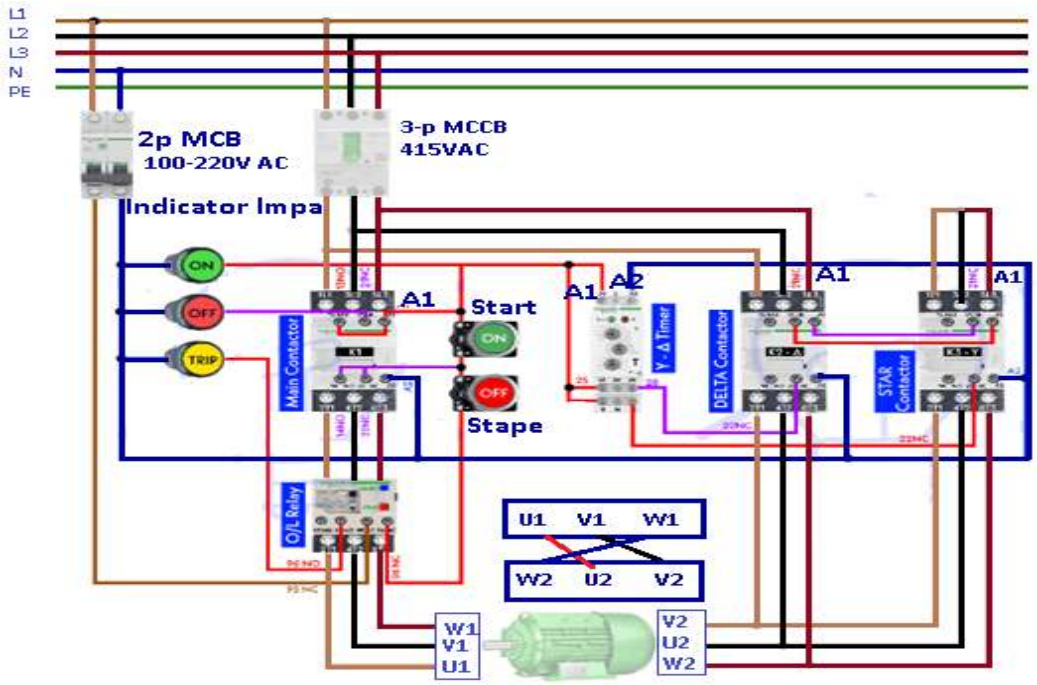
BUILDING ELECTRICAL INSTALLATION LEVEL-III

Based on October 2023, Curriculum Version II



Module Title: - Industrial Motor Control Installation

Module code: EIS BEI3 M4 1023

Nominal duration: 96 Hour

Prepared by:

October, 2023

Addis Ababa, Ethiopia

Contents

Acknowledgment

Ministry of Labor and Skills wish to extend thanks and appreciation to the many representatives of TVET instructors and respective industry experts who donated their time and expertise to the development of this Teaching, Training and Learning Materials (TTLM).

Acronym

EBCS: .....Ethiopian Building Electrical Installation code and Standard

AC:---------- Alternative Current

DC: ---------- Direct Current

IEES:---------- International Electrical Engineers Standard

OH&S:---------- Occupational Health and Safety

MCC: ---------- Motor Control Center

VFD: ---------- Variable Frequency Drive

PLC: ---------- Programmable Logic Controller

HMI: ---------- Human Machine Interface

DOL: ---------- Direct-On-Line Starting

WSD: ---------- Wye-Delta Starting

SCR: ---------- Silicon-Controlled Rectifier

SSR: ---------- Solid State Relay

OCPD:---------- Overcurrent Protection Device

GFCI: ---------- Ground Fault Circuit Interrupter

E-Stop:---------- Emergency Stop

Introduction to the Module

In building electrical installation field, industrial motor control installation is very important for controlling & protecting the motor system installations. It helps to know the basic concepts of industrial motor control devices, selecting criterias, classifications & their symbols of control devices, connection types, motor control system circuits & motor control system installations.

This module is designed to meet the industry requirement under the Building Electrical Installation occupational standard, particularly for the unit of competency: Industrial Motor Control Installation

Module covers the units:

- Introduction to motor control system
- Motor control System installation

Learning Objective of the Module

- Identify motor control devices
- Select and gather motor control devices
- Classify motor control
- Clean /maintain the work place
- Notify completion of work.

Module Instruction

For effective use this modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit
2. Accomplish the Self-checks at the end of each unit
3. Perform Operation Sheets which were provided at the end of units
4. Do the “LAP test” giver at the end of each unit and
5. Read the identified reference book for Examples and exercise

UNIT ONE: MOTOR CONTROL SYSTEM

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Basic concepts of motor control system
- Functions of motor control system
- Characteristics of motor control system
- Types and Symbols of motor control device
- Working principle of motor controlling devices
- Tools, equipment and materials
- Manuals of control device

This unit will also assist you to attain the learning outcomes stated in the in the above unit. Specifically, upon completion of this learning guide, you will be able to:

- Understand basic concepts of motor control system
- Describe functions of motor control system
- Explain characteristics of motor control system
- Identify types and symbols of motor control device
- Explain working principle of motor controlling devices
- Identify tools, equipment and materials
- Understand manuals of control device

1.1. Basic concepts of motor control system

- Motor control system refers to a system or set of mechanisms that regulate and coordinate the movement and operation of motors. These systems are commonly used in various industrial, commercial and residential applications where precise control and automation of motor-driven devices are required.
- Motor control systems typically consist of three main components:
  - I. Motor
  - II. Motor Controller
  - III. Control System

I. Motor:

- The motor itself is the mechanical device responsible for converting electrical energy into mechanical movement. Most electric motors operate through the interaction between an electric motor's magnetic field and winding currents. This interaction generates a force in the form of torque which is applied to the motor's shaft.

A. DC motors

- The name implies, use direct-unidirectional current. It used in special applications where high torque starting or smooth acceleration over a broad speed range is required. The internal parts of the motor is looks like the following

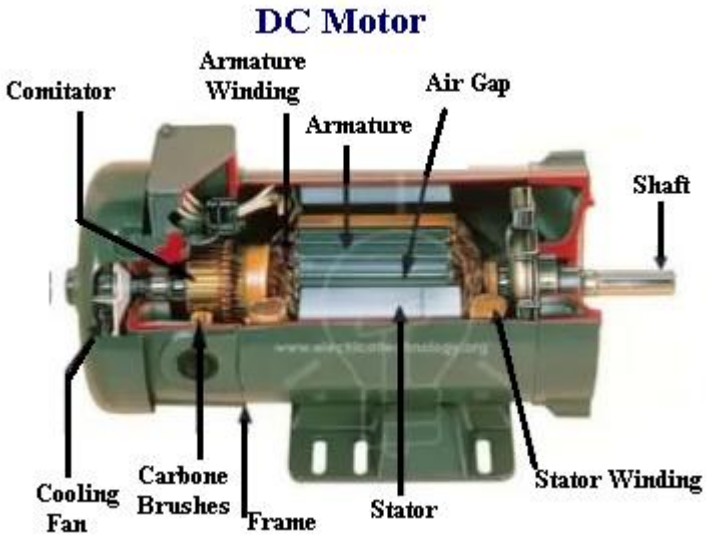


Fig.1.1: Internal parts of DC motor

- **DC Motor is classified as follow**

a. Shunt Motor:-

The rotor and stator windings are conne cted in parallel

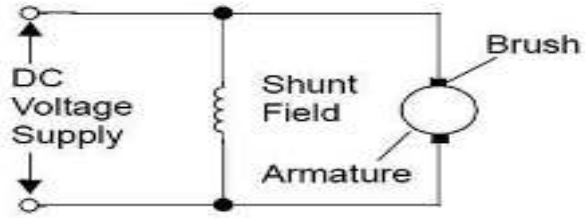


Fig.1.2: Shunt Motor

b. Series Motor:-

the stator and rotor windings are connec ted in series.

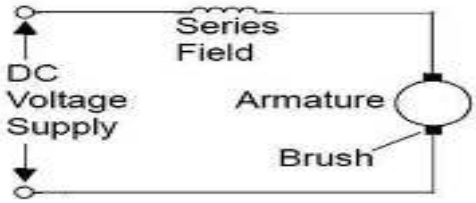


Fig.1.3: Series Motor

c. Compound Motor: -

the stator is connected to the rotor throu gh a compound of shunt and series windings.

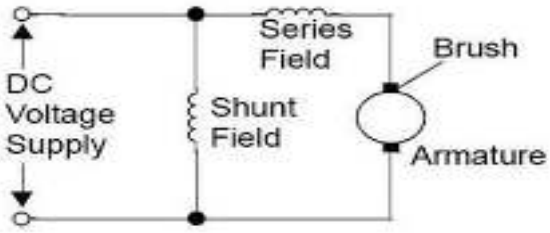


Fig.1.4: Compound Motor

d. Permanent Motor: -

The stator is a permanent magnet, so the motor is smaller in size.

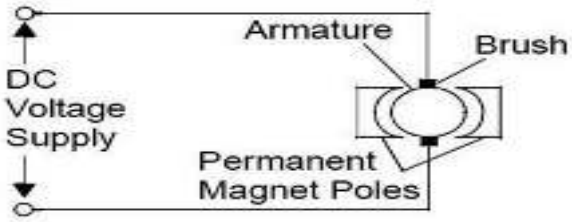


Fig.1.5: Permanent Motor

- The **main advantage** of DC Motor is speed control, which does not affect the quality of power supply. It can be controlled by adjusting:
  - The armature voltage – Increase the armature voltage will increase the speeds.
  - Field current – Reducing the field current will increase the speed.

B. AC motors

- It is an electric machine that converts alternating current into mechanical rotation. It is applicable from large industrial to small household power conversion appliances. The internal parts of the AC motor is looks like the following

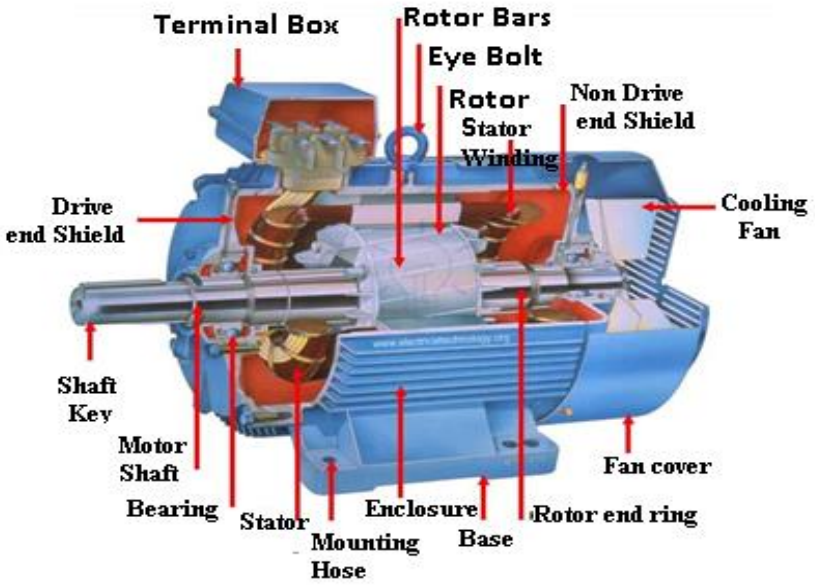


Fig.1.6: Internal parts of AC motor

- It is classified in to two major types. These are various:
  a. Synchronous Motor
  b. Induction motor

a. Synchronous Motor: It always runs at synchronous or no load speed. The speed of this motor is varied by varying the frequency (f) and number of poles (P),

i.e. $N_s = 120\ f/P$.

b. Induction motor: - It is also known as asynchronous motor. It runs at a speed lesser than synchronous speed the rotating torque. Its speed is governed. The actual speed of motor operates will be less than the synchronous speed. The difference between synchronous and full load speed is called slip and is measured in percent.

