Electrical Equipment - Course 230.2

SWITCHGEAR: PART 2

MOTOR CONTROL CENTRES

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1. OBJECTIVE

The student must be able to:

1. Explain the purpose of motor control centres.
2. State the essential control features of a motor control scheme.
3. Explain, for a given motor control scheme, the principle of operation and function of:
   (a) the control system.
   (b) the electrical protection and other safety features.
   (c) the indication system.
   (d) each operational component.

2. INTRODUCTION

In Ontario Hydro Nuclear Generation Division, motor control centres are used to supply and control groups of 600 V motors.

It is possible to control 600 V (and other voltage) motors from numerous locations. However, it is much more convenient from economy of space, economy in cabling and safety of location, to control motors from a central location. This central location is called a Motor Control Centre, (MCC for short). Each MCC contains several individual motor control units which are housed in metalclad cubicle and supplied from a common busbar.

This lesson explains the operation and safety features of MCC's.

3. FEATURES REQUIRED FOR EACH MOTOR CONTROL SCHEME

3.1 Essential Features

Every motor control scheme requires the following five essential control features:

(a) a means of isolating the power circuit.

(b) protection of the power and control circuits in the event of an electrical fault.

(c) circuits for controlling the stopping and starting of the motor.

(d) protection for the motor in the event of the motor becoming mechanically overloaded.

(e) grounding.

3.2 Additional Features

Motor control schemes may require some of the following additional features:

(a) *forward and reverse rotation of motor.*

(b) control of the motor from more than one location.

(c) automatic or logic control of the motor.

(d) indications showing the state of the circuit.

4. EQUIPMENT USED IN EACH UNIT OF AN MCC

4.1 Power Circuits

4.1.1 Circuit Using disconnect Switches and Fuses. Figure 1 shows how the power circuit is built up when a disconnect switch and fuses are used. It consists of:

(a) a disconnect switch - for isolation purposes.

(b) the main fuses - to protect the power circuit against short circuits.

(c) the contactor contacts - to control the motor.

(d) the overload heaters, 49 - to protect against mechanical overloads.

(e) the motor.

(f) the motor casing ground - to ensure safety.

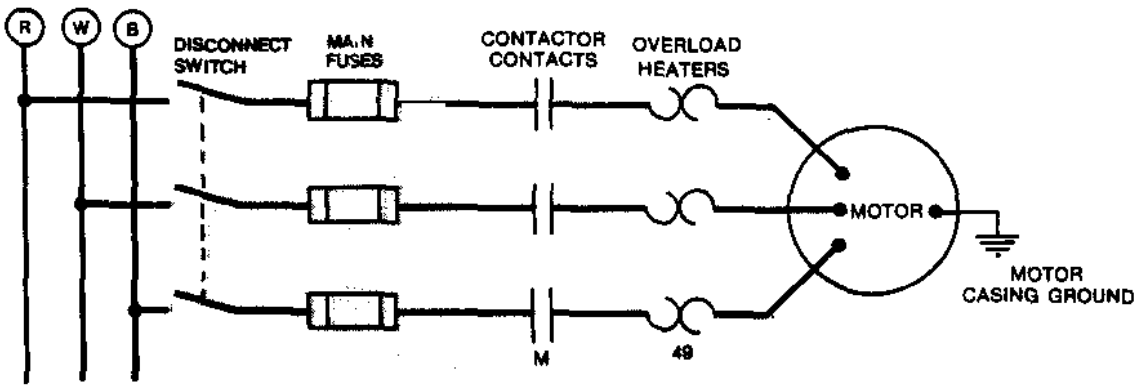


Figure 1: *Motor Power Circuit With a Disconnect Switch and Fuses.*

4.1.2 Circuit Using a Circuit Interrupter. Figure 2 shows how the power circuit is built up when a circuit interrupter is used. It consists of:

(a) the circuit interrupter - for isolation purposes and to protect the circuit against short circuits. (See Section 4.1.3 (a).)

