University of Global Village (UGV)

Department of Electrical and Electronic Engineering

Switch Gear & Protection

Course Title: Switch Gear & Protection Lab

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Course Rationale

The Switchgear & Protection Lab aims to provide students with practical exposure to the principles and techniques of electrical protection systems, emphasizing the operational characteristics and applications of fuses, circuit breakers, relays, and motor protection mechanisms. This course enhances students' ability to design, test, and troubleshoot protective devices in various electrical networks, preparing them for real-world challenges in power system protection.

Course Objectives

1. To familiarize students with the operation and characteristics of fuses, circuit breakers, relays, and motor starters.
2. To enable students to analyze time-current characteristics of protective devices for system coordination.
3. To provide hands-on experience in testing and configuring protective devices for different fault scenarios.
4. To develop students' skills in dismantling and assembling protective devices to understand their components and functionality.
5. To instill a strong understanding of protection schemes for motors, transformers, and feeders in low and high-voltage systems.
6. To enhance the students' ability to troubleshoot and ensure the reliability of protection mechanisms in electrical systems.

CLO: After successful completion of the course students will be able to :

CLO Number	Learning Outcome
CLO1	Understand the fundamental principles of protection devices such as fuses, circuit breakers, and relays.
CLO2	Analyze and interpret the time-current characteristics of various protective devices.
CLO3	Configure and test relays for proper coordination in electrical systems.
CLO4	Identify and describe the components and functions of circuit breakers and motor starters.
CLO5	Evaluate and implement suitable protection schemes for electrical systems under various fault conditions.
CLO6	Demonstrate the ability to diagnose faults and propose protection solutions for motors and feeders.

Table 1: Lab activities overview for Switchgear & Protection Lab course

Sl.	Experiment Title	Topics Covered	Theory Time (hours)	Practical Time (hours)	Learning Outcomes	CLO
1	Introducing different types of fuses and plotting the Time Current Characteristics (TCC) curve of a rewireable fuse	Fuse types, working principle, TCC curves, short circuit and overload protection, fusing current	1	2	Understand fuse operation, analyze fuse characteristics, and develop insights into fuse protection mechanisms.	CLO1, CLO2
2	Introducing different types of Circuit Breakers and plotting the TCC curve of a Miniature Circuit Breaker (MCB)	MCB working principles, advantages over fuses, components, types of MCBs, comparison of fuse and MCB curves	1.5	2.5	Learn MCB operation, compare with fuses, and analyze the TCC curve for circuit breakers.	CLO2, CLO3
3	Dismantle MCCB and identify various parts	MCCB components: operating mechanism, trip unit, arc chute, contacts, housing	1.5	2	Identify MCCB components, understand their functions, and develop skills in handling electrical devices.	CLO2, CLO4
4	Carry out time setting & plug setting (with PSM & TSM) of a relay	Relay settings, PSM, TSM, overcurrent relay coordination, inverse time-current characteristics	1.5	2.5	Apply relay settings for system protection, analyze the impact of PSM and TSM, and evaluate coordination schemes.	CLO3, CLO5
5	Test overcurrent relay by performing load test	Overcurrent relay parameters, pick-up current, fault current, time-current characteristic curve	1.5	2.5	Test relay performance under different load conditions, plot characteristic curves, and interpret relay response.	CLO3, CLO5
6	Study of DOL motor protection system and its operation	DOL starter working, fuse protection, overload relay	1.5	2.5	Analyze DOL starter protection mechanisms and evaluate the	CLO4, CLO5

		protection, short circuit protection			effectiveness of fuses, relays, and breakers.	
7	Study of Y-Δ starter protection scheme and its operation	Y-Δ starter operation, reduction in starting current, transition timer, overload and phase failure protection	1.5	2.5	Understand Y-Δ starter operation, analyze its protection mechanisms, and evaluate transition timing and fault responses.	

Table 2: Week-wise details with assessment and resources for Switchgear and Protection Lab.

Week	Experiment Title	Topics Covered	Assessment	Resources
Week 1	Introducing different types of fuses and plotting the Time Current Characteristics (TCC) curve of a rewireable fuse	Types of fuses, fuse operation, TCC curves, fusing current, and protection mechanisms	Practical demonstration, TCC graph submission, and viva-voce	Lab manual, rewireable fuses, ammeter, stopwatch, single-phase auto transformer
Week 2	Introducing different types of Circuit Breakers and plotting the TCC curve of a Miniature Circuit Breaker (MCB)	MCB working principles, advantages over fuses, types of MCBs, and TCC curves comparison	MCB analysis report, TCC graph, and oral questioning	MCB, current injector, log-log graph paper, and lab manual
Week 3-4	Dismantle MCCB and identify various parts	MCCB components: operating mechanism, trip unit, arc chute, contacts, and housing	Component identification quiz, practical observation sheet, and group discussion	MCCB samples, screwdrivers, pliers, and datasheets
Week 5	Carry out time setting & plug setting (with PSM & TSM) of a relay	Relay settings, PSM, TSM, and inverse time-current characteristics	Relay configuration assignment, fault simulation test, and viva-voce	Overcurrent relays, current transformers, adjustable load, and multimeter

Week 6-7	**Test overcurrent relay by performing load test**	**Overcurrent relay testing, pick-up current, fault current, and time-current characteristic curve**	**Load test evaluation, characteristic curve plotting, and individual presentation**	**Overcurrent relay, variable load bank, AC power source, and stopwatch**
Week 8-9	**Study of DOL motor protection system and its operation**	**DOL starter, fuse protection, overload relay protection, and short circuit protection**	**Practical implementation report, protection mechanism evaluation, and oral questioning**	**DOL starter, induction motor, fuses, overload relays, circuit breakers, and multimeter**
Week 10-11	**Study of Y-Δ starter protection scheme and its operation**	**Y-Δ starter operation, starting current reduction, transition timer, and protection mechanisms**	**Performance evaluation, transition timing analysis, and practical fault-response demonstration**	**Y-Δ starter panel, induction motor, timer relays, voltage monitoring devices, and tools**

Experiment No. 01

Experiment Name: Introducing different types of fuses and plotting the Time Current Characteristics (TCC) curve of a rewireable fuse

Objective:

1. To understand the role of fuse in protection.
2. To study the working operation of a fuse.
3. To understand different types of a fuse.
4. To draw the characteristics of a fuse.