Induction motor classifies in to two types.

- **Single phase motor**. It is used where three phase power is not available. Typically it is used in residential, commercial & agricultural applications with power requirements below 1HP.
- **Three phase motor:** The name implies that it uses three different voltage sources but the voltage of each sources/lines are almost equal. It requires three pairs of windings 120º apart, energized by voltages that also have a 120- degree phase displacement. The mains system itself consists of the three current-carrying conductors L1, L2 and L3, a neutral

conductor N and the protective earth conductor PE. Its supply voltage is 380V. Most commonly it is used in very large industries application.

II. Motor Controller:

The motor controller is an electronic device that manages the operation of the motor. It receives input signals or commands from a control system and generates the necessary electrical signals to control of the motor's speed, direction, and torque.

III. Control System:

The control system is responsible for providing the desired inputs or commands to the motor controller. It can be a simple manual control interface or a complex automated system.

1.2. Functions of motor control system

The motor control system performs several key functions to ensure the efficient and reliable operation of motors. Here are some important functions of a motor control system:

- **Start and stop the motor:**

  Control system enables the smooth start-up and shutdown of the motors. It ensures proper motor initialization and prevents sudden blows or unexpected stopping.

- **Control the speed:**

  The primary functions of control systems are to regulate the speed of the motor. It is crucial in applications such as industrial machinery, pumps, fans, and conveyors.

- **Motor direction Control:**

  Control systems facilitate the change of motor rotation direction. This function is essential in applications where bidirectional movement is required, such as in motorized actuators, robotics, or conveyor systems.

- **Protecting the motor from damage:**

  Control systems can be used to protect the motor from damage in a variety of ways. For example, motor control systems can be used to prevent the motor from overheating, overcurrent, and short circuit.

- **Monitor the motor's performance:**

Motor control systems can be used to monitor the motor's performance in a variety of ways. For example, motor control systems can be used to monitor the motor's speed, current, voltage, and temperature. Motor control systems can also be used to detect and diagnose problems with the motor.

Motor control systems are used in a wide variety of applications, including:

- Industrial automation
- Robotics
- HVAC systems
- Appliances
- Vehicles

1.3. Characteristics of motor control system

Motor control systems possess several characteristics that contribute to their effectiveness and suitability for controlling motors. Here are some key characteristics of motor control systems:

- **Accuracy:**

  Motor control systems must be able to control the speed and direction of a motor with a high degree of accuracy.

- **Efficiency:**

  Motor control systems should be as efficient as possible. This means that the system should minimize the amount of power lost during the conversion of electrical energy to mechanical energy.

- **Reliability:**

  Motor control systems must be reliable and dependable. They must be able to operate safely and continuously for extended periods of time.

- **Flexibility:**

  Motor control systems should be flexible and adaptable. They should be able to control a wide variety of motors and applications.

- **Cost-effectiveness:**

  Motor control systems should be cost-effective. The system should be affordable to purchase and maintain.

1.4. Types & Symbols of motor control device

1.4.1. Types of motor control devices

- Motor control devices are used to start, stop, control the speed and direction of rotation and protect electric motors.
- They can be classified into the following types:

A. Magnetic starter/contactor starter: It is a device that is used to start, stop and control electric motors. Typically they are applicable in industrial, commercial residential applications.

Fig.1.7: contactor starter

B. Magnetic Contactors: It is an electrically controlled switch used to switch a high-current electrical power circuit. Typically they are applicable to control electric motors, lighting, heating, capacitor banks, thermal evaporators and other electrical loads.

Fig.1.8: Magnetic Contactors

- It consists three parts. These are:
  - **Coil:** The coil is represented by a rectangle with a wavy line inside.
  - **Main contacts**: The main contacts are represented by two parallel lines with a gap between them.
  - **Auxiliary contacts**: The auxiliary contacts are represented by two smaller parallel lines with a gap between them

C. Overload relay: It is a device that protects electric motors from overheating. It does this by monitoring the current flowing through the motor and disconnecting the power supply if the current exceeds a certain threshold.

Fig.1.9: Overload relay

D. Motor terminal block: It is an electrical connector that is used to

connect the wires of an electric motor to the power supply and other control devices.

Fig.1.10: Motor terminal block

E. Timer Relay: It is a device that combines a timer and a relay to provide automatic control of electrical circuits. Timer relays can be used to turn on or off circuits at specific times, or to delay the operation of circuits for a set period of time.

Fig.1.11: Timer Relay

- It is used to control:
  - Motor and equipment in industrial applications, such as conveyor belts pumps and automated production lines.
  - Lighting, heating and ventilation systems in buildings.
  - Lights, sprinklers, alarms, security devices and other devices in homes.

F. Industrial push button: It is a type of electrical switch that is designed for use in industrial applications.

Fig.1.12: Industrial push buttons

- They are available in a variety of different configurations, including:
  - **Normally open (NO)**: NO push button is operating when the button is pressed and breaks when the button is released.
  - **Normally closed (NC):** NC push buttons are closed when they are not pressed, and they open when they are pressed.

G. Fuse: It is an electrical safety device that protects electrical circuits from overcurrent. Fuses work by melting a thin strip of metal when the current flowing through the circuit exceeds a

certain threshold. This disconnects the circuit and prevents damage to the electrical wiring and equipment.

Fig.1.13: Fuses

H. Circuit breaker: It is an automatically operated electrical switch that protects electrical circuits from damage caused by overload or short circuit. Its basic function is to disconnect the circuit when the current exceeds a certain safe value.

Fig.1.14: Circuit breaker

- Circuit breakers are used in a wide variety of applications, including:
  - Electrical panels in residential and commercial buildings
  - Industrial control systems
  - Motor control centers
  - Power distribution systems

I. Selector switch

The cam switch is also called a combination switch. It is different from the operation of the knife switch. It is a plane operation that rotates left and right. It consists of an operating mechanism, a panel, a handle, and several contact seats.

Fig.1.15: selector switch

The terminals on a selector switch are typically numbered, with each terminal corresponding to a different position of the switch. For example, a 3-position selector switch will have three terminals, numbered 1, 2, and 3. When the switch is in position 1, terminal 1 will be connected to the common terminal (C). When the switch is in position 2, terminal 2 will be connected to the common terminal. And when the switch is in position 3, terminal 3 will be connected to the common terminal.

Fig.1.16: Selector switch terminals

The common terminal is typically connected to the power source. The other terminals are connected to the devices that you want to control with the selector switch.

For example, if you have a selector switch that you want to use to control two motors, you would connect the common terminal to the power source. Then, you would connect one terminal to the first motor and the other terminal to the second motor. When you turn the selector switch to position 1, the first motor will turn on. When you turn the selector switch to position 2, the second motor will turn on.

Selector switches can be used to control a variety of different devices, such as motors, lights, and fans. They can also be used to select different modes of operation for a single device. For example, a selector switch could be used to select between different speeds for a fan or different brightness levels for a light

J. Indicator lights

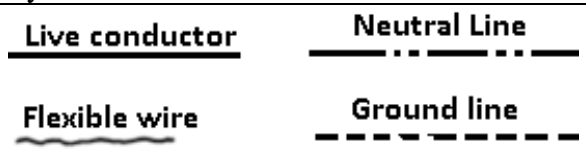
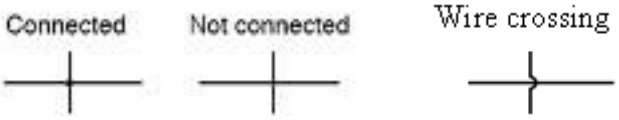
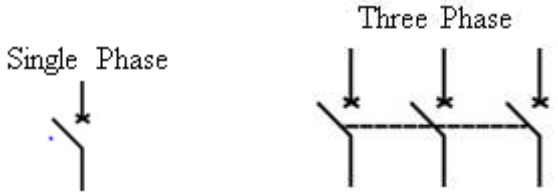
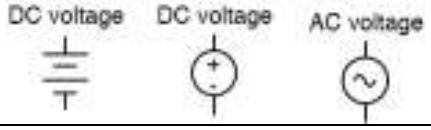
- The role of the indicator light:
- 1. Indicate the running or stopping status of the equipment.

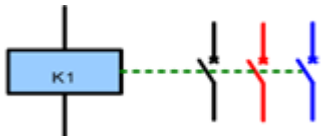
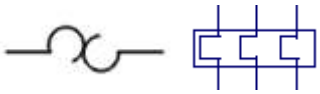
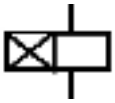
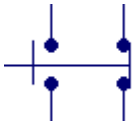
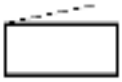
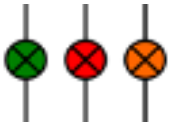
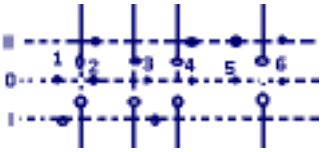
- 2. Monitor whether the power supply of the control appliance is normal.
- 3. Use the red light to monitor whether the trip circuit is normal, and use the green light to monitor whether the closing circuit is normal.

Fig.1.17: Indicator lights

1.4.2. Symbols of motor control devices

Table 1.1: Symbols of motor control devices

No	Items	Symbol
1	wire symbol	
2	Connection symbols	
	Circuit breaker	
4	Supply symbols	
5	Isolator Switch Disconnector	
6	Fuse	

7	Contactor	
8	Overload Relay	
9	Timer	
10	Push button	
11	Danger symbols	
12	Switch board symbol	
13	Main switch symbol	
14	Regulator symbol	
15	Light indicator	
16	selector switch	
	Motor general symbol 1Ø motor 3Ø motor	

1.5. Working principle of motor control devices

There are many different types of motor control devices, but they all work on the same basic principle: they use electrical power to control the flow of current to the motor. By controlling the current flow, the motor control device can control the speed, direction, and torque of the motor. Here are some of the most common controlling devices and how they work:

- **Contactors:** It work by using a coil to create a magnetic field that pulls the contactor's contacts together, closing the circuit and allowing current to flow to the motor.
- **Overload relays:** Typically it work by using a bimetallic strip, which is a strip of metal that bends when it is heated. If the current flowing through the motor exceeds the overload relay's setting, the bimetallic strip will bend and open the overload relay's contacts, disconnecting the power supply to the motor.
- **Circuit breakers**: It works by using a bimetallic strip and a magnetic coil. If the current flowing through the circuit exceeds the circuit breaker's setting, the bimetallic strip will bend and open the circuit breaker's contacts, disconnecting the power supply to the circuit. If there is a short circuit in the circuit, the magnetic coil will create a strong magnetic field that will trip the circuit breaker and disconnect the power supply to the circuit.
- **Push buttons**: It works by closing or opening a circuit when the button is pressed.
- **Limit switches**: Limit switches are switches that are activated by the movement of a machine or object. Limit switches are often used to control the operation of electric motors and other devices.
- **Selector switches**: Selector switches are switches that allow the user to select between different circuits or devices. Selector switches are often used to control the operation of electric motors and other devices.
- **Timer relays**: Timer relays are devices that combine a timer and a relay to provide automatic control of electrical circuits. Timer relays can be used to turn on or off circuits at specific times, or to delay the operation of circuits for a set period of time.