(b) the contactor contacts - to control the motor.

(c) overload heaters (49) - to protect against overloads.

(d) the motor casing ground - to ensure safety of personnel.

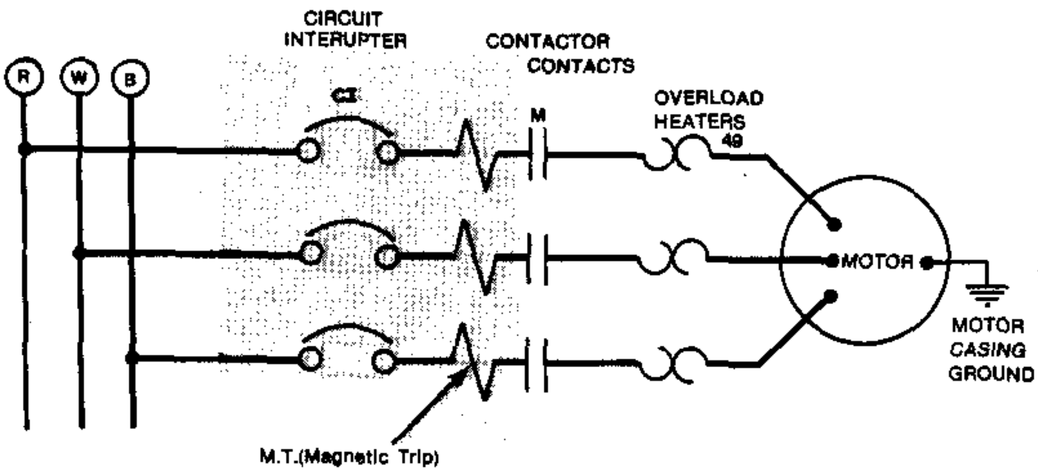


Figure 2: *Motor Power Circuit with a Circuit Interrupter.*

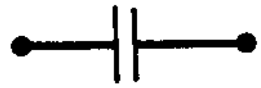
4.1.3 Main Component Details

(a) In Figure 1, the circuit isolation is provided by a disconnect switch. Short circuit protection is provided by the main fuses. Another method of achieving isolation and short circuit protection (see Figure 2) is to use a device called a circuit interrupter. (CI for short.) A CI is constructed so that it will interrupt short circuit currents. It has an internal magnetic trip (MT) mechanism that mechanically trips the CI when the current flow is above a pre-determined value. This value will be greater than motor starting current.

(b) Motors having an output rating up to approximately 30 kW (40 HP) are operated from a 600 V 3 phase supply and are controlled by contactors. Figure 4(a) and 4(b) show the coil and contact arrangement for a contactor. When the coil is energized, all four contacts close. Note there are at least four contacts on a contactor. Three contacts are required for the power circuit and one is required for the "seal-in" circuit, which is described later. Additional contacts may be provided for interlock and indication purposes.

In Figure 4(b), the contactor coil is called M and the four contacts that are operated by this contactor are called M-1, M-2, M-3, M-4.

It is a convention, that all relay and contactor contacts are shown in their position when the relay or contactor is de-energized. Figure 3(a) shows a contact which is open when the relay or contactor is de-energized and closed when the relay or contactor is energized. Figure 3(b) shows a contact which is closed when the relay or contactor is de-energized and open when the relay or contactor is energized.