Theory:

Fuse:

Fuse is essentially a small piece of metal connected in between two terminals mounted on insulated base which forms a series part of the circuit. The duty of a rewire able fuse wire is to carry the normal working current safely without heating the wire but when the normal operating current is exceeded it should rapidly heat up to the melting point and eventually circuit is opened. It can provide two types of protection.

1. Short circuit protection
2. Over load protection

The melting point follows inverse characteristics between the melting time and the melting current. At normal rated current the fuse element will never be heated to its melting point. At overloaded current the melting will occur after certain time. As the amount of overloading is increased the melting time will be shorter.

Low voltage Fuse are again classified as rewire able (kitkat) fuse , HRC Fuse& HRC Fuse with Tripping Devices Where as high voltage fuse are of cartridge Type, liquid type, & metal clad fuse.

Current Rating of Fuse: It is the maximum value of current which fuse element can carry without overheating/ melting.

Types of fuse

1. Expulsion fuses	2. Cartridge fuse
3. Drop out fuse	4. Liquid fuse
5. Open fuse	6. Striker fuse
7. Switch Fuse	8. HRC Fuse

1. Expulsion Fuse -

The Expulsion fuse consists of modern cutout. In such fuse the arc occurring during the current interruption is extinguished by the expansion produced by the arc.

2. Rewirable Fuse or Semi closed Fuse-

In such a fuse the fuse element is placed in a semi closed carrier. Fuse carriers can be pulled out & the fuse element can be replaced, after the fuse operation. The carrier can be then placed in the fuse base.

3. Cartridge Fuse –

This fuse is totally enclosed fuse. The fuse element is placed in a totally enclosed carrier with two Metal contacts provided on the two sides of a carrier. The entire cartridge is required to be replaced once fuse operates.

4. Drop-out Fuse –

In such fuse, the fuse carrier drops out once, the fuse operates, the dropping out of fuse carrier provides the necessary isolation between the terminals.

5. Liquid Fuse –

When fuse operates, in case of high current there exists an arc. The arc must be extinguished properly. The fuse in which the arc is extinguished using a liquid medium is called liquid fuse. The liquid medium used is generally oil. The various types of liquid fuses are:-

a) Oil break
b) Oil expulsion fuse
c) Oil blast fuse

6. Open Fuse

This fuse consists of a plain fuse wire and the fuse operates any provision for extinguishing the arc.

7. Striker Fuse

In this fuse, there exists a combination of a fuse and a mechanical device. When the fuse operates, strikes get released under pressure which gives the tripping indication.

8. Switch Fuse

This fuse is a combination of a switch & fuse. The combined unit is called switch fuse.

9. HRC Fuse

It is high rupturing capacity fuse. It is also called breaking capacity cartridge fuse. In such a fuse the arc is extinguished with the help of quartz, sand powder such a powder provides very high resistance which helps to extinguish the arc. It is basically a low voltage fuse which is used for

Time Current Characteristics of protective devices:

Time is plotted on the vertical axis and current is plotted on the horizontal axis of all time current characteristic curves. Log-log type graph paper is used to cover a wide range of times and currents. Characteristic curves are arranged so that the area below and to the left of the curves indicate points of "no operation," and the area above and to the right of the curves indicate points of "operation." The procedure involved in applying characteristic curves to a coordination study is to select or set the various protective devices so that the characteristic curves of series devices from the load to the source are located on a composite time-current graph from left to right with no overlapping of curves. The result is a set of coordinated curves on one composite time current graph

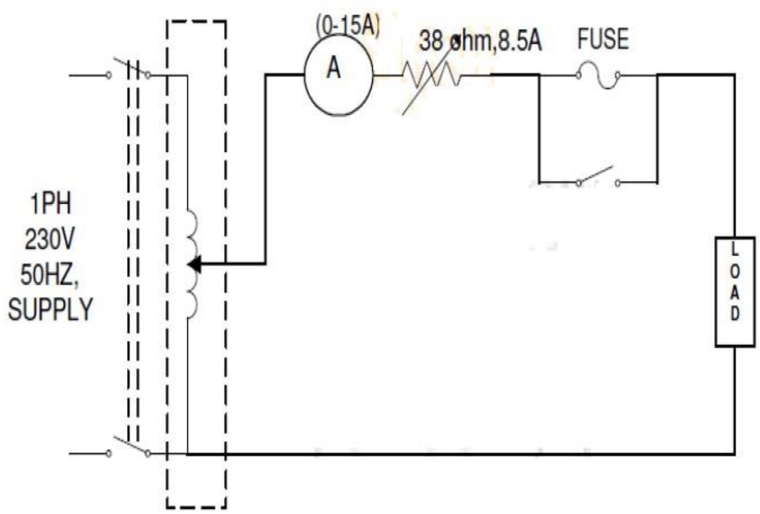
Fusing Current:
It is minimum current at which fuse element melts & thus protect circuit from overheating.

Fusing Factor:
It is ratio of fusing current to current rating of Fuse.

Equipment:

Sl.No	Name of Equipment/items	Specification	Qty Required
01	Fuse Wire	10 Amp	1
02	Ammeter	(0-20 Amp)	1
03	Stopwatch		1
04	1 Phase Auto Transformer	(0 – 230 V)	1
05	Resistive Load		1
06	Connecting Wires		1

Circuit Diagram:



Procedure:

1. Make the connections as per circuit diagram
2. Switch on the supply
3. Gradually increase load current above rating of fuse with increasing load.
4. Note down time of operation of fuse with the help of stopwatch.
5. Repeat above procedure by Increasing load current through Fuse.
6. Plot Graph of current and time of operation of fuse.

Observation Table:

Sr.No	Current through Fuse (Amp)	Time ofOperation in Seconds.
1		
2		
3		
4		
5		

Graph :

Results:

Experiment No. 02

Experiment Name: Introducing different types of Circuit Breaker and plotting the Time Current Characteristics (TCC) curve of a Miniature Circuit Breaker (MCB).

Objective:

1. To be familiar with electrical protection devices like different types of Circuit Breaker (CB)
2. To take readings of currents and their corresponding tripping time of MCB.
3. To draw the TCC curve of fuse and MCB from the data.

Theory:

The MCB has some advantages compared to fuse -

1. It automatically switches off the electrical circuit during abnormal condition of the network means in overload condition as well as faulty condition. The fuse does not sense but miniature circuit breaker does it in more reliable way. MCB is much more sensitive to over current than fuse.