1.6. OHS Requirement

Occupational Health and Safety requirements for motor control systems are designed to creat safe working environment protect workers & systems from injury.

The most common OHS requirements for motor control systems are:

- All motor control systems must be designed and installed in accordance with the OHS Act) and Regulations.
- All motor control systems must be properly maintained and inspected on a regular basis.
- All motor control systems must be operated in a safe manner.
- All motor control systems must be properly labeled and identified.
- All motor control systems must be accessible for maintenance and inspection.

In addition to general requirements, there is a specific OHS requirement for motor control systems in certain industries or applications. These are:

- Use qualified personnel to design, install, and maintain your motor control system.
- Use high-quality components in your motor control system. This will help to reduce the risk of component failure and electrical shock.
- Provide adequate training to all employees who operate or maintain the motor control system.
- Have a regular inspection and maintenance schedule.

1.7. Tools, equipment and materials

Tools: Tools refer to manual and electric-powered tools respectively, designed to assist construction workers, carpenters, and other manual laborers in the performance of work. While hand and power tools are a big help, they pose various physical hazards which can cause both minor and major injuries if not guarded against.

Table 1.2: Tools, equipment and materials

No,	Materials		
	Type of tool, equipments & materials	**Function of tools**	**Name**
	Connecting material	• Used to connect control devices	Electrical wire
	Source	• Used as a source of power	Industrial socket
		• Used as a bridge and protect short circuit	Terminals & Connectors
	Protection &	• Used to protect the system from overload current	Fuses

	controlling devices	• Used to control & protect the system and motor	Circuit breakers
			Overload relays
		• Used to switching a power circuit	Contactors
	Indicators	• Used to indicate the condition of the system	Indicator lamp
	Tools & Equipments		
1	Measuring & testing tool & equipments	• Used to measure the length wire/cable • Used to test the functionalities of control devices, control & power circuits & motor terminals • Used to measure the speed of the motor • Used to measure line current & Voltage	• Tap-meter • Neon tester • Multi-meter • Tachometer • clamp meter, • Phase sequence tester •
2	Cutting & splicing tool	• Used to cut sheath from non-metallic cable, to cut off electrical tape, and to open cardboard boxes. • Used to cute the wire and conduit. • Used to join or connect the wire /cables.	• Pliers (Combination plier, side cutter) • Wire striper & Electrician knife • Hacksaw
3	Fastening Tools	• Used to tighten or loose screws • Used to striking the chisel and cut the nails and screws	• Screw drivers such as Philips & flat. • Hammers

1.8. Manuals of control device

Motor control device manuals are documents that provide information on the installation, operation, and maintenance of motor control devices.

1.8.1. Manufacturer's Specification Manuals

Manufacturer's specification manuals give informations about:

- **Device type and model number**: This information is essential for identifying the correct replacement parts and troubleshooting procedures.
- **Electrical ratings**: This information includes the voltage and current ratings of the device, as well as the maximum motor horsepower that it can control.
- **Physical dimensions**: This information is helpful for determining if the device will fit in the available space.
- **Wiring diagrams**: These diagrams show how to connect the device to the motor and power supply.
- Operating instructions: These instructions explain how to use the device safely and effectively.

1.8.2. Repair Manual

Repair manuals give informations about:

- **Common problems and troubleshooting procedures**: This information can help to identify the cause of a problem and determine the appropriate solution.
- **Disassembly and assembly instructions**: These instructions explain how to disassemble and assemble the device safely and correctly.
- **Repair procedures**: These procedures step-by-step instructions on how to repair common problems.
- **Parts list**: This list provides the part numbers and descriptions of all of the components in the device.

1.8.3. Maintenance Procedure Manual

Maintenance procedure manuals give informations about:

- **Recommended maintenance schedule**: This schedule tells the user how often to perform specific maintenance tasks.
- **Maintenance tasks**: These tasks may include things like cleaning the device, inspecting the wiring, and testing the operation of the device.
- **Instructions on how to perform the maintenance tasks**: These instructions explain how to perform each maintenance task safely and correctly.

1.8.4. Periodic Maintenance Manual

It includes the same information as maintenance procedure manuals, but they are specific to a particular period of time, such as monthly, quarterly, or annually.

1.8.5. Quality Manual

Quality manuals for motor control devices typically include the following information:

- **Quality control procedures**: These procedures describe how the manufacturer ensures the quality of its products.
- **Testing procedures**: These procedures describe how the manufacturer tests its products to ensure that they meet its quality standards.
- **Inspection procedures**: These procedures describe how the manufacturer inspects its products to identify and correct any defects.

1.8.6. Manual of Instruction

Manuals of instruction Maintenance procedure manuals give informations about:

- **Safety precautions**: This information explains how to use the device safely.
- **Operating instructions**: These instructions explain how to use the device to control the motor.
- **Troubleshooting procedures**: This information can help to identify the cause of a problem and determine the appropriate solution.

Self-check #1

I. <u>Choose the best answer from the give alterative</u>

1. What is the main purpose of a motor control system?

   A. To control the speed and direction of a motor.

   B. To protect the motor from damage.

C. To both control the speed and direction of a motor, and protect it from damage.

D. None of the above.

2. What are the three main types of motor control systems?

A. Contactors, overload relays, and circuit breakers.

B. Manual, automatic, and semi-automatic.

C. Open-loop and closed-loop. D. AC and DC.

3. What are the five main functions of a motor control system?

A. Starting, stopping, reversing, speed control, and protection.

B. Switching, monitoring, regulating, controlling, and protecting.

C. Energizing, de-energizing, rotating, stopping, and protecting.

D. None of the above.

4. What are the three main characteristics of a motor control system?

A. Reliability, durability, and safety. B. Efficiency, flexibility, and accuracy.

C. Both reliability, durability, and safety, and efficiency, flexibility, and accuracy.

D. None of the above.

5. What is the most common type of motor control device?

A. Contactor. B. Overload relay. C. Circuit breaker. D. Push button.

6. What is the purpose of an overload relay?

A. To start the motor. C. To protect the motor from overheating.

B. To stop the motor. D. To reverse the direction of the motor.

7. What is the symbol for a contactor?

A. A circle with a line through it. C. A square with a line through it.

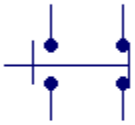
B. A triangle with a line through it. D. A rectangle with a line through it.

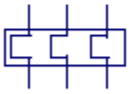
II. Mach column "B" to column "A"

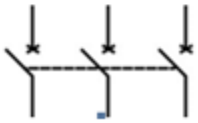
A **B**

1. 

2. 

3. 

4. 

5. 

A. Circuit breaker

B. Overload Relay

C. Isolator Switch Disconnector

D. Fuse

E. Contactor

F. Push button

III. <u>Give short ad precise answers for the following questions</u>

1. What are the three main types of motor control systems?
   A. Contactors
   B. Overload relays
   C. Circuit breakers
2. What are the five main characteristics of a motor control system?
   A. Reliability
   B. Durability
   C. Safety
   D. Efficiency
   E. Flexibility
3. What are the three main tools and equipment used to install and maintain motor control systems?
   A. Multimeter
   B. Voltage tester
   C. Screwdriver

Operation sheet #1

Operation Title: Identifying motor control devices and their symbols

Instruction: Using the Flip chart and given equipments Identifying Electrical Symbol Used in Motor Controls instructor must check the circuit before you applies power.

Purpose: When you have completed this Unit, the trainee should be able to identify the electrical symbols used in motor controls.

Required tools and equipment: unit one of this module, tools from workshops like screw drivers, pliers, measuring instrument,

Precautions:

- Safe handling of hand tools, testing instruments and components

Procedures:

Step 1: Properly identify motor control devices

Step 2: Prepare electrical symbols for the given task

Quality criteria: Reading the circuit properly, safety procedures were followed & all hand tools were cleaned

LAP Test # 1

Name: _____ Date: _____

Time started: _____ Time finished: _____

Instruction I: Given necessary templates, tools and materials you are required to perform the following tasks within 5 hours.

Task 1: Identify motor control devices properly
Task 2- Prepare electrical symbols for the given task

UNIT TWO: MOTOR CONTROL INSTALLATION

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Selection of motor control device
- motor control circuits
- Functionality test of motor control devices.
- Installation of motors control system
- Quality assurance & inspection

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Select of motor control device
- Apply motor control system circuits
- Perform functionality test of motor control devices.
- Install motors control system
- Inspect & assure quality of work

2.1. Selection of motor control device

The selection of motor control devices is a critical aspect of designing and implementing a motor control system. The right selection ensures efficient and reliable motor operation.

When selecting the right motor control components for your application, it is important to consider the following factors:

- **Motor type and rating**: The first step is to identify the type and rating of the motor that you need to control. This includes the motor's voltage, current, horsepower, and speed.
- **Control requirements**: What features do you need in your motor control system? For example, do you need to be able to start and stop the motor, control its speed, or reverse its direction?
- **Environment:** Where will the motor control system be installed? Consider the temperature range, humidity, and other environmental factors.
- **Budget**: How much are you willing to spend on motor control components?

Once these factors have been considered, the following steps can be used to select the appropriate motor control devices:

- Identify the type of motor control device required.
- Select the appropriate size motor control device.
- Select the motor control device features.
- Select the motor control device enclosure.

Examples:

- Starters: Starters are used to start and stop AC motors. They are typically used for smaller motors (up to 100 horsepower).
- Contactors: Contactors are also used to start and stop AC motors. They are typically used for larger motors (over 100 horsepower).
- VFDs: Variable frequency drives (VFDs) are used to control the speed and torque of AC motors. They can be used to start and stop motors, as well as to control the speed of motors while they are running.

Note:

The selection of the appropriate motor control devices is important for the safe and reliable operation of electric motors. By following the steps outlined above, you can select the correct motor control devices for your application.

2.2. Motor control circuits

Motor control circuits are electrical circuits that are used to control the operation of electric motors. It is responsible for turning the motor on and off, and for providing protection against overcurrent and other faults. It is typically powered by a lower voltage than the power circuit, and it uses a contactor or motor starter to control the flow of power to the motor.

