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Bytewise Fellowship – PLC
Final

1- Motors

1 Phase starting method

A 1-phase induction motor is not self-starting. Somehow, by producing a rotating stator magnetic field, the 1-phase induction motor can be made self-starting. This may be accomplished by converting a single supply into two-phase supply through the use of an additional winding or auxiliary winding.

As soon as the motor attains a sufficient speed, the starting means may be removed depending on the type of the motor. Hence, the single-phase induction motors are classified and named according to the method used to make them self-starting which are given as follows:

- Split-phase Induction Motor – These motors are started by 2-phase motor action, which is achieved by the use of a starting or auxiliary winding.
- Capacitor Motor – To start a capacitor motor, the two-phase motor action is achieved by the use of an auxiliary winding and a capacitor.
- Shaded Pole Motor – This type of single-phase induction motor is started by the motion of magnetic field produced by the means of a shading coil around the portion of the pole structure.

3 Phase Squirrel cage and Slip ring motor.

A 3 phase squirrel cage induction motor is a type of three phase induction motor which functions based on the principle of electromagnetism. It is called a ‘squirrel cage’ motor because the rotor inside of it – known as a ‘squirrel cage rotor’ – looks like a squirrel cage.

The rotor, a cylindrical assembly of steel laminations, incorporates highly conductive metals like aluminum or copper. When alternating current flows through the stator windings, it generates a rotating magnetic field.

This process induces a current in the rotor, creating its own magnetic field that interacts with the stator’s field to produce torque.

A Slip Ring Motor, commonly referred to as a wound-rotor motor, is a type of induction motor characterized by its unique design and operating principle. Unlike its counterparts that employ a shorted, squirrel-cage rotor, the slip ring motor features a wound rotor, with the windings connected to the external circuit through a set of rotating contacts known as slip rings. This type of rotor construction offers the flexibility to control the motor’s torque or speed, allowing applications requiring high torque and adjustable speed to benefit immensely from this motor variant.

3 Phase Motors Control and Starting Method.

A three-phase induction motor is inherently self-starting. When the supply is connected to the stator of a three-phase induction motor, it generates a rotating magnetic field that causes the rotor to start rotating. At the moment of starting, the slip is at its maximum (unity), resulting

in a very high starting current. Starting methods refer to the various techniques employed to start a three-phase induction motor in a smooth, safe, and efficient manner.

Starters help reduce the initial large current when the supply is switched on, ensuring smooth motor operation. There are various commonly used starting methods for three-phase induction motors.

- Direct on-line starting Method
- Stator resistance starting method
- Star-Delta starting method
- Auto Transformer Starting Method
- Rotor-Resistance Starting

3 phase motor Star , delta and star delta connection.

Star and Delta connections are two types of connections used in 3-phase circuits. In a Star Connection, the system has a neutral wire, and the line voltage is root three times the phase voltage. It is a balanced circuit connection. In a Delta Connection, there is no neutral wire, and the line voltage is equal to the phase voltage. It is commonly an unbalanced circuit connection.

How to find resistance required to attach with rotor in slip ring motor.

To calculate the resistance of a slip ring motor, you need to understand the motor's expected slip at full load, which is provided in the motor's specifications. The slip is the difference in speed between the rotating magnetic field and the rotor divided by the

$R2 = (s * V2) / (I2 * (1-s))$

Where:

- R2 is the rotor resistance per phase,
- s is the slip of the motor,
- V2 is the rotor voltage per phase, and
- I2 is the rotor current per phase at full load.

Motor Faults (Phase Missing and Body short)

When one of the three-phases of the supply is lost, the fault occur in that case is termed as single-phasing fault. Because of this fault, the three-phase induction motor will heat up or can burn. This is due to the fact that we need balanced three-phase supply for the normal operation of the three-phase induction motor.

When one of the three phases comes in contact with body of the three-phase induction motor, a short-circuit between the phase and metal body of the motor occurs. This type of fault is called the earth fault. In the condition of earth fault, the motor starts drawing very high current from the supply and heat up. Also, if a living being touches the motor's body, that can get a heavy electric shock.