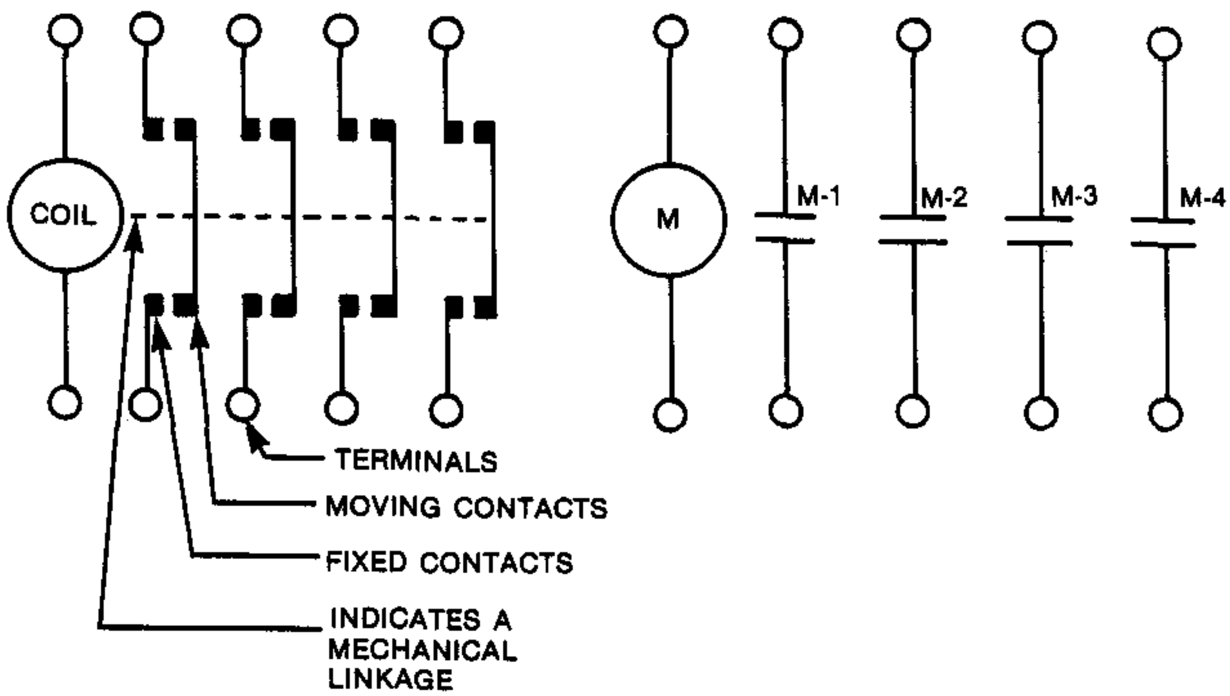
Contact open when relay or contactor is de-energized. Contact closed when relay or contactor is energized.

(a)

Contact closed when relay or contactor is de-energized. Contact open when relay or contactor is energized.

(b)

Figure 3: Contact Conventions.



(a) Physical Arrangement

(b) Diagramatic Representation

Figure 4: Contact and Coil Arrangement for a Contactor. Contactor Shown De-energized.

(c) The fuse or the circuit interrupter is provided to protect the motor in the event of a short circuit in the motor, the terminal boxes or in the supply cable. However, if the motor is subjected to a continuous mechanical overload which causes the load current to be 115% (or more) of rated load current, the motor will in time suffer damage due to excess I^2R_m heating (R_m is the resistance of the motor windings). Because a fuse cannot be adjusted and a circuit interrupter cannot be set closely enough to protect the overloaded motor, an overload relay is used. This type of relay can be accurately set and is arranged to open the contactor and stop the motor, if it consumes excess current for longer than the prescribed time.

The most common type of overload relay is the thermal relay which is given the IEEE Code number 49. See Appendix I. Thermal relays operate on the principle where a "thermal image" of the I^2R_m heating produced in the motor is reproduced in a small heater as I^2R_h (R_h is the resistance of the heater. The heat produced by this heater bends a bimetal strip and at a preset current (and hence temperature), operates a contact. Figure 5 shows the principle of operation. Note only one phase is shown, in practice there are three heaters and three bimetals, ie, one per phase. All three bimetals operate a mechanical linkage which operates the contacts. Because the heater and bimetal take time to warm up, a thermal relay has an inherent time delay. This delay is necessary to allow for the high current, typically 6 times full load current, taken during starting. By careful choice of heater, bimetal and adjustment, the relay can be accurately set and it will protect the motor. Thermal overload relays are usually to set to operate at 105% to 110% of motor full load current, ie, to operate just before the motor can be damaged by prolonged 115% full load current flow.