It includes:

- Control Circuit
- Power Circuit

The induction motor draws a high amount of current at startup. This starting current can damage the motor windings. In order to avoid any damage, we use different techniques to reduce the starting current using Motor Starter. These techniques depend on the motor ratings and the load connected to the motor. Apart from this, the motor starter also protects the motor from overloading and overcurrent.

Control circuits are used to start, stop, and reverse the direction of motor rotation. They are also used to protect the motor from overcurrent and other faults. Control circuits are typically powered by a lower voltage than power circuits, and they use a contactor or motor starter to control the flow of power to the motor. Some common types of control circuits are:

I. Direct on line (across the line) starter

A. Definition: The DOL starter employs full voltage or across the line starting technique where the motor is directly connected to full voltage through MCCB or circuit breaker and relays for overload protection. This is why such a starter is used with induction motors rated below 5 hp. In direct online starter method of motor starting, the motor stator windings is directly connected to the main supply where the DOL protect the motor circuit from high

inrush current which may damage the overall circuit as the initial current is much more higher than the full rated current.

B. Construction of DOL Starter circuits

- **Push buttons**; Green and Red.

Where: - Green button - used for starting. It connects the terminals and closes the circuit

- Red - used for stopping. It disconnects the terminals and breaks the circuit.

- **Circuit breaker (MCCB) or fuse**. It is directly connected to the power mains and it is used for protection against short circuits. It trips the power supply in case of short circuit to protect the system from any potential hazards.
- **Overload relay**. It is the last part used in the DOL starter and it is used for protection against overloading of motor.
- **Magnetic Contactor or coil**. It is an electromagnetic switch that operates electromagnetically to switch the power supplied to the motor.
  Look at the following

C. Working of DOL Starter

- The DOL starter connects the 3 phase voltage supply i.e. R-phase, Y-phase and B-phase to the induction motor terminals.
- There are two types of circuits in the DOL starter diagram given above; the control circuit and the power circuit.

D. Control circuit

- It is powered by only 2 phases of the power supply and it is responsible for starting and stopping the power supplied to the motor.
- The green start button and red stop button is connected inside the control circuit. Pressing the green button for an instant starts the motor and the power is supplied when it is released. Pushing the red button stops the power supply and stops the motor

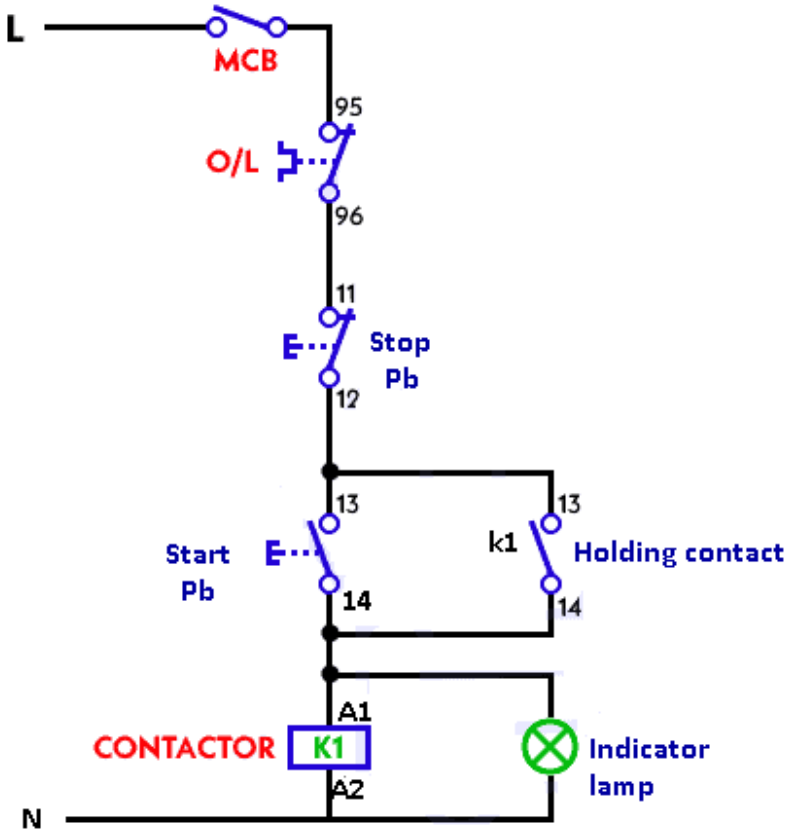


Fig. 2.1: DOL Control circuit

a. Power circuit

The power circuit of direct-on-line (DOL) motor control is a simple and effective way to control the operation of an electric motor.

- It consists of the following components:
  - A power supply (typically a three-phase AC supply)
  - Three phase Fuse
  - A contactor
  - An overload relay
  - A motor
- The power circuit of DOL motor control is wired as follows:
  - The power supply is connected to the line terminals of the fuse.
  - The load terminals of the fuse connected to the line terminals of the contactor.
  - The load terminals of the contactor are connected to the motor terminals.
  - The overload relay is connected in series with the contactor of the motor. See fig.2.9

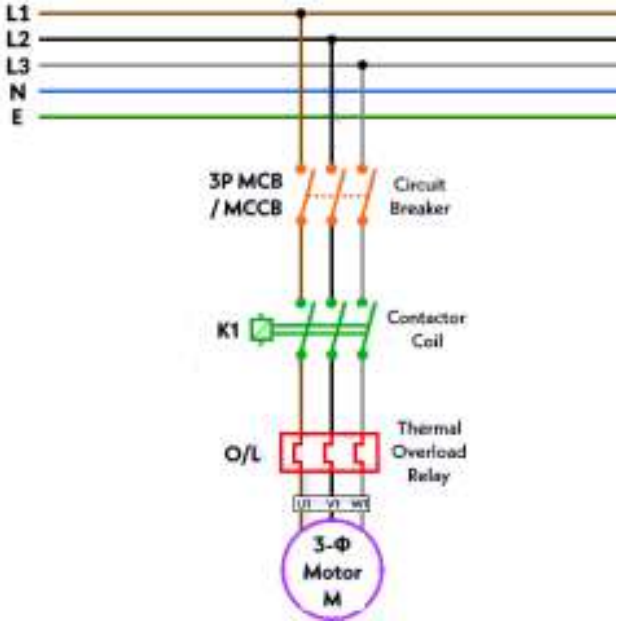


Fig. 2.2: Power circuit of DOL motor control circuit

- Typically it is controlled by a push button switch. When the push button switch is pressed, the contactor is energized and the motor starts to run. When the push button switch is released, the contactor is de-energized and the motor stops running.

b. **Advantages of DOL motor control**:

- It is very simple to design, operate and maintain.
- It is the most cheapest and economical starter.
- It has a compact design and occupies less space.
- It provides 100% of the starting torque.
- The control circuit (green and red button) is simple and a layperson can operate it.
- Understanding and troubleshooting the system is easier.
- It connects the delta winding of the motor

c. Disadvantages of DOL motor control

- As it utilizes full voltage starting technique, the starting current is very high.
- The starting high current may damage the motor thus only low rating motors should be used.
- The high inrush current causes a voltage dip in the power lines that can be dangerous for other appliances connected in parallel.
- The high starting torque can be unnecessary in some cases.

- High starting torque causes mechanical stress reducing the life span of the motor itself.
- There is no control over the starting current and torque.

d. Applications:

- The DOL starters are used for motor having low power ratings.
- Where the starting current does not damage the windings of the motor.
- For applications where the starting current does not cause huge dips in the line voltage.
- Direct online starters are used for small water pumps, conveyor belts, fans and compressors.

II. Forward-reverse control circuit

A. Definition: It is a type of motor circuit that allows a motor to be rotated in either the forward or reverse direction.

B. Construction of forward and revers Starter circuits

The construction of forward and revers Starter circuits is similar to direct online circuit the only difference is additionally use one green push button and one contactor for reversing the motor direction and use timers in order to automate the system. It is directly connected to the power mains and it is used for protection against short circuits. It trips the power supply in case of short circuit to protect the system from any potential hazards.

C. Working principle

It consists of two contactors, one for forward rotation and the other for reverse rotation. The contactors are wired so that only one contactor can be energized at a time. When the forward contactor is energized, the motor rotates in the forward direction. When the reverse contactor is energized, the motor rotates in the reverse direction.

The forward-reverse motor control starter is typically controlled by a set of two push buttons, one for forward and one for reverse. When the forward push button is pressed, the forward contactor is energized and the motor rotates in the forward direction. When the reverse push button is pressed, the reverse contactor is energized and the motor rotates in the reverse direction.

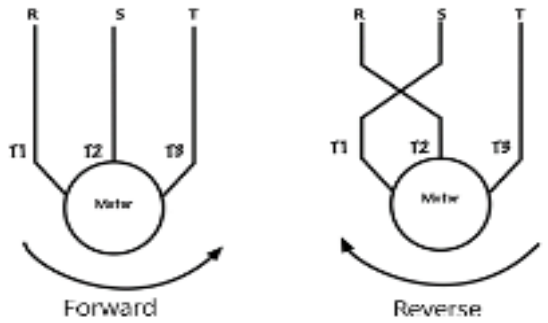


Fig. 2.3: working principles of forward-reverse motor control circuit

a. Control circuit

The figure below is a basic control circuit diagram for reversing a three-phase motor using a three-position switch.

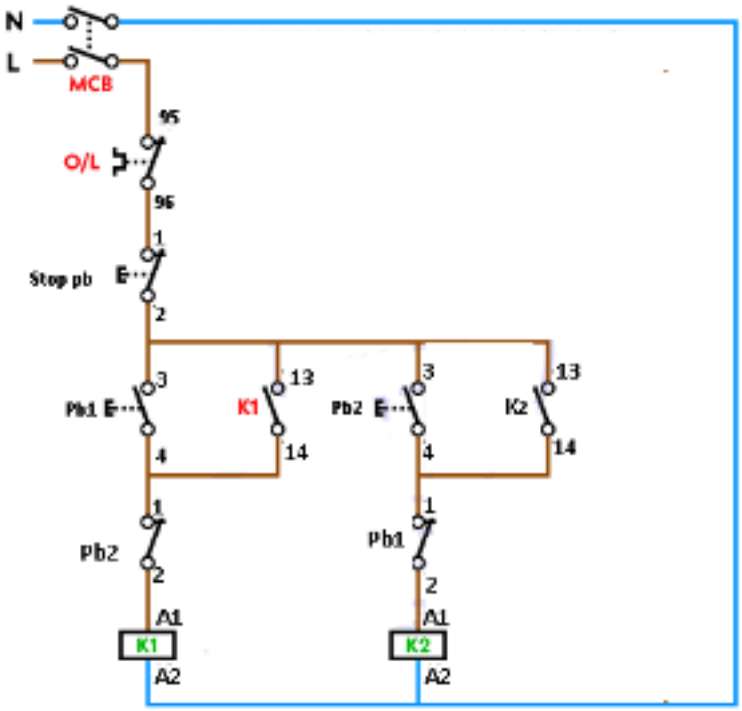


Fig. 2.4: forward-reverse motor control circuit

b. Power circuit

It is similar to the power circuit of a DOL motor control system, but it includes two contactors, one for forward rotation and one for reverse rotation. It is controlled by two push buttons, one for forward and one for reverse.