2. Another advantage is, as the switch operating knob comes at its off position during tripping, the faulty zone of the electrical circuit can easily be identified. But in case of fuse, fuse wire should be checked by opening fuse grip or cutout from fuse base, for confirming the blow of fuse wire.

3. Quick restoration of supply cannot be possible in case of fuse as because fuses have to be rewireable or replaced for restoring the supply. But in the case of MCB, quick restoration is possible by just switching on operation.

4. Handling MCB is more electrically safe than fuse. Because of to many advantages of MCB over fuse units, in modern low voltage electrical network, miniature circuit breaker is mostly used instead of backdated fuse unit. Only one disadvantage of MCB over fuse is that this system is costlier than fuse unit system.

<u>Miniature Circuit Breaker (MCB):</u>

MCBs are used extensively in LV domestic, commercial and industrial applications. They replace conventional fuses and combine the features of a good HRC fuse and a good switch. For normal operation it is used as switch. During overloads or faults, it automatically trips off. The tripping mechanism is actuated by magnetic and thermal sensing devices provided within the MCB. Over current is sensed by over current release which helps to open the contact of the MCB. On the other hand short circuit is sensed by magnetic release which provides the means of opening the contact of MCB.

Tripping mechanism and the terminal contacts are assembled in a moulded case, moulded out of thermo setting powders. They ensure high mechanical strength, high dielectric strength and virtually no ageing. The current carrying parts are made of electrolytic copper or silver alloy depending upon the rating of the breaker.

All other metal parts are of non ferrous, non rusting type. Sufficient cross section for the current carrying parts is provided to ensure low temperature rise even under high ambient temperature environment. The arc chute has a special construction which increases the length of the arc by the magnetic field created by the arc itself and arc chute is so placed in the breaker that the hot gases may not come in contact with any of the important parts of the breaker.

Fig : Showing the MCBs

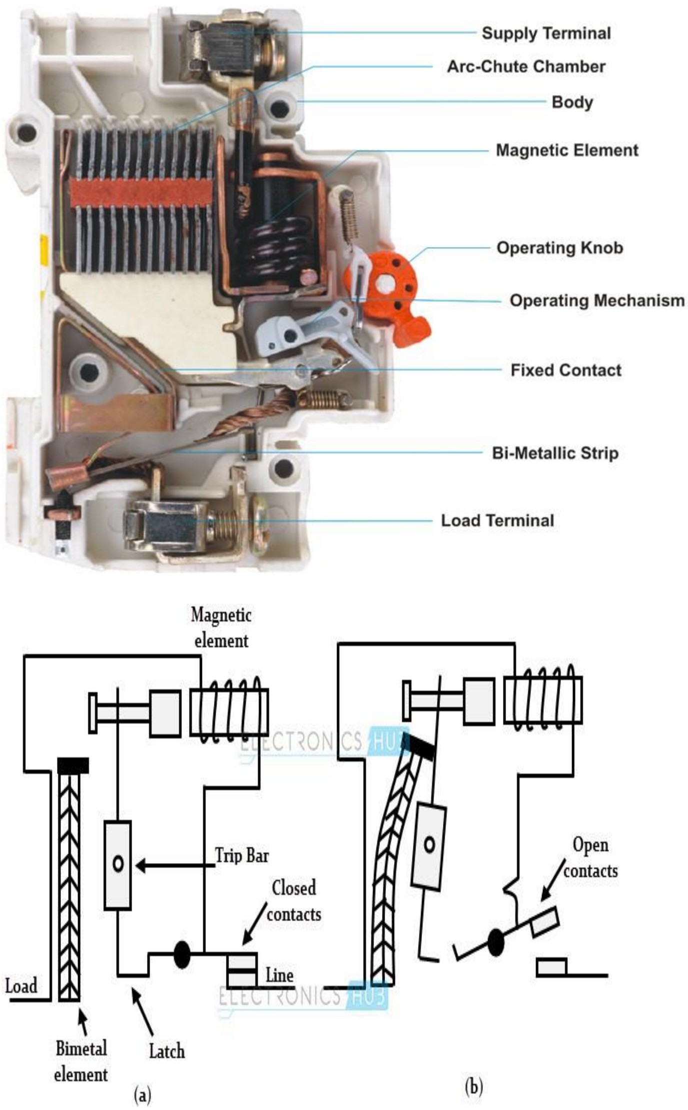


Fig: Construction and working principal of MCB

Types of MCB: MCBs are classified into three major types according to their instantaneous tripping currents. They are

i. Type B MCB
ii. Type C MCB
iii. Type D MCB

MCB Type	Minimum Trip Current	Maximum Trip Current
Type B	3 Ir	5 Ir
Type C	5 Ir	10 Ir
Type D	10 Ir	20 Ir

Ir= Rated current

Molded Case Circuit Breaker (MCCB):

The current rating of the MCCB is higher than 63 Amp.Its also provides short circuit and overload protection. Additional fact is, operating current setting can be controlled in a possible range.

Fig: Showing the MCCBs

Time Current Characteristics of protective devices:

Time is plotted on the vertical axis and current is plotted on the horizontal axis of all time current characteristic curves. Log-log type graph paper is used to cover a wide range of times and currents. Characteristic curves are arranged so that the area below and to the left of the curves indicate points of "no operation," and the area above and to the right of the curves indicate points of "operation." The procedure involved in applying characteristic curves to a coordination study is to select or set the various protective devices so that the characteristic curves of series devices from the load to the source are located on a composite time-current graph from left to right with no overlapping of curves. The result is a set of coordinated curves on one composite time current graph

Fusing Current:

It is minimum current at which fuse element melts & thus protect circuit from overheating.

Instrument and Components:

1. Current Injector.
2. Clamp on meter.
3. Rewire able Fuse Wire (5 A).
4. Wooden Board fitted with Fuse Holder.
5. MCB
6. Connecting Wire.