Motor Speed control using VFD

A Variable Frequency Drive (VFD) is used as a motor controller that controls an electric motor speed by varying the frequency and voltage supplied to the electric motor. They are

also known as variable speed drive, adjustable speed drive, adjustable frequency drive, AC drive, Microdrive, and inverter.

Frequency is directly related to the motor's speed (RPMs). Faster the frequency, the faster the RPMs. Depending on the motor load, the VFD can be used to ramp down the frequency and voltage of the motor input. As the application's motor speed requirements change, the VFD can simply turn up or down the motor speed to meet the speed requirement.

2- Control and Safety

Circuit Breakers

A circuit breaker is an electrical switch designed to protect an electrical circuit from damage caused by overcurrent/overload or short circuit. Its basic function is to interrupt current flow after protective relays detect a fault.

VCB

The Vacuum Circuit Breaker (VCB) is a switching device capable for operational switching (on-off operations) of individual circuits or electrical equipment in normal or emergency modes with manual or automatic control, made for a medium voltage of over 1 kV based on the principle of quenching an electric arc that occurs when the contacts open in a vacuum gap.

ACB

Air Circuit Breaker (ACB) is an electrical protection device used for short circuit and overcurrent protection up to 15kV with amperes rating of 800A to 10kA. It operates in air (where air-blast as an arc quenching medium) at atmospheric pressure to protect the connected electric circuits. ACB has completely replaced by oil circuit breaker because it is still a preferable choice to use an ACB because, there is no chance of oil fire like in oil circuit breaker.

Contactors (Magnetic Contactors)

A magnetic contactor is an electromechanical switch used in applications that require a circuit "on and off" process, such as starting motors, heaters, and lighting applications. Through the switch contacts, the magnetic contactor takes care of transferring energy from one place to another.

The working principle of the magnetic contactor is that the main contact is closed due to the coil being energized, and the main contact is disconnected due to the de-energization of the coil.

Relays (Thermal Relay, Time Relay, Over load Relay, Glass Relay)

A relay is an electrical switch that control (switch on and off) a high voltage circuit using a low voltage source. A relay completely isolates the low voltage circuit from the high voltage circuit.

- Thermal Relay: Protects electrical circuits from overheating by tripping when the temperature exceeds a certain limit.
- Timer Relay: Activates or deactivates circuits after a set time delay.
- Overload Relay: Prevents damage to motors or other equipment by tripping when current levels are too high.

- Glass Relay: A type of relay typically enclosed in a glass casing, often used in specialized or delicate applications.

3- Power

Wire into Current Rating

Ampacity refers to the maximum safe current a conductor can carry continuously under specific operating conditions without exceeding its designated temperature limit. Current is measured in amperes (amps). Selecting the appropriate wire size for a circuit is crucial to prevent overheating, which can lead to damage and fire hazards. The number and type of electrical devices connected to a circuit determine the ampacity requirement of the conductor.

4- Electronics

Types of Resistances

A resistor is a device that obstructs the flow of current. It is a passive two-terminal device which is used to regulate the flow of electric current. Glass, Mica, Wood, Rubber, etc. are examples of resistive materials.

The Carbon Composite Resistor is a low to medium type power resistor which has a low inductance making them ideal for high frequency applications but they can also suffer from noise and stability when hot. Carbon composite resistors are generally prefixed with a “CR” notation.

Metal Film Resistors have much better temperature stability than their carbon equivalents, lower noise and are generally better for high frequency or radio frequency applications. Metal Oxide Resistors have better high surge current capability with a much higher temperature rating than the equivalent metal film resistors.

Solid resistors use a baked kneaded mixture of a carbon-based resistive material and ceramic, etc., as the resistive element. These resistors have the feature of being robust and capable of being used in harsh conditions

Types of Capacitors

A capacitor is defined as a passive component which is used for storing electrical energy. A capacitor is made of two conductors that are separated by the dielectric material. These dielectric materials are in the form of plates which can accumulate charges. One plate is for a positive charge while the other is for a negative charge.