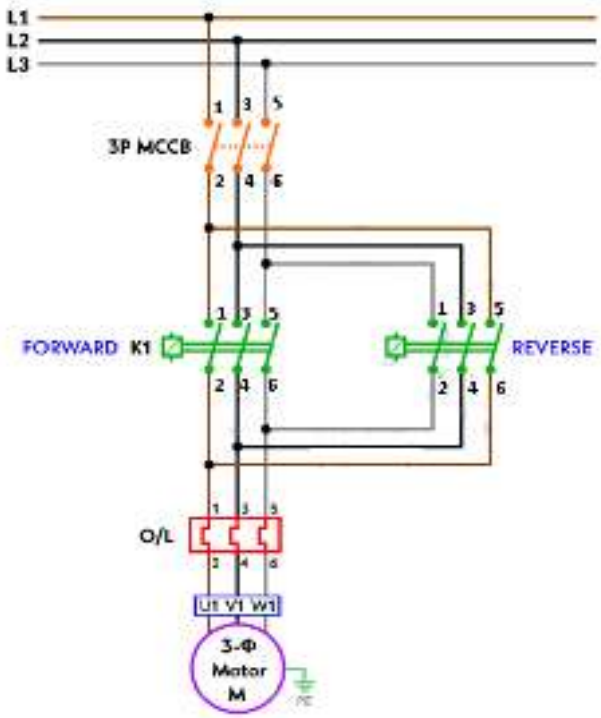


Fig. 2.5: Power circuit of forward-reverse motor control circuit

D. Advantages of forward-reverse motor control:

- It allows the motor to be operated in both forward and reverse directions, making it versatile and flexible.
- It provides a simple and cost-effective way of controlling the direction of rotation of a motor.
- It is easy to install and requires minimal maintenance

E. Disadvantages of forward-reverse motor control:

- More complex and expensive than DOL motor control
- Requires more wiring

F. Applications of forward-reverse motor control:

- Conveyor systems
- Cranes and hoists
- Pumps and compressors
- Machine tools
- Fans and blowers

III. Sequential motor control system Circuit: It is a type of motor starter that allows motors to be started in a sequence. This can be necessary for applications where the motors must be started in a specific order to prevent damage to the equipment or to ensure proper operation. It implements in two common methods

A. Working of Sequential Motor Control Circuit

The working of a sequential motor control circuit is relatively simple. The control circuit first activates the first motor in the sequence by sending a signal to the associated starter, contactor and relay. Once the relay receives the signal, it switches on the power to the motor, causing it to start running.

When the first motor reaches a specific set point or condition, it sends a signal to the control circuit to switch off the power to the first motor and activate the second motor in the sequence. This signal can be generated by a timer or a sensor that detects the first motor's state.

i.e. Timer delay and Interlock

B. Sequential Motor Control Circuit

a. Control Circuit.

This sequential circuit diagram is designed to operate three motors in sequence using ON and OFF buttons to control automatically the starting and stopping operation of each three phase motor with the help of timers.

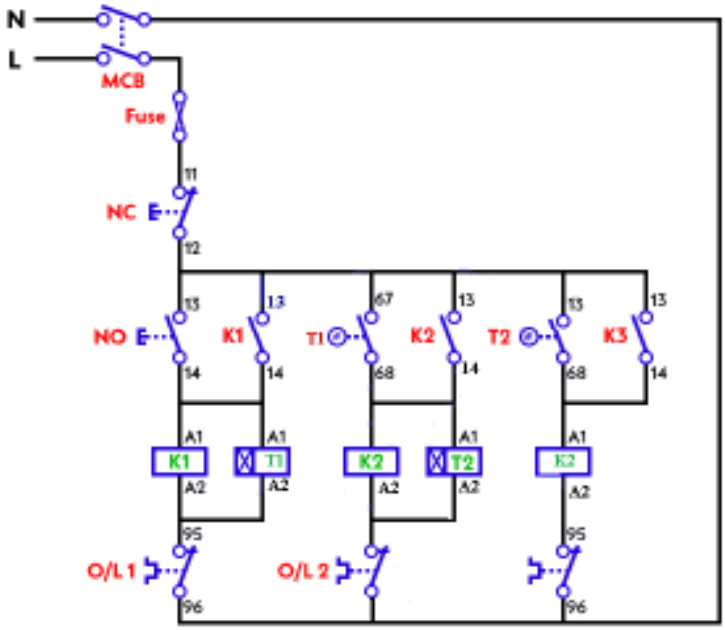


Fig. 2.6: Sequential motor control circuit

b. Power circuit

In the power circuit diagram, each motor is connected to a separate contactor with thermal overload relay. Two timers (T1 & T2) are used with M1 and M2.

- In this arrangement, the coil of first Timer “T1” is connected in parallel with the coil of Contactor “KM2”, while the timer coil “T1” is in series with the normally closed contact of “KM2”. As a result, when Contactor “KM2” is energized, the timer will be disconnected from the power supply, but Contactor “KM1” will remain active.
- The automatic operation of the circuit is as follow.
  - 3-Φ Motor “M1” is controlled by a set of push buttons, including an “ON” and “OFF” button.
  - Three phase Motor 2 “M2” is controlled by the Timer “T1” and connected in series to the ON button.
  - 3-Phase Motor 3 “M3” is controlled by the Timer “T2” and connected in series with ON button.

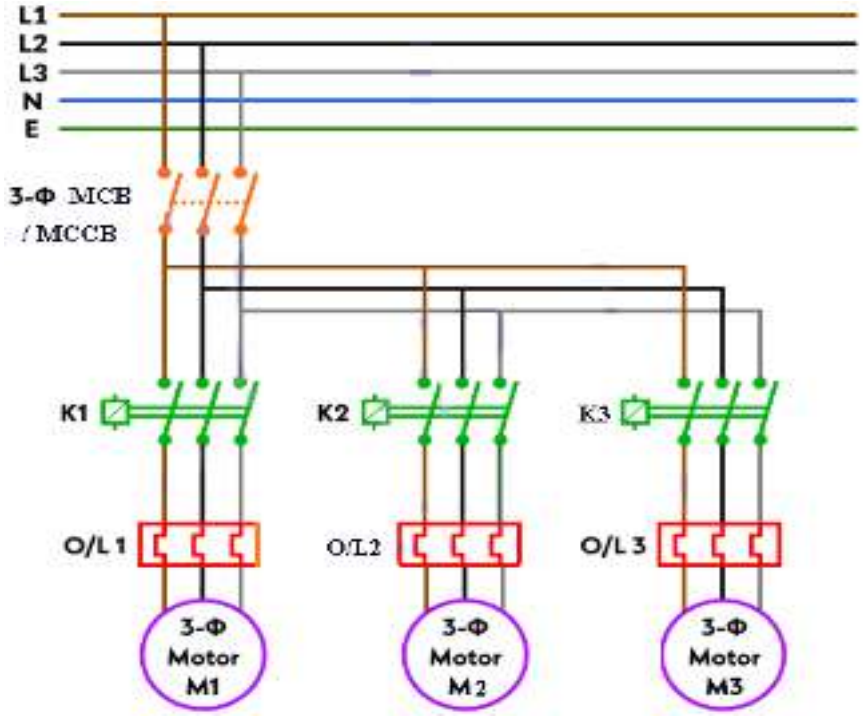


Fig. 2.7: Power circuit of sequential motor control circuit

- The sequence of operation of the three phase motors is as follow:
  - The operation of Motor “M2” and Motor “M3” is dependent on the running status of Motor “M1”.
  - Motor “M2” can only run when Motor “M1” is already in operation.
  - Motor “M3” can only operate when both Motor “M1” and Motor “M2” are already running.

- **Applications:-** It is applicable in:

a. Conveyor belts
b. Machine tools
c. Pumps
d. Fans
e. Air conditioners
f. Refrigeration systems

IV. Stare-delta motor control circuit

A. **Definition**: A star-delta motor control circuit is a type of motor starter that reduces the starting current of a motor by connecting the motor windings in a star configuration during start-up and then switching to a delta configuration once the motor has reached a certain speed.

B. **Types of** Stare-delta motor control circuit

a. Control circuit

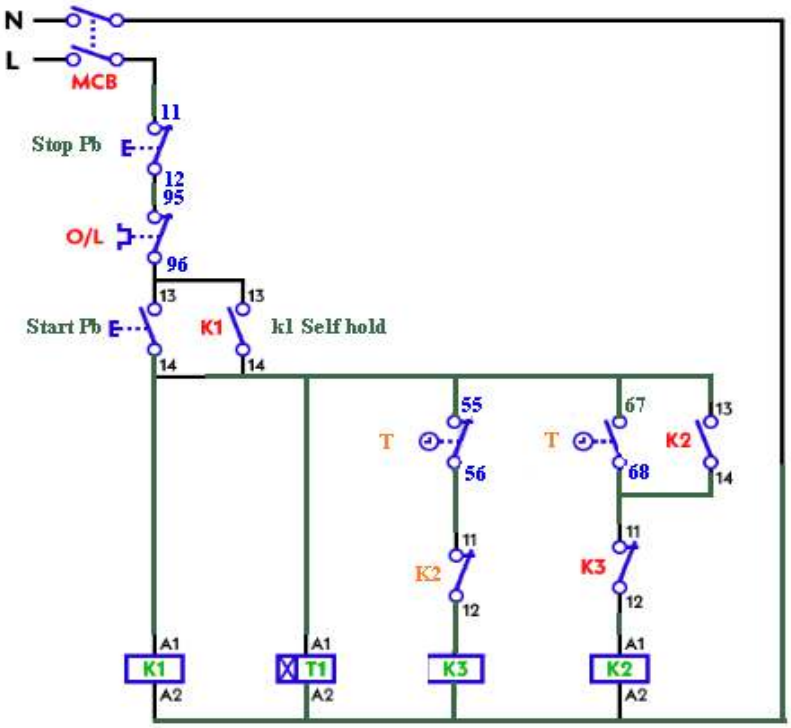


Fig. 2.8: Power circuit of star-delta motor control circuit

b. Power circuit

It is a type of motor control circuit that is used to reduce the starting current of a motor. It does this by connecting the motor windings in a star configuration during start-up and then switching to a delta configuration once the motor has reached a certain speed. See fig. 2.13