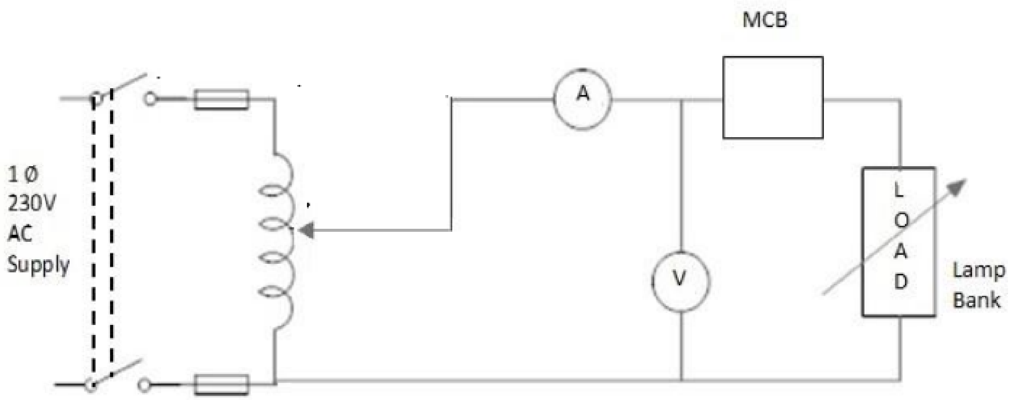
Procedure:

Connect the current injector set to a 230 V supply line. There are two output current terminals, one is of 0-20A and other is 0-200A. Use 0-20A output terminal. Set the output current at a desired value by changing the current varying knob. This can only be achieved by shorting the output terminals by a thick wire. Keeping the knob position at the desired current value, switch off the current injector and connect the fuse holder fitted with fuse wire across the output terminals. Then switch on the injector. The desired current flows through the fuse wire. Measure the blow out time of the fuse wire. As the increased current flows through the fuse wire, the fuse blow out time reduces. Measure and record the currents and the corresponding fuse and blow out time in the table
and for MCB, connect directly it to the 0-200A output terminals after disconnecting the shorting wire. Then switch on the current injector set. The desired current flows through the MCB. Measure and record the tripping time of the MCB. As the increased current flows through the MCB, the tripping time of the MCB is reduced. Measure and Record the currents and their corresponding tripping time of the MCB in Table

Table

Sl. No	Current (A)	Tripping time of the MCB (sec)
1		
2		
3		
4		
5		

Circuit Diagram:



Testing of a MCB

Task to the Students ;

1. Explain how a fuse can provide time delayed protection for normal overload and high speed protection for short circuit.
2. What are the differences between a MCB and a MCCB?
3. Draw the TCC curve on a graph. Use Current in the X-axis and time in Y-axis.
4. Discuss the special feature for selecting the fuse rating for the protection of motor.
5. Discussion the special feature for selecting rating of MCB .

Experiment No. 03

Experiment Name: Dismantle MCCB and identify various parts.

Objective

- To dismantle a Molded Case Circuit Breaker (MCCB).
- To identify and understand the function of various parts of an MCCB.
- To develop practical skills in handling electrical devices.

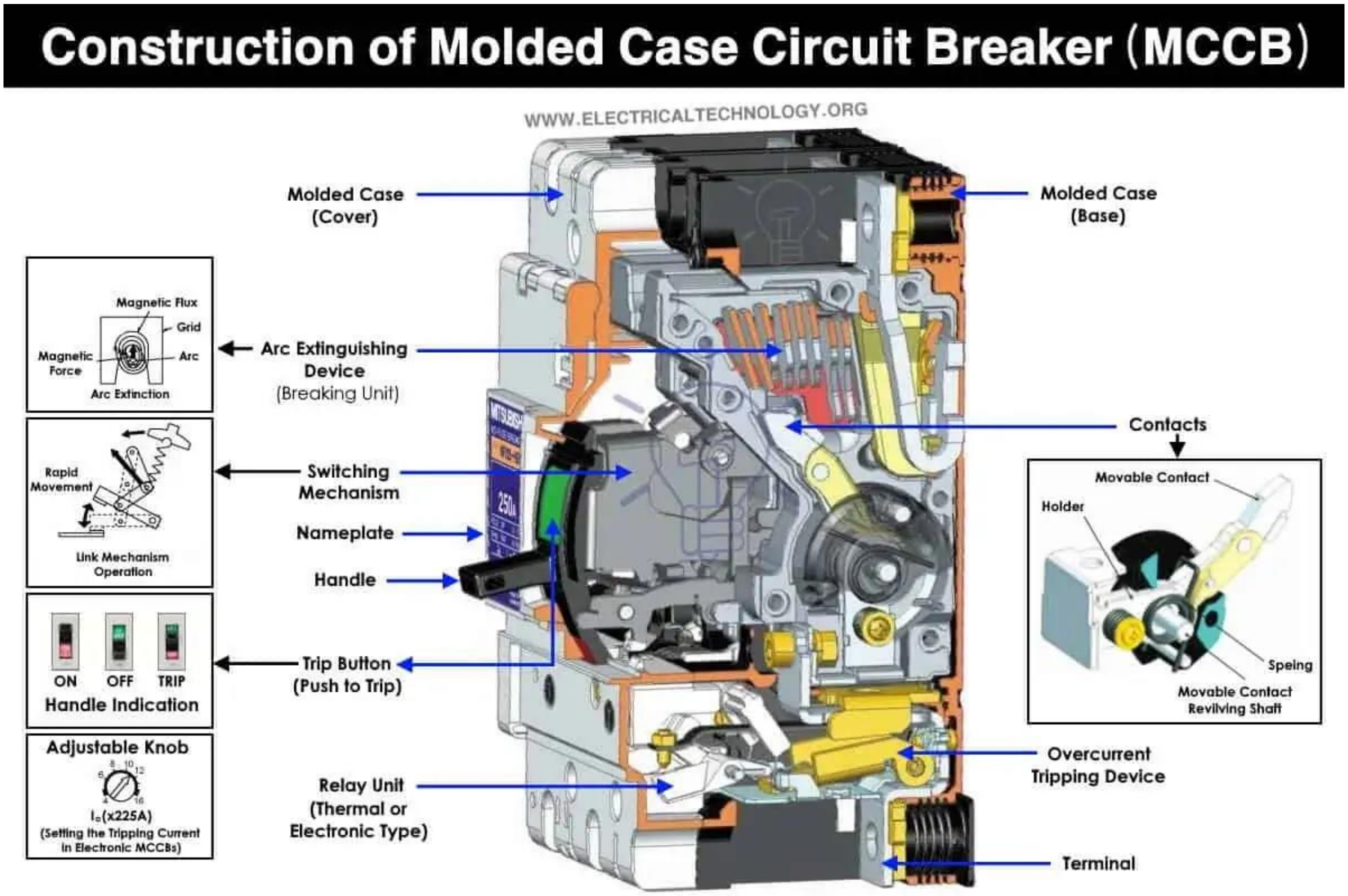
Apparatus Required

1. Molded Case Circuit Breaker (MCCB)
2. Screwdrivers
3. Pliers
4. Multimeter

Theory

MCCBs are protective devices designed to protect electrical circuits from overload, short circuits, and other faults. They are used in residential, commercial, and industrial settings. Understanding the components of an MCCB is essential for maintenance and troubleshooting.
Key components of an MCCB include:

- **Operating Mechanism**: Facilitates manual and automatic switching of the circuit.
- **Contacts**: Conduct electricity and disconnect during faults.
- **Trip Unit**: Detects fault conditions and initiates tripping.
- **Arc Chutes**: Extinguish arcs generated during disconnection.
- **Housing**: Provides insulation and protects internal components.



Safety Precautions

1. Ensure the MCCB is not connected to any live circuit.
2. Wear insulated gloves and safety goggles.
3. Use tools with insulated handles.
4. Follow the instructor's guidelines during the experiment.
5. Handle all components carefully to avoid damage.

Procedure

1. **Preparation**:
   Gather all required tools and safety equipment.
   Verify that the MCCB is completely de-energized.

2. **Initial Inspection**:
   Inspect the MCCB for any visible damage or wear.
   Record the ratings and specifications printed on the MCCB.

3. **Dismantling the MCCB**:
   Use a screwdriver to remove the screws holding the MCCB housing.
   Carefully separate the housing to expose the internal components.
   Note the arrangement and connections of the internal parts.

4. **Identifying Components**:
   Identify the following parts:
   - Operating mechanism
   - Fixed and moving contacts
   - Trip unit (thermal and magnetic elements)
   - Arc chutes
   - Terminals

   Refer to the MCCB datasheet or manual for detailed descriptions.

5. **Testing Components**:
   Use a multimeter to check the continuity of contacts.
   Verify the functionality of the trip unit if possible.

6. **Reassembling the MCCB**:
   Reassemble the MCCB by placing the components back in their original positions.
   Secure the housing with screws.

7. **Post-Experiment Checks**:
   Ensure all screws are tightened.
   Confirm the MCCB operates smoothly after reassembly.

Observation Table:

Sr.No.	**Name of the part**	**Material used**	**Function**
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			

Result Analysis and Discussion:

Experiment No. 04

Experiment Name: Carry out time setting & plug setting (with PSM & TSM) of a relay

Objective:

To understand and apply the time setting and plug setting (PSM & TSM) of an overcurrent relay for proper coordination and protection of electrical systems.

Equipment Needed:

1. **Overcurrent Relay** (Electronic/Mechanical type)
2. **Power Supply** (AC voltage source)
3. **Current Transformer (CT)** (for current sensing)
4. **Timer Relay** (optional, for coordination)
5. **Adjustable Load** (for simulating overcurrent conditions)
6. **Multimeter** (for measuring voltage, current)
7. **Wires and Connectors**
8. **Test Bench with Circuit Breaker/Protection Device**
9. **Control Panel** (for setting and monitoring relay parameters)

Theory:

1. Overcurrent Relay:

An **Overcurrent Relay** is designed to detect and respond to excessive current. It is used for protection against short circuits and overloads. The operation of the relay depends on two main parameters:

Plug Setting (PSM): Determines the threshold of current at which the relay will operate. This is typically set as a multiple of the rated current (e.g., 1.5, 2.0, etc.).

Time Setting (TSM): Controls the delay time before the relay activates once the current exceeds the set threshold. It is usually adjusted according to the inverse time-current characteristic.

The **Inverse Time-Current Characteristic** defines how quickly the relay trips based on the magnitude of the overcurrent. For higher currents, the relay will trip faster, and for lower over currents, it will trip more slowly.

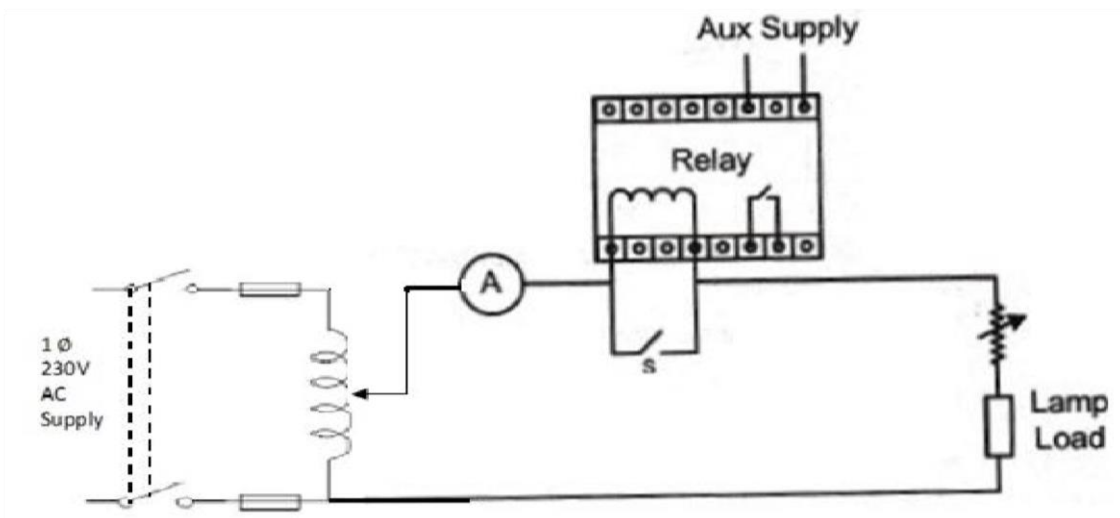
2. PSM (Plug Setting Multiplier):

PSM is the factor by which the relay current threshold is multiplied to determine the setting. For example, if the rated current of the system is 10 A and the PSM is set to 2, the relay will start operating if the current exceeds 20 A.

3. TSM (Time Setting Multiplier):

TSM adjusts the delay time according to the time-current curve, making it more or less sensitive to smaller or larger over currents.