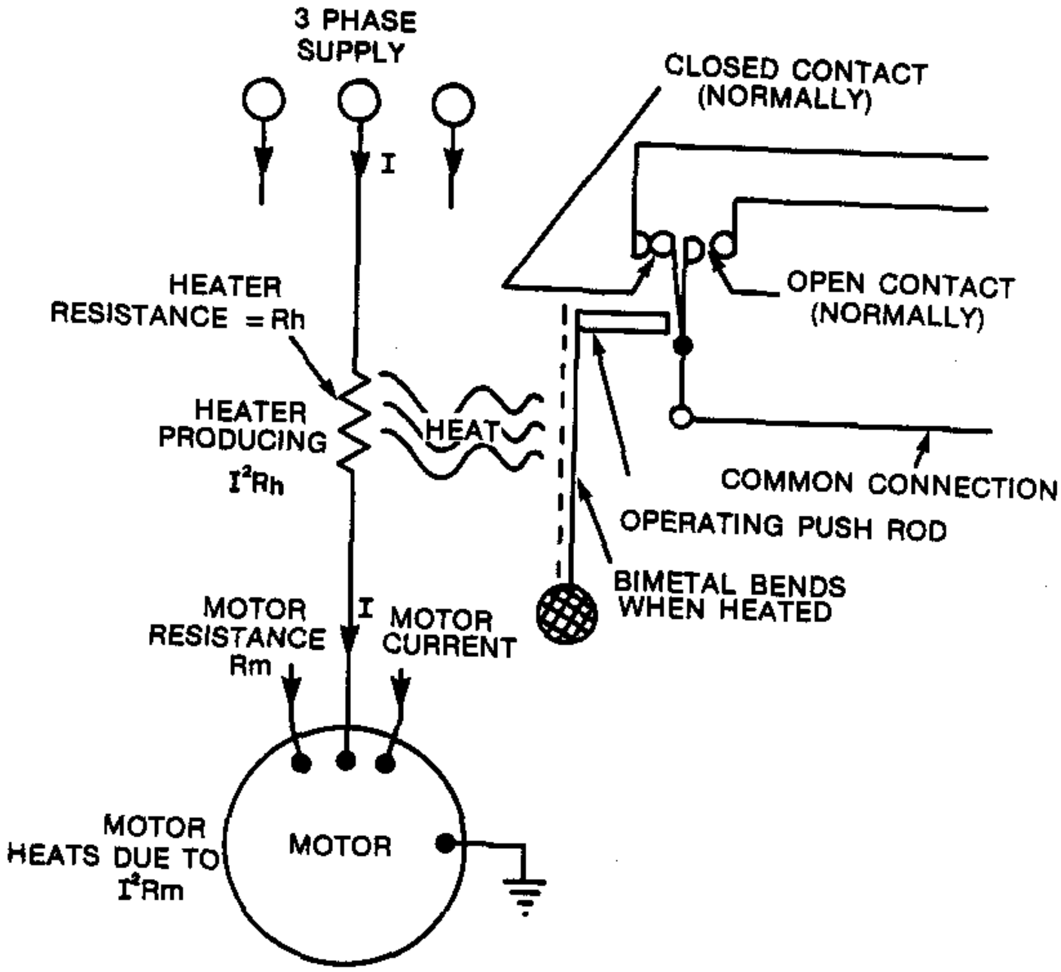


Figure 5: Principle of a Thermal Relay.

(d) The current passes from the overload relay through the supply cable to the motor terminals and windings. The motor casing is connected to the station grounding system. This ground connection ensures that the motor casing cannot become live with respect to ground.

4.2 The Control Circuit

4.2.1 The Basic Control Circuit

Figure 6 shows the basic power and control circuits using a contactor. Control circuits are shown in the de-energized state. The control circuit has the following features:

(a) a control transformer supplied from the 600 V circuit, which supplies the control circuit at 120 V (a safe voltage).