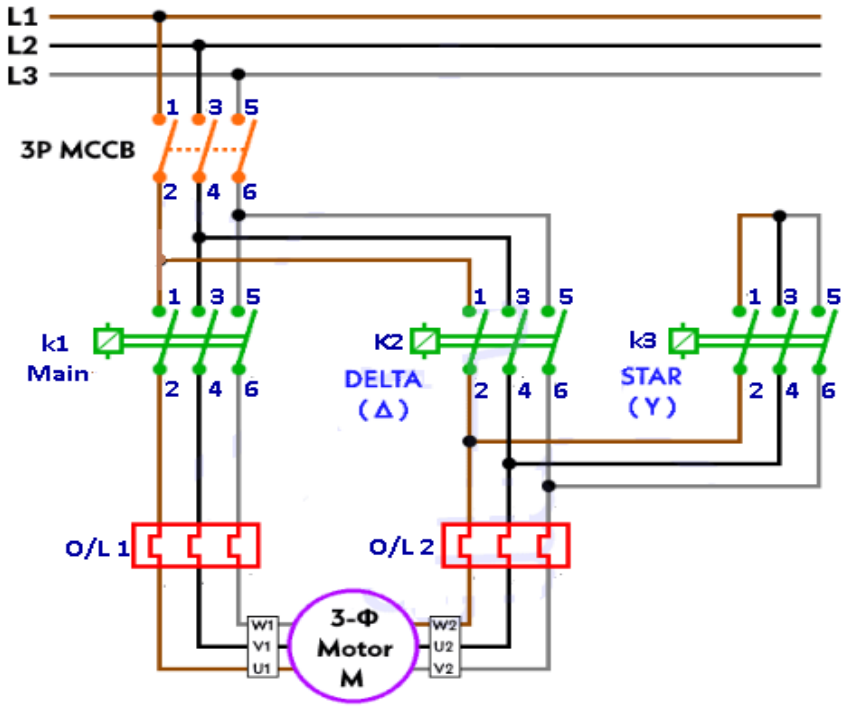


Fig. 2.9: Power circuit of Star-delta motor control circuit

Look Before discussing about the control circuit you must know star & delta connections. Motor is at the end start to run using either star, delta or star-delta connections.

I. Star connection

It obtained by joining together similar ends of coils either "starting" or finishing. The other ends are joined to the line wires. The common point is called the Neutral or Star Point. It is used in power distribution, transformers and small scale domestic and residential applications. It is known as **three Phase four wire system** (**3-Phase 4 Wire**) and it is the most preferred system for AC power distribution while for transmission.

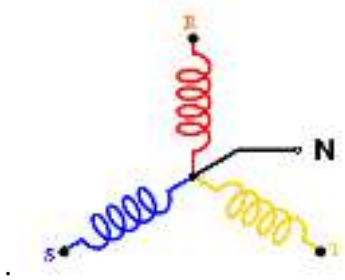


Fig. 2.10: Star connection

V. In star connection

- Line Current is Equal to the Phase Current. i.e.

- ✓ Line Current = Phase Current
- ✓ $I_L = I_{PH}$

- Line Voltage is √3 times of Phase Voltage. i.e.
  - ✓ Line Voltage = √3 × Phase Voltage
  - ✓ $VL = \sqrt{3} \times V_{PH}$
- The total Power supplied by three Phases could be found by:
  - ✓ $P = \sqrt{3} \times V_L \times I_L \times \text{Cos } \Phi$ … Or
  - ✓ $P = 3 \times V_{PH} \times I_{PH} \times \text{Cos } \Phi$
  - ✓ $P = \sqrt{3} \times V \times I$
- The speeds of Star connected motors are slower as they receive 1/√3 voltage.
- Smooth starting and operation with nominal power and normal operation without overheating can be achieved.
- The phase voltage is low as 1/√3 of the line voltage. Therefore, it needs a low number of turns, hence saving in copper.
- Low insulation required as phase voltage is low as compared to Delta.
- Star connection is preferred for long distance transmission and distribution as it requires low insulation and has a Neutral which helps to balance the circuit.
- Two different voltage levels can be achieved by using star connection i.e. single phase and three phase supply.
- It is preferably used in the domestic and residential applications for single phase supply (Line or Phase + Neutral = 220V AC) and three phase supply (Three Phases = 380V AC-EBCS).
- Star connection is commonly used for appliances which need less amount of starting current e.g. small load applications.
- Star connection is commonly used for appliances which need less amount of starting current e.g. small load applications.

II. Delta connection

The opposite ends of three coils are connected together which forms the shape of Greek alphabet "Δ". In other words, the end of each coil is connected with the starting point of another coil, and the common joints form the three phase wires. No Neutral Point in Delta Connection. There are three conductors in the delta connection (3 Phase Wires e.g. All are phases).

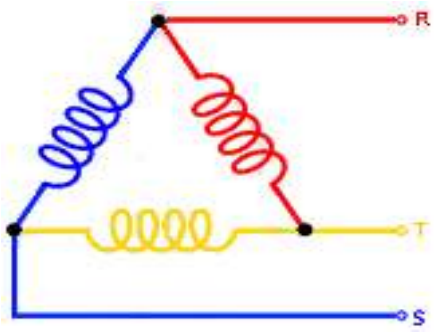


Fig. 2.11: Delta connection

In Delta Connection:

- Line Current is √3 times of Phase Current. i.e.
  - ✓ Line Current = √3 × Phase Current
  - ✓ $I_L = \sqrt{3} \times I_{PH}$
- Line Voltage is Equal to the Phase Voltage. i.e.
  - ✓ Line Voltage = Phase Voltage
  - ✓ $VL = V_{PH}$
- The total Power of three phases could be found by:
  - ✓ P = √3 × VL × IL × Cos Φ … Or
  - ✓ P = 3 x VPH x IPH x Cos Φ
  - ✓ P = 3 × V × I
- The speeds of Delta connected motors are high because each phase gets the total of line voltage.
- Motor receives the highest power output.
- The phase voltage is equal to the line voltage; hence it needs more turns which increase the total cost.
- More insulation is required as Phase voltage = Line Voltage.
- It is preferred for shorter distance transmission and distribution as it requires more insulation and has the problems of unbalanced currents.

- Generally It is used in the industrial and commercial applications for three phase supply (Three Phases = 380V AC – EBCS).

C. Advantages of a star-delta motor control Circuit

- Reduced starting current: The starting current of a motor is typically 5-7 times the running current. A star-delta motor control starter can reduce the starting current by up to 60%. This can help to prevent the motor from tripping circuit breakers or overloading the electrical system.
- Improved motor life: The reduced starting current can also help to extend the life of the motor by reducing wear and tear on the windings.
- Reduced voltage sag: A star-delta motor control starter can also help to reduce voltage sag, which can occur when a large motor is started. This can help to prevent other equipment from being affected by the voltage sag.

D. Disadvantages of a star-delta motor control circuit

- Increased cost: A star-delta motor control starter is more expensive than a direct-on-line (DOL) motor starter.
- Increased complexity: star-delta motor control starter is more complex than a DOL motor starter, which can make it more difficult to install and maintain. Applications of star-delta motor power circuits:
- Star-delta motor power circuits are typically used for large motors (over 10 horsepower) that are used in applications where a smooth start is important, such as pumps, fans, and compressors.

2.3. Functionality test of motor control devices.

Functionality testing is an important part of ensuring the safe and reliable operation of motor control devices. By performing these tests, engineers and technicians can identify and correct problems with the motor control devices before they cause a failure.

To test the functionality of motor control devices before installing, you can follow these steps:

1. **Prepare the test area**: Make sure that the test area is clean and well-lit. Disconnect all power to the motor control device before starting the test.
2. **Gather the necessary tools and equipment**: You will need a multimeter, a voltage tester, and a current tester. You may also need a test motor and a motor control test simulator, depending on the type of motor control device being tested.

3. Gather data /informations about the operation
4. **Identify the test points**: The test points for the motor control device will vary depending on the type of device. Consult the manufacturer's instructions to identify the test points.
5. **Inspect the device visually**. Look for any signs of damage physically, such as cracks, loose wires.
6. **Check the electrical connections**. Make sure that all of the terminals are properly tightened and that there is no insulation damage.

Example contactor terminal testing

Fig. 2.12: Contactor terminal testing

Note: as we know contactor contains NO & NC terminals.

- The contactor is failed
  - ✓ When we test NO terminals the multimeter gives sound or sound
  - ✓ When we test NC terminals the multimeter does not gives sound or sound
  - ✓ When we test the spring contact terminals the multimeter does not gives the expected reading.

2.4. Installation of motors control system

Industrial motor installation is the process of mounting, wiring, and testing the motor control components to ensure that the motor operates safely and efficiently. The specific steps involved in installing a motor control system will vary depending on the type of motor, the motor control components used, and the application.

A. Before installing a motor control system, you should:

- Read and understand the manufacturer's instructions.
- Inspect & test the motor and control system components for any damage.
- Gather all of the necessary tools and materials.
- Prepare the work area by making sure that it is clean, well-lit, and free of obstructions.

B. Installation steps: General steps involved in installing a motor control system:

1. Mount the motor control system components in a suitable enclosure. The enclosure should be sized appropriately and should protect the components from dust, moisture, and other environmental hazards.
2. Wire the motor control system components according to the manufacturer's instructions. Be sure to use the correct wire size and type for the current and voltage requirements of the system. Make sure that all connections are tight and secure
3. Connect the motor to the motor control system. Be sure to use the correct wire size and type of conduit for the motor leads.
4. Connect the power supply to the motor control system.
5. Connect the ground wire properly. This will help to protect the system and the user from electrical shock
6. Test the motor control system to make sure that it is operating properly.

C. Steps to testing the motor control system

1. Apply power to the system.
2. Start the motor using the motor control system.
3. Check the motor to make sure that it is running in the correct direction and at the correct speed.
4. Stop the motor using the motor control system.

a. Install direct online motor control system installation

Based on the above procedure three ***Phase DOL Starter Wiring Diagram connected like below diagrams***