Circuit Diagram:



Procedure:

Step 1: Preparation of Test Bench:

1. Connect the **overcurrent relay** to the test panel and ensure that it is properly wired with the control circuit.
2. Set up the **current transformer (CT)** and the load so that the current can be adjusted. This will simulate various current conditions.
3. Connect the **multimeter** to measure the current flowing through the circuit.
4. If using a **timer relay** for time coordination, wire it in series or parallel, depending on the protection logic required.

Step 2: Setting the Plug and Time Settings on the Overcurrent Relay:

1. **Plug Setting (PSM)**:

   Set the **Plug Setting** on the relay. Choose a setting based on the rated current of the circuit. If the relay is set to a PSM of 2, and the rated current is 10A, the relay will operate if the current exceeds 20A.

   - Example: For a system rated at 10A, select PSM = 2 for 20A operation threshold.

2. **Time Setting (TSM)**:

   Set the **Time Setting** (TSM) to determine the time delay before the relay trips when an overcurrent occurs.

   - **Long Time Protection (TSM)**: Adjust the delay to suit the protection requirements. Typically, a long-time delay is used for overloads, and a short-time delay is used for short circuits.

   - **Inverse Time Setting**: Select an inverse time characteristic (standard inverse, very inverse, etc.) to match the application. A higher TSM will result in a longer delay time for lower overcurrent conditions.

Step 3: Simulate Overcurrent Conditions:

1. Slowly increase the current using the **adjustable load**. Monitor the current through the relay using the multimeter.
2. When the current exceeds the set PSM (e.g., 20A for a PSM of 2 and a rated current of 10A), observe the relay response.

   If the current exceeds the threshold, the relay should trip after a delay determined by the TSM.

3. **Test the Time Setting (TSM)**:

   Increase the current to a value above the plug setting and observe the time delay before the relay trips.

   Vary the TSM setting (increase or decrease) and observe how the time delay changes. The higher the TSM, the longer the delay before tripping.

Step 4: Timer Relay (Optional for Coordination):

If using a **timer relay**, adjust its setting to introduce a fixed delay before a circuit breaker or another relay operates, in coordination with the overcurrent relay. This is typically done for system-wide coordination, ensuring that the most upstream protection device operates first during a fault.

Set the timer to delay the tripping of the system until after the overcurrent relay has been activated.

Step 5: Trip and Reset:

1. After the relay trips, manually reset the relay and test again to ensure the correct operation of settings.
2. Verify that the relay behaves as expected, with the proper plug setting and time delay corresponding to the overcurrent condition.

Observation and Calculation:

Sr. No.	% tap used	Current through relay coil (A)	Time of operation(sec.)	PSM value
1				
2				
3				
4				
5				
6				
7				

Note: The current plug setting range used from 50% to 200% in steps of 25% for phase to phase fault and 10% to 70% in steps of 10% for earth fault.

PSM value = Current through relay coil / (Nominal current of relay X % tap used /100)

Analysis:

1. **Plug Setting**: Note the threshold current at which the relay trips based on the PSM setting.
2. **Time Setting**: Observe the time delay before tripping occurs, and how it changes with different TSM values.
3. **Relay Performance**: Compare the expected trip time with the actual trip time to check if the relay settings are working correctly.

Conclusion:

Experiment No. 05

Experiment Name: Test Over-current relay by performing load test.

Objective: To test and analyze the performance of an over-current relay by conducting a load test and determining its operating characteristics.

Apparatus Required:

1. Over-current relay (electromechanical or digital type)
2. AC power source
3. Variable load bank
4. Ammeter (AC)
5. Voltmeter (AC)
6. Stopwatch
7. Circuit breaker
8. Connecting wires and accessories

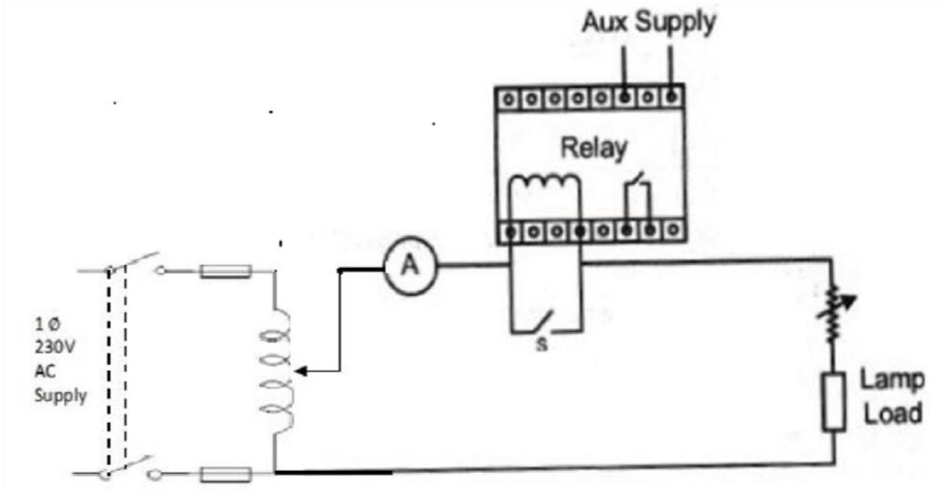
Theory:

Over-current relays are protective devices designed to operate when the current exceeds a pre-set value. They play a critical role in protecting electrical systems from faults, ensuring system stability, and minimizing equipment damage. The relay operates based on the principle of electromagnetism (for electromechanical types) or digital processing (for modern relays).

Key parameters:

- **Pick-up Current:** The minimum current at which the relay starts to operate.
- **Time-Current Characteristic:** The relationship between the operating time and the fault current.
- **Plug Setting Multiplier (PSM):** Ratio of fault current to pick-up current.

Circuit Diagram:



Procedure:

1. Setup: a. Connect the circuit as per the circuit diagram. b. Ensure all connections are tight and secure.
2. Calibration: a. Adjust the relay settings to a specific pick-up current value. b. Verify the calibration of the ammeter and voltmeter.
3. Load Testing: a. Gradually increase the load and observe the current reading on the ammeter. b. Note the current at which the relay picks up (activates). c. Record the time taken by the relay to trip the circuit after pick-up.
4. Repeat Tests: a. Vary the load to simulate different fault conditions. b. Measure and record the operating time for each fault current.
5. Reset: a. After each trip, reset the relay and circuit breaker. b. Ensure the system is stable before the next test.