- **AC Capacitor:** Designed for use in alternating current (AC) circuits, often in power factor correction and motor applications.
- **DC Capacitor**: Designed for use in direct current (DC) circuits, used in devices like power supplies and battery systems.
- **Mica Capacitor**: Uses mica as a dielectric material, known for high precision, stability, and reliability, typically used in high-frequency applications.
- **Ceramic Capacitor**: Uses ceramic as the dielectric, commonly found in general-purpose circuits.
- **Electrolytic Capacitor**: Known for high capacitance, mainly used in power supplies and low-frequency circuits.

- **Film Capacitor**: Uses a thin plastic film as the dielectric, known for stability and low losses.
- **Tantalum Capacitor**: A type of electrolytic capacitor with higher performance, used in space-constrained circuits.

Diodes

A diode is a semiconductor device that essentially acts as a one-way switch for current. It allows current to flow easily in one direction, but severely restricts current from flowing in the opposite direction.

Diodes are also known as rectifiers because they change alternating current (ac) into pulsating direct current (dc). Diodes are rated according to their type, voltage, and current capacity.

Thyristor

A thyristor is a three-junction (J1, J2, J3), Four layer of alternating P-type and N-type materials (PNPN) Semiconductor device, which has an Anode, Cathode, and Gate (three terminals). It typically has three electrodes: an anode, a cathode, and a gate (the control electrode). The silicon-controlled rectifier (SCR) is the most prevalent type of thyristor. The primary function of a thyristor is to control electric power and current by acting as a switch. A small current on its gate terminal controls the larger current of the anode-to-cathode path. For such a small and lightweight component, it offers adequate protection to circuits with large voltages and currents.

Transistor

A transistor is a type of semiconductor device that can be used to conduct and insulate electric current or voltage. A transistor basically acts as a switch and an amplifier. In simple words, we can say that a transistor is a miniature device that is used to control or regulate the flow of electronic signals.

Crystal

Crystal oscillators operate on the principle of the inverse piezoelectric effect. When an alternating voltage is applied to the crystal, it vibrates at its natural frequency. These vibrations are then converted into oscillations.

These oscillators are usually made of Quartz crystal. Although Rochelle salt and Tourmaline also exhibit the piezoelectric effect, Quartz is preferred because it is inexpensive, readily available, and mechanically strong.

CT

The Current Transformer (C.T.), is a type of “instrument transformer” that is designed to produce an alternating current in its secondary winding which is proportional to the current being measured in its primary. Current transformers reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter. The principal of operation of a basic current transformer is slightly different from that of an ordinary voltage transformer.

PT

A potential transformer, also called a PT, is an instrument transformer used in power systems for voltage transformation. It converts higher voltage values to lower voltage values for measurement and protection purposes. By presenting a minimal load, it maintains an accurate voltage ratio and phase relationship, ensuring precise secondary connected metering.

IC

Integrated circuits are made up of several components such as R, C, L, diodes and transistors. They are built on a small single block or chip of a semiconductor known as an integrated circuit (IC). All of them work together to perform a particular task. The IC is easily breakable, so to be attached to a circuit board, it is often housed in a plastic package with metal pins.

Voltage Regulators

A voltage regulator is a circuit that creates and maintains a fixed output voltage, irrespective of changes to the input voltage or load conditions. Voltage regulators (VRs) keep the voltages from a power supply within a range that is compatible with the other electrical components. While voltage regulators are most commonly used for DC/DC power conversion, some can perform AC/AC or AC/DC power conversion as well.

Heat Sink

A heat sink is a piece of metal that sits on top of a computer chip such as a CPU and draws power away from components by letting it rise through a series of fins.

By themselves, heat sinks are passive, meaning they have no moving parts. In most cases, however, the heatsink is combined with a fan that blows the hot air away or a liquid cooling solution that carries the heat halfway through the pipes.

Full and Half Wave Rectification and their power factor

A half wave rectifier is defined as a type of rectifier that only allows one half-cycle of an AC voltage waveform to pass, blocking the other half-cycle. Half-wave rectifiers are used to convert AC voltage to DC voltage, and only require a single diode to construct.

Full-wave rectifier circuits are used for producing an output voltage or output current which is purely DC. The main advantage of a full-wave rectifier over half-wave rectifier is that such as the average output voltage is higher in full-wave rectifier, there is less ripple produced in full-wave rectifier when compared to the half-wave rectifier.