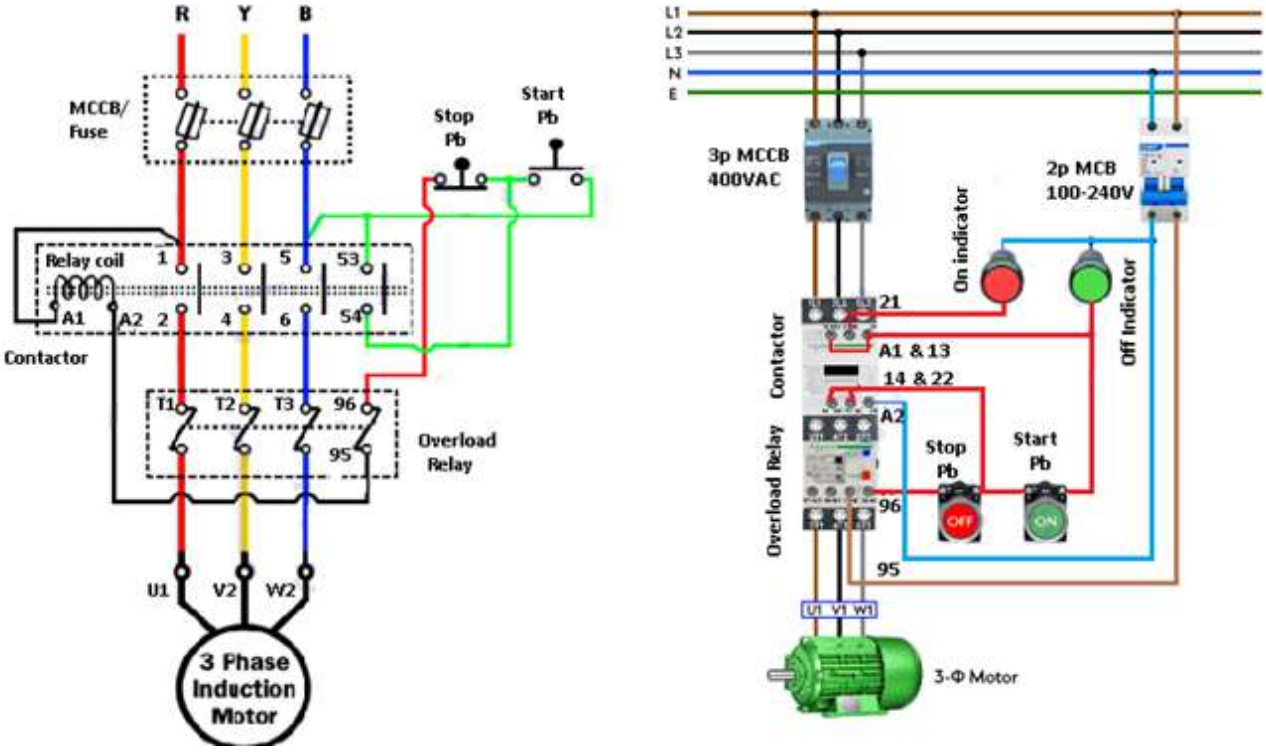


Fig. 2.13: Wiring diagrams of DOL motor controlling system

- **MCCB or Circuit Breaker**: The R, Y and B phase are connected through MCCB to the contactors.
- **Magnetic Contactor**: The contactor has 3 types of contacts:
  - **Main Contacts**: The contactor has 3 main (NO) contacts known as L1, L2 and L3.
    - ✓ L1 is connected to the R phase through MCCB
    - ✓ L2 is connected to the Y phase through MCCB
    - ✓ L3 is connected to the B phase through MCCB
    - ✓ Point 1 is connected to R-phase while point-2 is connected to overload relay T1 point.
    - ✓ Point 3 is connected to Y-phase while point-4 is connected to overload relay T2 point.
    - ✓ Point 5 is connected to B-phase while point-6 is connected to overload relay T3 point.
  - **Auxiliary NO Contacts**: the auxiliary NO contact 53 and 54 closes when the coil energizes. It is connected through the green and red push button.

- ✓ The point-53 is connected to the point-96 start button
- ✓ The point-54 is connected through the stop button.

- **Auxiliary NC Contacts**: the NC contact 95 and 96 is normally closed contacts of overload relay and it opens when the current exceeds a certain limit.
  - ✓ The point-96 is connected to the stop button.
- **Relay Coil**: The relay coil points A1 and A2 are connected to the voltage supply through OLR, start button and stop button.
  - ✓ The Point A1 is connected to R-phase from point 1.
  - ✓ Point A2 is connected to the NC terminal of overload relay point 95.
- **Overload Relay:** The overload relay has normally connected terminals T1, T2 and T3 that supply power to the motor.
  - ✓ The T1 is connected to the point-2 of the contactor.
  - ✓ The T2 is connected to the point-4 of the contactor.
  - ✓ The T3 is connected to the point-6 of the contactor.

b. Install star delta motor control system installation

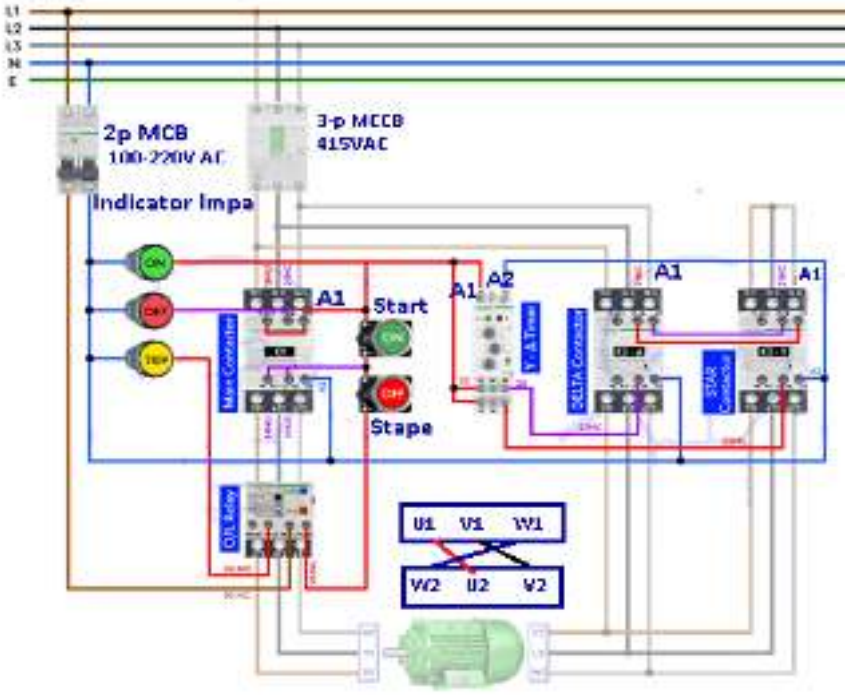


Fig. 2.14: Wiring diagrams of Star-delta motor control circuit

Operation & Working of Automatic Y-Δ Starter

- he phase current flows from L1 to the thermal overload contact through an MCB/MCCB or general fuse, then to the OFF push button, On push button interlocking contact 2, and then to K3. The circuit is thus completed, and both contactor coil C3 and timer coil (T) are energized simultaneously. As a result, the motor winding is connected in Star, and when K3 is energized, its auxiliary open links will close, and the close links will open.
- Consequently, Contactor K1 is also energized, and the Three Phase Supply reaches the motor. Since the winding is connected in Star, each phase will receive √3 times less than the line voltage, which ensures safe motor starting. The close contact of K3 in the Delta line opens, preventing the activation of contactor 2 (K2).
- After the push button is released, Timer coil and coil 3 will receive a supply through Timer contact (Ia), Holding contact 3, and the close contact 2 of K2. When Contactor 1 (K1) is energized, the two open contacts in the line of K1 and K2 will close.
- For a specific time (generally 5-10 seconds), the motor will be connected in Star. After that, the Timer contact (T) will open (which can be adjusted by rotating the timer knob to set the time again), and as a result, Contactor 3 (K3) will turn off, and the open link of K3 (in the line of K2) will close, causing K2 to energize. When K3 is off, the star connection of the winding will also open, and K2 will close, connecting the motor winding in Delta. Contact 2 (which is in the line K3) will also open, preventing the activation of coil 3 (K3).
- Now that the motor is connected in Delta, each phase will receive full line voltage (415V), and the motor will start to run at full speed.

D. Safety precautions

When installing a motor control system, it is important to follow all safety precautions. This includes:

- Always disconnect the power supply to the system before working on it.
- Use the correct PPE, such as safety glasses, gloves, and a long-sleeved shirt.
- Be aware of the electrical hazards involved in working with motor control systems.

2.5. Quality assurance & inspection

They are essential for ensuring the safety and reliability of motor control systems. QA & inspection activities should be implemented throughout the installation process, from planning to execution to completion.

2.5.1. Planning

During the planning phase, QA activities should focus on the following:

- Reviewing the design and specifications for the motor control system.
- Identifying and mitigating potential risks.
- Developing a quality assurance plan (QAP).

The QAP should document the QA activities that will be implemented during the installation process. It should also identify the personnel who are responsible for implementing and overseeing the QA activities.

2.5.2. Execution

During the execution phase, QA activities should focus on the following:

- Inspecting all materials and components before installation.
- Monitoring the installation process to ensure that it is being performed in accordance with the design and specifications.
- Testing the motor control system after installation to ensure that it is operating properly.

Inspections should be conducted at regular intervals throughout the installation process. Inspections should focus on the following areas:

- Correctness of wiring and connections.
- Tightness of all connections.
- Proper installation of all components.
- Compliance with all applicable codes and standards.

Testing should be conducted after all of the installation and wiring is complete. The testing should verify that the motor control system is operating properly and that it meets all of the design requirements.

2.5.3. Completion

Once the motor control system has been installed and tested, the following QA activities should be completed:

I. **Clean worksite**

- Disconnect the power supply to the motor control system.
- Sweep up any debris from the work area.
- Wipe down any surfaces that are dirty or greasy.
- Clean up any spills or leaks.
- Remove any tools, equipment, or materials that are no longer needed.
- Clean all tools and equipment with a damp cloth.
- Dry the tools and equipment thoroughly.
- Apply a thin coat of oil to any metal surfaces to prevent rust.
- Store the tools and equipment in a clean and dry place.

➢ Steps to store surplus materials

- Sort the surplus materials by type and size.
- Label the surplus materials clearly.
- Store the surplus materials in a clean and dry place.
- By following these steps, you can help to keep your motor control installation worksite safe, professional, and efficient.

II. Reviewing all inspection and test results.

g. To review all inspection and test results

- Collect all inspection and test results.
- Organize the results by inspection type, test type, or other criteria.
- Compare the results to the acceptance criteria.
- Identify any corrective actions that need to be taken.
- Document the review process and the results of the review.

Example how to review inspection and test results for a motor control system installation

➢ Collect all inspection and test results, including:

- Inspection report for the motor control system installation
- Test reports for the motor control system components
- Test reports for the motor and load

➢ Organize the results by inspection type and test type:

- Inspection report
- Test reports for motor control system components

- Test reports for motor and load

➢ Compare the results to the acceptance criteria. The acceptance criteria for the motor control system installation may be specified in the project contract, the project scope of work, or the applicable codes and standards.

➢ Identify any corrective actions that need to be taken:

- If you find any discrepancies or anomalies in the inspection or test results, identify the corrective actions that need to be taken to address the problems.

➢ Document the review process and the results of the review:

- Create a summary report that documents the inspection and test results, the acceptance criteria, and any corrective actions that need to be taken.

III. Preparing a final inspection report.

To prepare a final inspection report, follow these steps:

1. Identify the purpose of the report.
2. Gather all relevant information.
3. Organize the information in a logical way.

Example:

Final Inspection Report

Project Name: Motor Control System Installation

Date of Inspection: 2023-10-11

Inspectors: [Inspector Name 1], [Inspector Name 2]

Table 2:1 Inspection of Motor Control System Installation

Item	Acceptance Criterion	Result	Finding	Corrective Action
All inspections were completed	All inspections must be completed and documented.	Pass	None	None
All findings were documented	All findings must be documented, including the date and time of the finding, the name of the inspector, and a description of the finding.	Pass	None	None

Table 2:2 Testing of Motor Control System Components

Item	Acceptance Criterion	Result	Finding	Corrective Action
Contactor	Must be able to switch the rated current and voltage.	Pass	None	None
Starter	Must be able to start and stop the motor properly.	Pass	None	None
Overload relay	Must protect the motor from overload conditions.	Pass	None	None

Table 2:3 Testing of Motor and Load

Item	Acceptance Criterion	Result	Finding	Corrective Action
Motor	Must start and run smoothly and quietly.	Pass	None	None
Load	Must be compatible with the motor and the motor control system.	Pass	None	None

Summary

The motor control system installation was inspected and tested on 2023-10-11. All inspections were completed and all findings were documented. All motor control system components passed the tests and the test results met the acceptance criteria. The motor and load are operating properly and they are compatible with the motor control system.