Observations: Prepare a table to record the following:

Load Current (A)	**Pick-up Current (A)**	**Fault Current (A)**	**Operating Time (s)**	**Remarks**

Calculations:

1. **Calculate the Plug Setting Multiplier (PSM) Plot the Time-Current Characteristic Curve:**

    X-axis: Fault Current

    Y-axis: Operating Time

Result:

Precautions:

1. Ensure all connections are made as per the circuit diagram to avoid errors.
2. Do not exceed the rated capacity of the relay or load bank.
3. Reset the relay and circuit breaker properly before each test.
4. Use proper personal protective equipment (PPE) to ensure safety.

Conclusion:

Experiment No. 06

Experiment Name: Study of DOL motor protection system and its operation.

Objective

To understand and analyze various motor protection mechanisms used in Direct-On-Line (DOL) starters, and to study their operation and performance.

Equipment Required

1. DOL Starter Panel
2. Induction Motor (e.g., 3-phase, 5 HP)
3. Fuses (of appropriate rating)
4. Overload Relays
5. Circuit Breakers (MCB/MCCB)
6. Multimeter/Clamp Meter
7. Voltage and Current Monitoring Devices
8. Thermal Protection Devices
9. Three-Phase Power Supply
10. Connecting Wires and Tools

Theory:

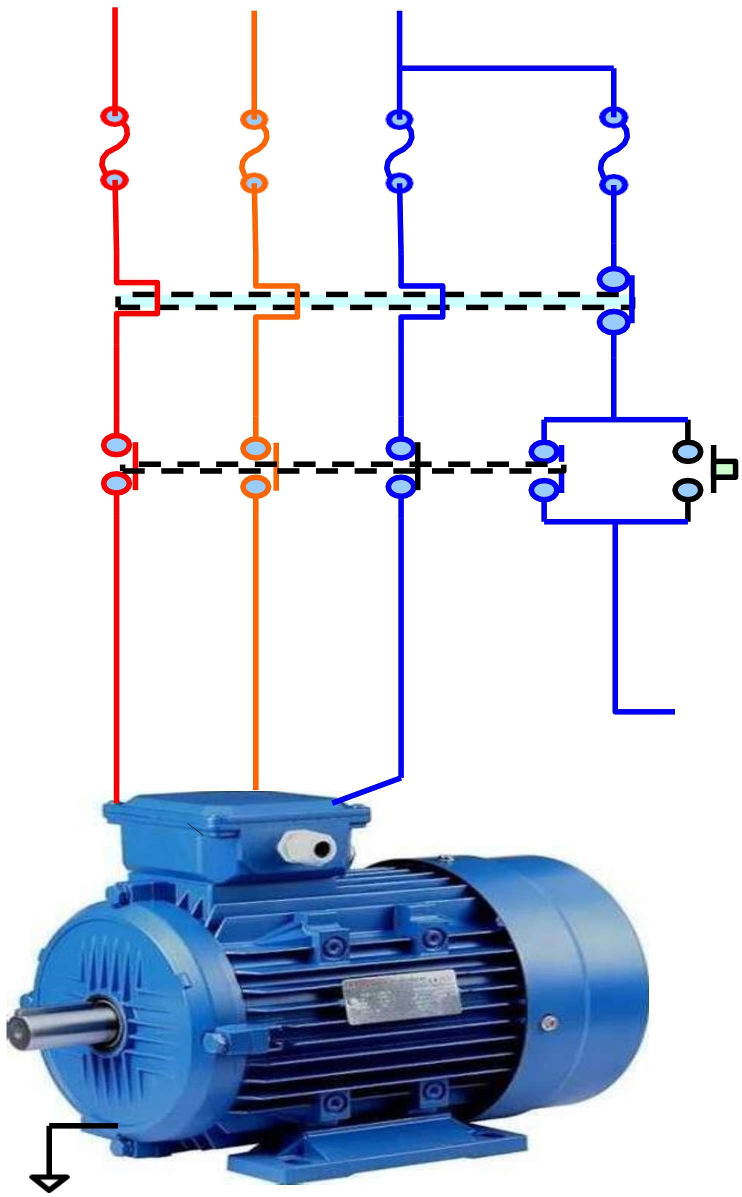
DOL protection system:

In electrical engineering, a direct on line (DOL) or across the line starter starts electric motors by applying the full line voltage to the motor terminals. This is the simplest type of motor starter. A DOL motor starter also contain protection devices, and in some cases, condition monitoring. Smaller sizes of direct on-line starters are manually operated; larger sizes use an electromechanical contactor (relay) to switch the motor circuit. Solid-state direct on line starters also exist.

A direct on line starter can be used if the high inrush current of the motor does not cause excessive voltage drop in the supply circuit. The maximum size of a motor allowed on a direct on line starter may be limited by the supply utility for this reason. For example, a utility may require rural customers to use reduced-voltage starters for motors larger than 10 kW.

DOL starting is sometimes used to start small water pumps, compressors, fans and conveyor belts. In the case of an asynchronous motor, such as the 3-phase squirrel-cage motor, the motor will draw a high starting current until it has run up to full speed. This starting current is commonly around six times the full load current, but may be as high as 6 to 7 times the full load current. To reduce the inrush current, larger motors will have reduced-voltage starters or variable speed drives in order to minimize voltage dips to the power supply.

Circuit diagram:



Experimental Procedure

Fuse Protection

1. Connect the DOL starter, motor, and fuses in series as per the circuit diagram.
2. Switch on the power supply and record the motor's normal operating current.
3. Gradually increase the load on the motor until the fuse blows.
4. Note the current value at which the fuse trips.

Overload Relay Protection

1. Set the overload relay to the motor's full-load current rating.
2. Start the motor using the DOL starter.
3. Gradually increase the load until the relay trips.
4. Record the tripping current and time delay.

Short Circuit Protection

1. Replace the fuse with an MCB/MCCB of suitable rating.
2. Simulate a short circuit by connecting a low-resistance path across the motor terminals.
3. Observe the operation of the circuit breaker.
4. Note the tripping time and characteristics.

Phase Failure and Unbalance Protection

1. Install a phase failure relay in the circuit.
2. Start the motor and observe its operation under normal conditions.
3. Disconnect one phase and observe the relay's response.
4. Reconnect the phase and introduce a voltage imbalance. Observe the relay's tripping.

Thermal Protection

1. Install thermal protection (e.g., bimetallic strip) in the starter circuit.
2. Operate the motor under varying loads.
3. Record the time taken for the thermal protection to trip under high-load conditions.