(b) a fuse to protect the control circuit.

(c) a contact 49-1 which opens when the thermal overload relay 49 operates. When contact 49-1 opens, it breaks the control circuit which de-energizes the contactor and stops the motor.

(d) a start push button which energizes the contactor coil MC/4.

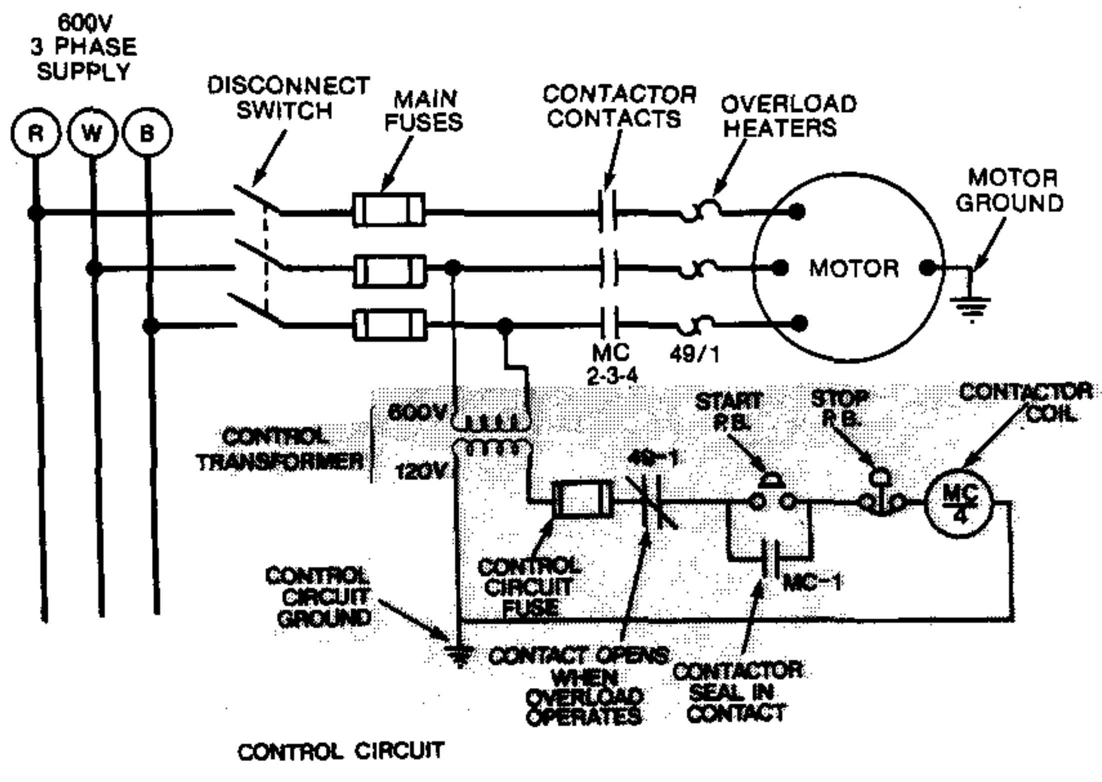


Figure 6: *Basic Motor Control Circuit Controlled by a Contactor.*

(e) a "seal in" contact MC-1, which is the fourth contact on the contactor. It closes at the same time as the other three contacts and keeps the contactor energized after the start push button is released.

(f) a stop pushbutton which breaks the control circuit, de-energizing the contactor.

(g) the contactor coil M which operates the four (or more) 'M' contacts.

(h) the control circuit ground.

This circuit is used for simple applications. Most control circuits have some of the additional features outlined in the following section.

4.2.2 Control Circuits With Additional Features

Figure 7(a) shows the power and 120 V ac control circuits for a non reversing motor, and Figure 7(b) shows the simplified 48 Vdc control circuit. The power circuit is the same as that shown in Figure 2.