Recommendations for Improvement

None at this time.

Signatures:

[Inspector Name 1]

[Inspector Name 2]

Self-check #2

I. Choose the correct answer from the give alterative

1. Which of the following is NOT a type of motor control device?

   A. Contactor B. Relay C. Starter D. Diode

2. What is the purpose of a motor overload protector?

   A. To prevent the motor from drawing too much current

   B. To protect the motor from overheating

   C. To disconnect the motor from the power supply if it stalls

   D. All of the above

3. What is the name of the circuit that controls the direction of rotation of a three-phase motor?

   A. Reversing contactor circuit B. Wye-delta circuit

   C. Forward-reverse switch circuit D. Star-delta circuit

4. What is the name of the test that is performed to verify that a motor control device is functioning properly?

   A. Functionality test C. Performance test

   B. Operational test D. All of the above

5. What is the purpose of a quality assurance inspection of a motor control system?

   A. To ensure that the system is installed correctly and meets all safety standards

   B. To identify and correct any potential problems with the system

   C. To verify that the system is functioning properly and meets the design specifications

   D. All of the above

6. What is a wye-delta starter?

   A. A type of motor starter that is used to start three-phase motors

   B. A type of motor starter that is used to start single-phase motors

   C. A type of motor starter that is used to start DC motors

   D. A type of motor starter that is used to start AC motors

II. Mach column “B” to column “A”

A	B

_____ 1: Contactor	A. Start the motor smoothly and reduces inrush current
_____ 2: Overload Relay	B. Controls the direction of rotation of the motor
_____ 3: Motor starter	C.
_____ 4: Timer	
_____ 5: Forward-Reverse	
_____ 5: Star-Delta	

III. Give short ad precise answers for the following questions

Q1: What are the key considerations for installing a motor control system?

Q2: What factors should be considered when selecting a motor control device?

Q3: What are the different types of motor control system circuits?

Q4: How do you perform a functionality test of a motor control device?

Q5: What are the steps involved in installing a motor control system?

Operation sheet # 2

Operation Title: D.O.L. Starter

Purpose: - A three-phase induction motor- is to be-started and stopped direct-on line with the help of two push buttons. Provide overload and short circuit protection to the motor and draw the control circuit and complete wiring diagram.

Instruction: Construct control circuit and power circuit by interconnecting motor starter components.

Required tools and equipments: - Circuit breakers or Fuses, Magnetic Contactors, Relays, Power Cabinet, Pilot lamps push buttons, Insulators, Cable duct, Din rail, Wire strap, Conductors, Disconnecting switches, pliers, screw drivers, multi meter.

Precautions:

- Safe handling of hand tools, testing instruments and components
- Don't give supply before checking your system installation.

Procedures: -

1. Read the given instraction below carefully
2. Prepare tools & materials which used to the task
3. Test the control device functionalities & select the standard wires/cables.
4. Draw the wiring diagrams of DOL motor control system installation
5. Based on the diagram install cables, wires, mounting rail and push button holder (if any) on the installation board.
6. Fix or mount contactor, over load relay, circuit breakers, and push buttons and block terminals.
7. Install the control circuit diagrams of DOL.
8. Connect the power circuit to the system.
9. Test the correct function of the circuit by operating it with push button.
10. Test the out put on the motor terminals by use of multimeter.
11. Connect both power and control circuit
12. Do commissioning of an electrical motor circuit.

Quality criteria:- Reading the circuit properly, Safety procedures were followed, All hand tools were cleaned, the motor operate correctly & neatness/good looking

Operation sheet # 3

Operation Title: Forward Reverse motor control system

Purpose: - Upon completion of this unit, trainee should be able to discuss the operation of Forward Reverse Controller.

Instruction: Construct forward – reverse control circuit and power circuit by interconnecting motor starter components to reverse a three phase motor with a magnetic starter, two sets of main line Contactors are used with suitable controls.

Required tools and equipments: - Circuit breakers or Fuses, Magnetic Contactors, Relays, Power Cabinet, Pilot lamps push buttons, Insulators, Cable duct, Din rail, Wire strap, Conductors, Disconnecting switches, pliers, screw drivers, multi meter.

Precautions:

- Safe handling of hand tools, testing instruments and components
- Turn off the power and disconnect the cord before making any adjustment on the circuits.
- Before installing the controlling devices you must cheeked its functionalities.
- Do not start the motor without permission of instructor and circuit breaker

Procedures: -

1. Select the required motor control starter devices.
2. Inspect & test selected control devices
3. Draw the wiring diagrams of forward-reverse motor control system installation
4. Based on your wiring diagram, connect the control devices by interconnecting the terminals of the motor starter device with connecting cords.
5. When you have completed the connections of the control circuit, check the circuit by using Ohmmeter or multimeter.
6. After checking, connect the circuit to the electrical supply and tests its operation.
7. Now connect both power and control circuit.
8. Check the final wiring diagrams that connected to the control system of the motor.
9. Then press the start push button one start to run the motor for forward direction after a movement press push button two and see the result.
10. Finally do commissioning of an electrical motor circuit.

Quality criteria: - Draw the wiring diagram correctly, Safety procedures were followed, All hand tools were cleaned, the motor operate correctly and neatness/good looking

Operation sheet # 4

Operation Title: Sequential motor control system

Purpose: - Upon completion of this unit, trainee should be able to discuss the operation of Sequential Controller.

Instruction: Construct Sequential control circuit and power circuit by interconnecting motor starter components to Sequential a three phase motor with a magnetic starter, two sets of main line Contactors are used with suitable controls.

Required tools and equipments: - Circuit breakers or Fuses, Magnetic Contactors, Relays, Power Cabinet, Pilot lamps push buttons, Insulators, Cable duct, Din rail, Wire strap, Conductors, Disconnecting switches, pliers, screw drivers, multi meter.

Precautions:

- Safe handling of hand tools, testing instruments and components
- Turn off the power and disconnect the cord before making any adjustment on the circuits.
- Before installing the controlling devices you must cheeked its functionalities.
- Do not start the motor without permission of instructor and circuit breaker

Procedures: -

11. Select the required motor control starter devices.
12. Inspect & test selected control devices
13. Draw the wiring diagrams of for Sequential motor control system installation
14. Based on your wiring diagram, connect the control devices by interconnecting the terminals of the motor starter device with connecting cords.
15. When you have completed the connections of the control circuit, check the circuit by using Ohmmeter or multimeter.
16. After checking, connect the circuit to the electrical supply and tests its operation.
17. Now connect both power and control circuit.
18. Check the final wiring diagrams that connected to the control system of the motor.
19. Then press the start push button start to run the motor and see the result.
20. Finally do commissioning of an electrical motor circuit.

Quality criteria:- Draw the wiring diagram correctly, Safety procedures were followed, All hand tools were cleaned, the motor operate correctly and neatness/good looking

Operation sheet # 5

Operation Title: Star-Delta motor control system

Purpose: - Upon completion of this unit, trainee should be able to discuss the operation of stare-delta Controller.

Instruction: Construct of stare-delta control circuit and power circuit by interconnecting motor starter components to of stare-delta three phase motor with a magnetic starter, two sets of main line Contactors are used with suitable controls.

Required tools and equipments: - Circuit breakers or Fuses, Magnetic Contactors, Relays, Power Cabinet, Pilot lamps push buttons, Insulators, Cable duct, Din rail, Wire strap, Conductors, Disconnecting switches, pliers, screw drivers, multi meter.

Precautions:

- Safe handling of hand tools, testing instruments and components
- Turn off the power and disconnect the cord before making any adjustment on the circuits.
- Before installing the controlling devices you must cheeked its functionalities.
- Do not start the motor without permission of instructor and circuit breaker

Procedures: -

21. Select the required motor control starter devices.
22. Inspect & test selected control devices
23. Draw the wiring diagrams of for stare-delta motor control system installation
24. Based on your wiring diagram, connect the control devices by interconnecting the terminals of the motor starter device with connecting cords.
25. When you have completed the connections of the control circuit, check the circuit by using Ohmmeter or multimeter.
26. After checking, connect the circuit to the electrical supply and tests its operation.
27. Now connect both power and control circuit.
28. Check the final wiring diagrams that connected to the control system of the motor.
29. Then press the start push button start to run the motor and see the result.
30. Finally do commissioning of an electrical motor circuit.

Quality criteria:- Draw the wiring diagram correctly, Safety procedures were followed, All hand tools were cleaned, the motor operate correctly and neatness/good looking

LAP Test #2

Name: _____ Date: _____

Time started: _____ Time finished: _____

Instruction I: Given necessary templates, tools and materials you are required to perform the following tasks within 10 hours.

Task 1: Installing manual control switch D.O.L. Starti*n*g method of thee phase induction motor

Task 2: Installing Forward-Reverse-Forward automatically Using Timers

Task 3: Installing Sequence Starting of Two Motors automatically with time delay

Task 4: Installing Automatic Star – Delta Starter with contactors

Reference

1. Industrial Motor Control" by Stephen L. Herman (7th edition, 2019)
2. "Electric Motor Control" by Stephen L. Herman (11th edition, 2018)
3. "Industrial Motor Control" by Stephen J. Trenka (6th edition, 2017)
4. "Electric Motor Controls" by Gary Rockis and Glen Mazur (2nd edition, 2012)
5. "Industrial Motor Control" by Stephen Herman and Bennie Sparkman (7th edition, 2016)
6. "Electric Motors and Motor Controls" by Jeff Keljik (3rd edition, 2020)

Developer Profile

No	Name	Qualification (Level)	Field of Study	Organization/ Institution	Mobile number	E-mail
1	Mengistu Abiyu	MSc	Industrial Automation & Control Management	Lideta Manufacturing College	0913948480	menabiy@gmail.com
2	Samuel Bekele	MSc	Industrial Automation & Control Management	Haramaya PTC	910082977	samuelbekele460@gmail.com
3	Yidnekachew Seboka	BSc	Electrical Automation & Control Technology	Akaki PTC	920137899	www.yidne23@gmail.com
4	Zegeye Girma	BSc	Electrical Automation & Control Technology	Addis Ketema In.College	**926805563**	zegeyegirma2@gmail.com
5	Bacha Wake	MSc	Industrial Automation & Control Management	Hawassa Tegibarid PTC	**987065251**	bachawake@gmail.com