The rectification efficiency of full wave rectifiers is double that of half wave rectifiers. The efficiency of half wave rectifiers is 40.6% while the rectification efficiency of full wave rectifiers is 81.2%.

The ripple factor in full wave rectifiers is low hence a simple filter is required. The value of ripple factor in full wave rectifier is 0.482 while in half wave rectifier it is about 1.21.

5- PLC

SCADA

Supervisory Control and Data Acquisition (SCADA) systems are used for controlling, monitoring, and analyzing industrial devices and processes. The system consists of both software and hardware components and enables remote and on-site gathering of data from the industrial equipment. In that way, it allows companies to remotely manage industrial sites such as wind farms, because the company can access the turbine data and control them without being on site.

HMI

HMI stands for human-machine interface and refers to a dashboard that enables a user to communicate with a machine, computer program or system. Technically, you could apply the term HMI to any screen that someone uses to interact with a device, but it's typically used to describe such screens used in industrial settings. HMIs display real-time data and allow a user to control machinery using a graphical user interface.

PLC

PLC stands for programmable logic controller. A PLC is a programmable computing device that is used to manage electromechanical processes, usually in the industrial niche. A PLC is sometimes referred to as an industrial PC, a term that describes a PLC’s main function as a specialized industrial computing machine.

PLCs monitor the state of an input device such as signals from a light switch, and make decisions about the next state of an output device, for example switching a light on or off.

PLCs are also used to transfer information from devices at factories or from offsite locations to centralized applications, often running on PCs. PLCs are commonly used for device monitoring and reporting, to diagnose faults in hardware devices like industrial machines and tools, and to effect device events.

Modbus

Modbus is a request-response protocol implemented using a master-slave relationship. In a master-slave relationship, communication always occurs in pairs—one device must initiate a request and then wait for a response—and the initiating device (the master) is responsible for initiating every interaction. Typically, the master is a human machine interface (HMI) or Supervisory Control and Data Acquisition (SCADA) system and the slave is a sensor, programmable logic controller (PLC), or programmable automation controller (PAC). The content of these requests and responses, and the network layers across which these messages are sent, are defined by the different layers of the protocol.

RS 232

RS-232 (Recommended Standard 232) is a standard communication protocol used for serial communication between devices. It was commonly used for connecting computers to peripheral devices such as modems, printers, and mice.

RS 485

RS-485, also known as TIA-485 or EIA-485, is a serial communication standard that defines the electrical and functional characteristics of a balanced data transmission system. It’s

commonly used for long-distance communication in industrial and commercial applications where robustness, noise immunity, and multi-drop capabilities are important.

Profibus

It is a digital network responsible for providing the communication between the field sensors and the control system or the controllers. It is used to operate sensors and actuators via a centralized controller in production (factory) automation applications.

Profinet

Profinet implements the interfacing to peripherals. It defines the communication with field connected peripheral devices. Its basis is a cascading real-time concept. Profinet defines the entire data exchange between controllers (called "IO-Controllers") and the devices (called "IO-Devices"), as well as parameter setting and diagnosis

TCP/IP

TCP/IP (Transmission Control Protocol/Internet Protocol) is a suite of communication protocols that define how data is transmitted across networks. It's the foundation of the internet. PLCs (Programmable Logic Controllers) have increasingly adopted TCP/IP for communication due to its flexibility and widespread use.

UDP

User Datagram Protocol (UDP) is a communications protocol for time-sensitive applications like gaming, playing videos, or Domain Name System (DNS) lookups. UDP results in speedier communication because it does not spend time forming a firm connection with the destination before transferring the data.

PLC Digital and Analogue Input/output

Digital Input: Detects binary signals (ON/OFF, 0/1) from external devices like sensors, switches, or push buttons. The PLC reads these signals as either HIGH (ON/1) or LOW (OFF/0).

Digital Output: Sends binary signals (ON/OFF, 0/1) to external devices like relays, lamps, or motors. The PLC can turn devices ON or OFF based on its control logic.