On the 120 Vac control circuit, an undervoltage relay (27) is used to monitor the voltage supply to the power and control circuits. Relay 27 will release whenever the supply fails or the supply voltage fails to an unacceptably low level.

The 48 Vdc control system has two command inputs into the process logic. The ON command contact is closed by the operator whenever he wishes to manually run the motor. The AUTO command contact is closed whenever the operator selects auto operation. If the command is selected to ON or AUTO and provided:

(a) the process logic gives a permissive signal, and

(b) the overload relay 49 has not operated, relay R7 will energize and operate the contactor which will start the motor. In this circuit, the "seal-in" is provided by the ON or AUTO contacts remaining closed.

The white lamp (W) indicates when the motor is running. The amber lamp (A) indicates when the motor is stopped and the ac supplies are available.

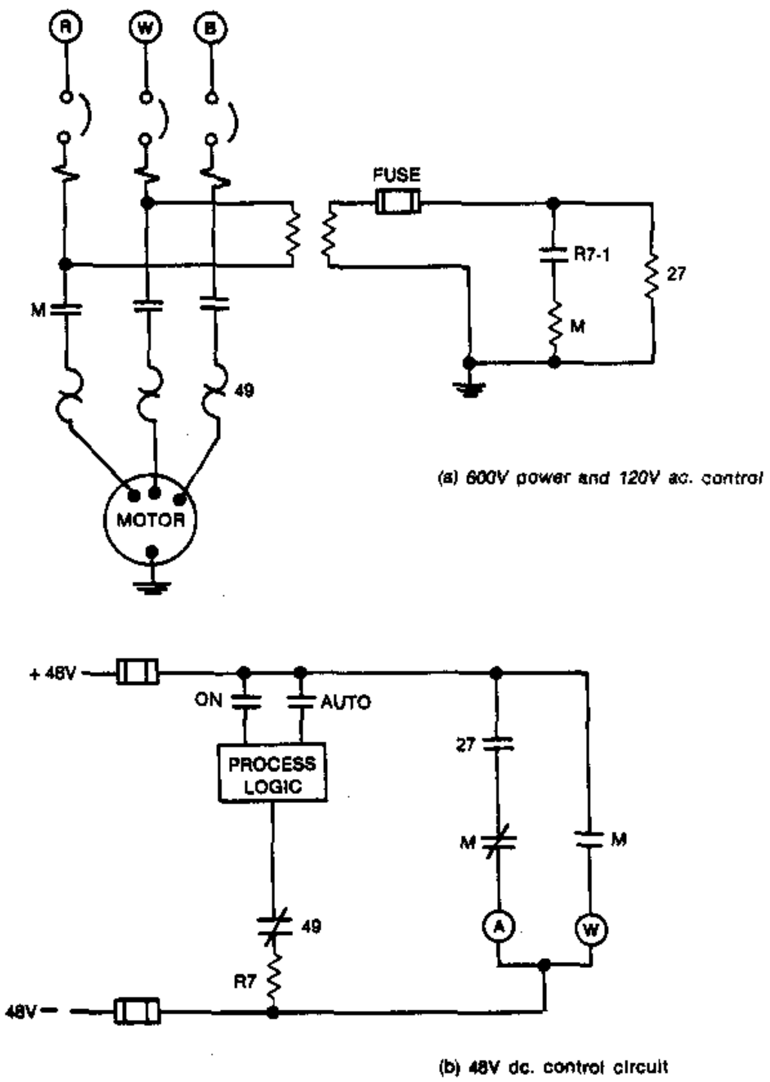


Figure 7: Simplified Control Circuit for a Non-Reversing Motor.

4.2.2 Reversing Motors

Reversing Motors have similar control systems to non-reversing motors except that two contactors are used, one for forward (F) and one for reverse (R). *Figure 8* shows that by using two contactors the R-W-B phase sequence is changed to B-W-R which reverses the motor. The contactors are interlocked to guard against simultaneous forward and reverse signals being given.

