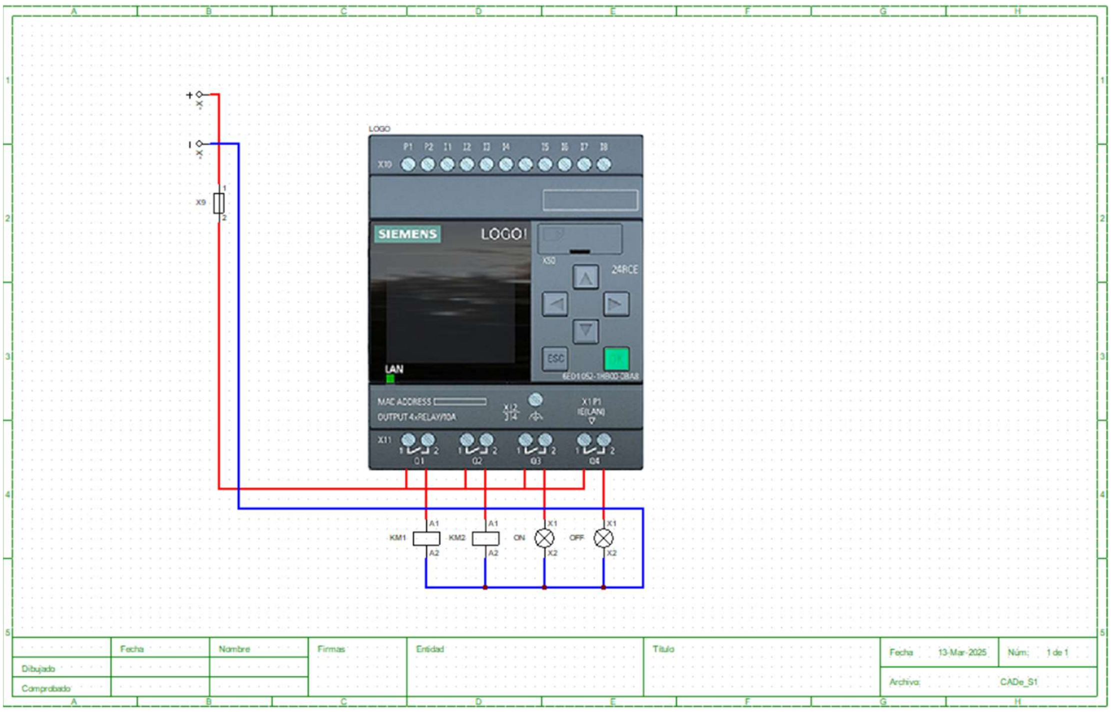

Figure 6. LOGO Outputs Wiring Diagram

The following connections are configured in the LOGO! PLC inputs: S0-I6, S1-I7, S2- I8. By changing the state of the switches on these inputs, the PLC will receive a signal, which it will process according to the scheme installed by the human operator, and then output a signal on the PLC outputs. At the PLC outputs, the following connections are made: contactor KM1-Q1, contactor KM2-Q2, green lamp H1-Q3 and red lamp H2-Q4. (figure 7)

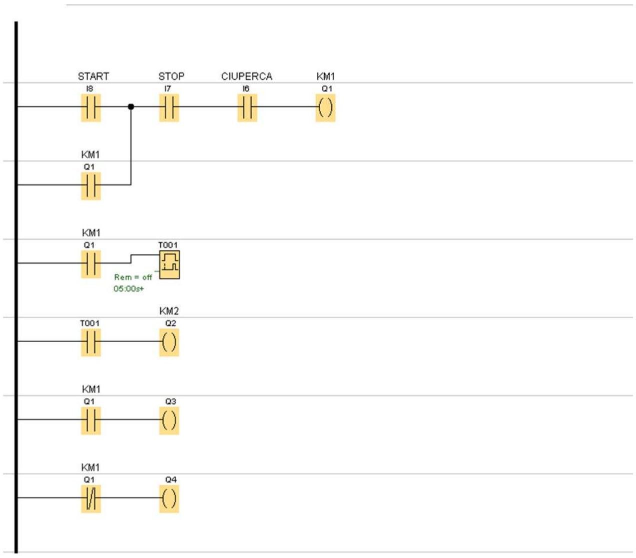

Figure 7. Ladder Diagram of sequential starting of two three-phase induction motors

The PLC and PC are connected via an Ethernet cable over the Ethernet network to allow the two to exchange information. This is one of the common methods of connecting devices in automation because it is reliable and very efficient. The Ethernet cable is used to create a data link between the PLC and the PC to allow the exchange of programs, settings and other data between the two devices. (figure 8)

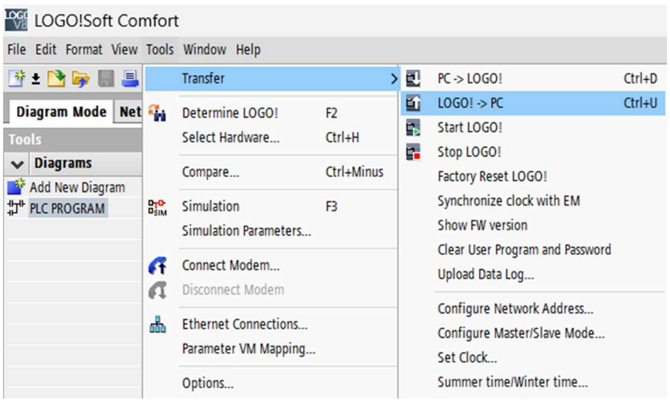

Figure 8. Data transfer LOGO! – PC

Compared to the PC-PLC interface via USB cable, the other widely used interface method, the Ethernet interface has the additional advantages of higher transfer rate and data carrying capacity. In addition, the Ethernet interface has the potential for simultaneous communication with multiple devices, which has the potential to manage and monitor a number of devices in an industrial network.