Observations and Calculations

1. **Tabulate the results for each protection mechanism:**

Protection Type	**Tripping Current (A)**	**Tripping Time (s)**	**Remarks**
Fuse Protection			
Overload Relay			
Short Circuit (MCB)			
Phase Failure Relay			
Thermal Protection			

2. **Analyze the performance of each protection system based on the recorded data.**

Result

Precautions

1. Ensure proper grounding of all electrical equipment.
2. Do not exceed the motor's rated capacity.
3. Use appropriate personal protective equipment (PPE).
4. Verify the connections before switching on the power supply.
5. Avoid manual handling of live wires.

Experiment No. 07

Experiment Name: Study of Y-Δ starter Protection Scheme and its operation.

Objective

To study the Y-Delta (Y-Δ) starter protection scheme used in induction motors, understand its operation, and analyze its effectiveness in reducing starting current.

Equipment Required

1. Y-Δ Starter Panel
2. Induction Motor (e.g., 3-phase, 5 HP)
3. Overload Relays
4. Circuit Breakers (MCB/MCCB)
5. Timer Relay for Transition Switching
6. Voltage and Current Monitoring Devices
7. Three-Phase Power Supply
8. Connecting Wires and Tools

Theory

A Y-Δ starter reduces the starting current by initially connecting the motor windings in a star (Y) configuration and then switching to a delta (Δ) configuration once the motor reaches a certain speed. This method provides a smoother start and reduces stress on the motor and electrical network.

Protection Features:

Overload Protection:

Prevents damage from excessive load during operation.

Short Circuit Protection:

Ensures safety during faults using MCB/MCCB.

Phase Failure Protection:

Detects loss of a phase and disconnects the motor.

Under-Voltage Protection:

Trips the circuit if supply voltage drops below a threshold.

Transition Timer Protection:

Ensures appropriate timing between Y and Δ transitions to avoid mechanical or electrical stress.

Operation

Initial Start (Y Mode):

The motor windings are connected in a star configuration, reducing the voltage across each winding to $1/\sqrt{3}$ of the line voltage.

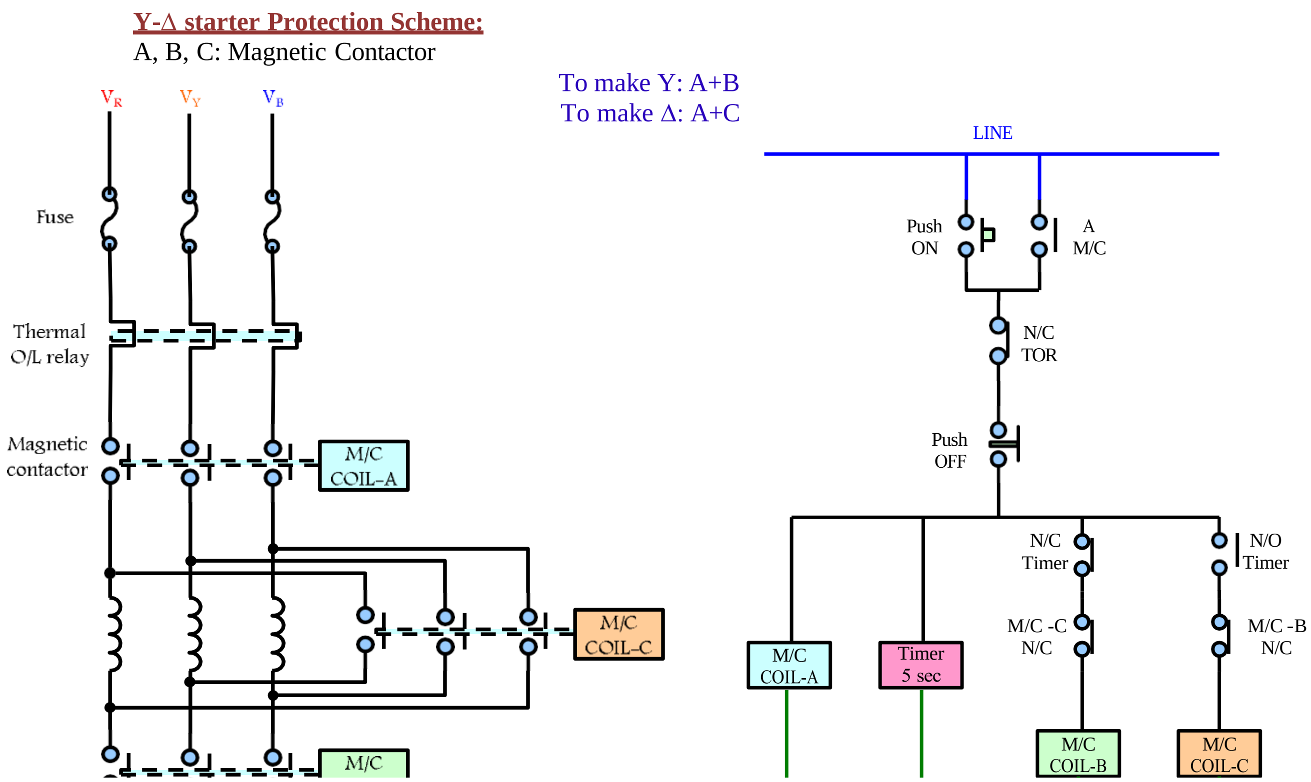
This limits the starting current and torque.

Transition to Δ Mode:

After the motor reaches a preset speed, a timer relay switches the winding configuration to delta (Δ).

Full line voltage is applied across each winding, providing full torque for normal operation.

Circuit diagram:



Procedure

Connect the Y-Δ starter to the induction motor as per the circuit diagram.

Ensure all protection devices (overload relay, MCB, phase failure relay) are in place and set to appropriate values.

Start the motor and observe its operation in the Y configuration.

Note the current and voltage values during the start.

Observe the transition to Δ configuration and record the current and voltage.

Simulate faults (e.g., overload, phase failure) and observe the response of protection devices.

Record all observations.

Observations and Calculations

1. Tabulate the starting current, operating current, and transition time:

Configuration	Voltage (V)	Current (A)	Time (s)
Star (Y) Mode			
Delta (Δ) Mode			

2. **Analyze the performance of the protection scheme under various fault conditions.**

Conclusion