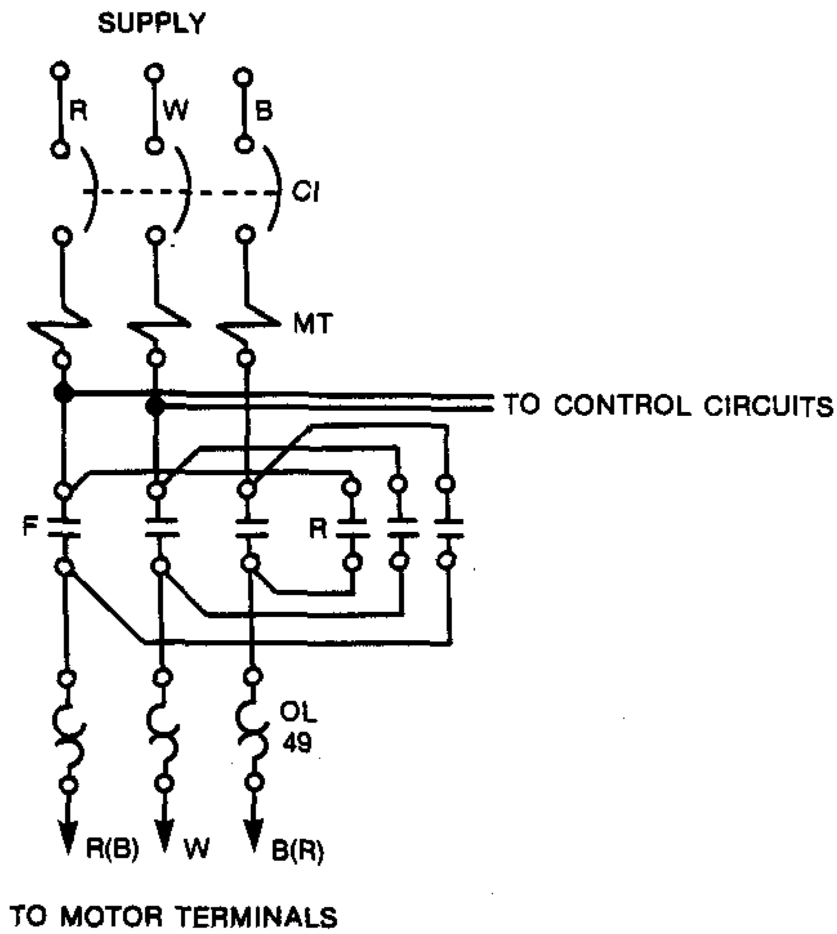


Figure 8: Forward and Reverse Contactors for a Reversing Motor.

ASSIGNMENT

1. State the five essential features that are required for any motor control circuit (Section 3.1).

2. (a) Draw and label a motor power circuit which includes a disconnect switch and fuses.

   (b) Explain the function of each component (Sections 4.1.1 and 4.1.3).

3. (a) Draw and label a motor power circuit which includes a circuit interrupter.

   (b) Explain the function of each component (Sections 4.1.2 and 4.1.3).

4. (a) Using a labelled diagram, explain the principle of operation of a thermal relay.

   (b) Explain the term "thermal image".

   (c) How is the time delay achieved in a thermal relay? (Section 4.1.3 (c).)

5. Given control circuits similar to that shown in Figures 6 and 7, name and explain the function of each component. (Sections 4.2.1 and 4.2.2)

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APPENDIX I

IEEE Device Numbers and Functions for Switchgear Apparatus.

Device Number	Function
3	Interposing Relay
4	Master Contactor or Relay
27	ac Undervoltage Relay
33	Position Switch
46	Phase Unbalance Relay
49	ac Thermal Relay
50	Short Circuit Selective Relay
51	ac Overcurrent Relay
52	ac Circuit Breaker
63	Fluid - Pressure, Level or Flow Relay
64	Ground Protection Relay
74	Alarm Relay
86	Lock-Out Relay
87	Differential Current Relay
89	Line Switch or Disconnect Switch
94	Tripping Relay