The link between PLC and PC is realized to interact and exchange data between the two systems in industrial automation. This facilitates PLC programming, monitoring, diagnostics, as well as maintenance and performance improvement.
Now that we have established the communication link between the PC and the PLC using the Ethernet cable, we can start loading the ladder diagram into the PLC. Now that we have established the communication link between the PC and the PLC using the Ethernet cable, we can start uploading the ladder diagram into the PLC.
We go to the "Tools" menu, then to transfer and click on "LOGO! to PC". Once clicked, a new window will pop up where we choose the type of connection (Ethernet) and start the transfer. During the transfer, the connection is established and the software structure is transferred to the PLC. It then executes the process based on the loaded plan. (figure 9)

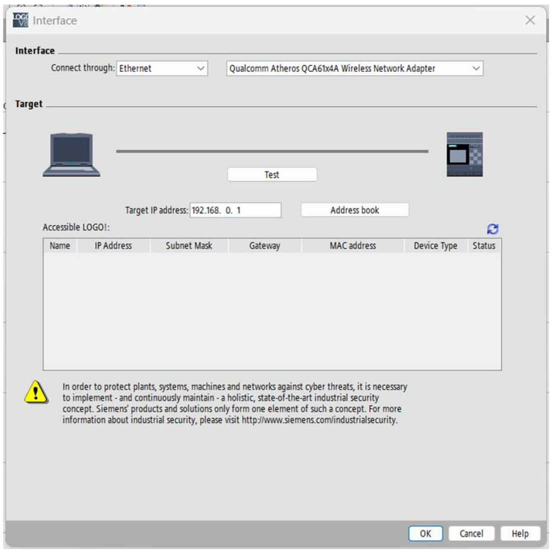

Figure 9. Connection procedure

4. Conclusions

The circuit for automatic sequential starting of two or more electric motors works relatively simply. The control circuit initially activates the first motor that has the highest rated current (i.e. starts the motor with the most difficult starting conditions) in the sequence by transmitting a signal to the manual motor starter or contactor (NO contacts).
Step-by-step simulation and analysis of the starting of two three-phase electric motors using Siemens LOGO! Soft Comfort highlights the role of PLC automation in industrial automation systems. PLC automation provides efficient, safe and programmable control with minimal intervention, high reliability and high dependability of operation.
Siemens LOGO! 12/24V DC PLC is an efficient, yet multi-functional automation unit capable of processing digital and analog input data, logic operation and relay output operation in any industrial application. The simulation and realization stage provides instant insight into realistic automation scenarios, allowing for proper configuration, monitoring and troubleshooting prior to actual application.
LOGO! Soft Comfort provides easy programming in Function Block Diagram (FBD) or Ladder Diagram (LD) to enable user-defined automation logic for specialized industrial tasks. Simulating the logic prior to download allows errors to be identified and corrected in a controlled environment, reducing downtime and increasing reliability.

The sequential motor start-up procedure incorporates several very important steps such as:It is recommended to include in the conclusions some of the following:

- Power wiring and I/O configuration - Proper connection of the power supply, input devices and output devices to the PLC ensures an organized and reliable wiring.
- Communication and monitoring - Communication between PC and PLC via Ethernet enables real-time data exchange, remote monitoring and troubleshooting.
- System optimization and troubleshooting - The ability to change program parameters and adjust settings online makes it possible to achieve greater flexibility and efficiency in an industrial environment.

However, there are certain limitations that must be tolerated. The number of input and output ports is not very large, and extension modules are required when working on large projects. No high-level industrial protocols such as PROFIBUS and MODBUS are supported, which limits the integration in large and complex automation networks. Despite these limitations, LOGO! PLC remains the ideal solution for small and medium automation projects.

Parallel operation of two three-phase motors using Siemens LOGO! Soft Comfort is the real challenge of the applicability of PLC-based automation in industrial process optimization. The system is capable of providing precise control, increased safety and improved efficiency through simulation, testing and field operation. LOGO! PLC and Soft Comfort software offer a low-cost, easy-to-use and scalable automation system, therefore applicable for industrial, academic and research purposes.

One of the biggest strengths of using Siemens LOGO! PLC here is that it is energy efficient and easy to integrate. It provides support for real-time clock (RTC) automation, so it is suitable for programmed and event-based control systems. It is based on a modular design, so is easily upgradable for complex automation tasks, but is less suitable than the higher-level Siemens S7 range PLCs in large-scale industrial situations.

Automatic, reliable and cost-effective control of three-phase motors with built-in protection functions and clear signaling is provided by the design scheme using PLC-based automation and electromechanical contactors.

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