Analog Input: Reads continuous signals from sensors or devices that measure varying physical quantities such as temperature, pressure, or flow. The input is typically represented as a voltage (e.g., 0-10V) or current (e.g., 4-20mA).

Analog Output: Sends continuous control signals to devices like variable speed drives, valves, or actuators. These outputs can control devices proportionally based on the PLC's logic (e.g., adjusting the speed of a motor or the position of a valve).

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6- Final Project

Design a PLC Based Project of your own choice

Water Heating System:

Problem Description

Controlling the heating process for the liquid in the tank. Also filling and emptying the tank when heated to the desired temperature.

Solution

In this system two sensors are used for level measurement in the tank, heater is used for material heating purposes in the tank.

We used a temperature sensor (it can be RTD or thermocouple) also for temperature measurement in the tank.

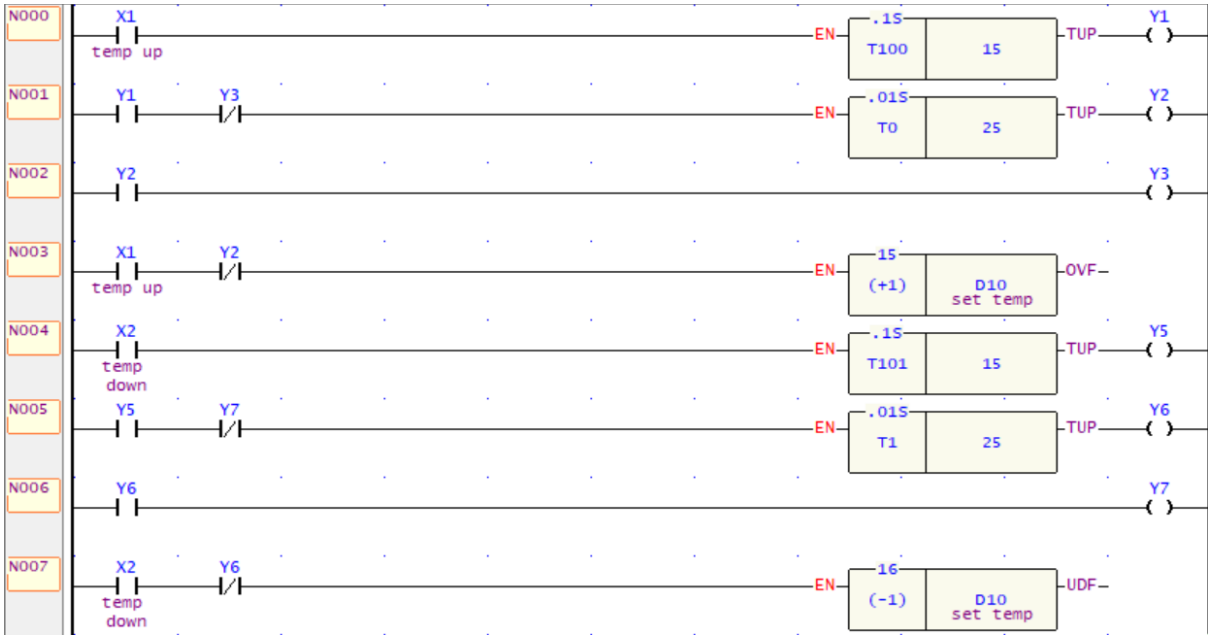
Two valves are used for the material inlet and outlet. The inlet valve is used for feeding the tank and the outlet valve for discharging the tank.

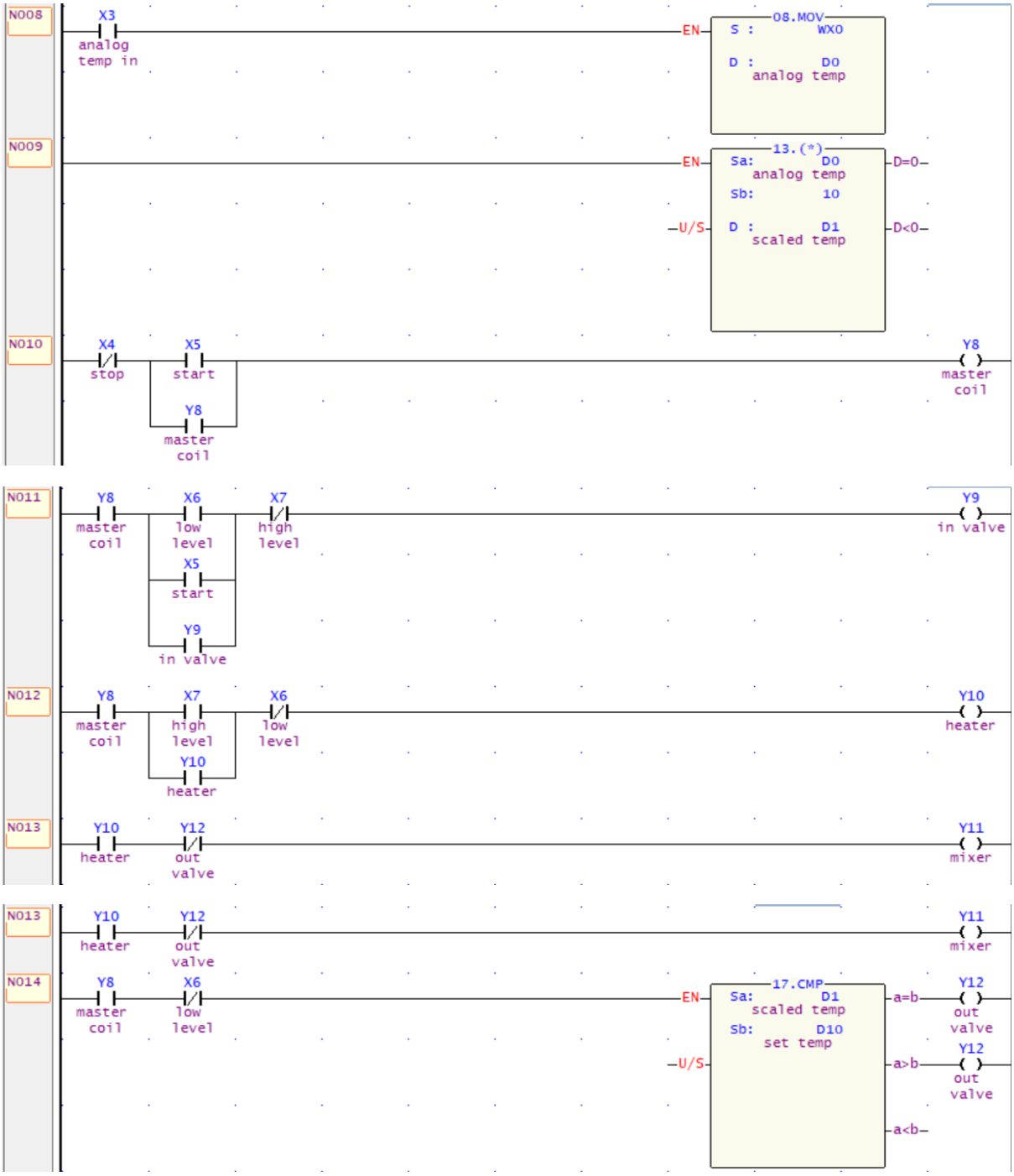
If the system detects a low level, the system will start to feed the tank. The feeding cycle will be OFF when the tank detects a high level.

We used a mixer to mix the liquid to promote equal heating.

We used push buttons to set the temp.

Fatek Code





Explanation

- Network 0-7: this network is used to set the temperature required for the liquid in the tank. Temp up increases the temperature and temp down decreases it. We can also hold press either button to change more temperature without pressing multiple times.
- Network 8-9: analog input from the temperature sensor is stored and then scaled to readable value and easier comparison.
- Network 10: Master coil will start when START will be pressed and cycle can be stopped by pressing STOP.
- Network 11: When low level switch is detected, in valve will be ON.

- Network 12-13: When high level switch is detected, heater will be ON. And when thw heater is on a mixer will also turn on to mix the liquid in the tank and to make it heat equally.
- Network 14: If actual temperature is greater than set temperature, out valve of the tank will be ON.