Industrial Motor Control

Control devices

Control Diagram

Starting Method

Control Devices

Disconnecting switches

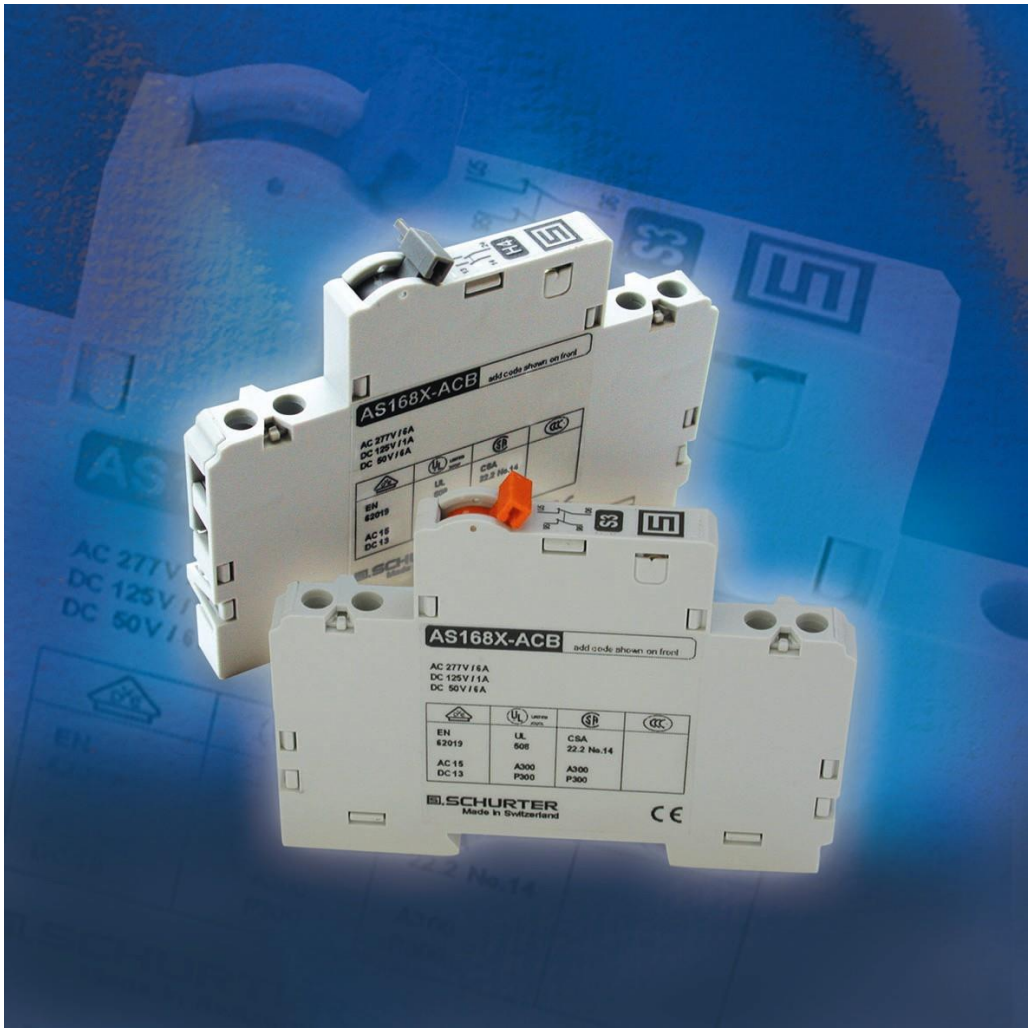
- A disconnecting switches isolates the motor from the power source.
- It consist of 3 knife-switches and 3 line fused enclosed in a metallic box.
- The knife switch can be opened and simultaneously by external handle.
- Disconnecting switches are selected to carry the nominal full load current of the motor , and to withstand short circuit currents for brief interval.

Disconnecting switches

Manual circuit breaker

- Manual circuit breaker opens and close a circuit like a toggle switch.
- It trips automatically when current exceeds a predetermined limit. After tripping, it can be reset manually.
- Manual circuit breaker are often used instead of disconnecting switches because no fuses has to be replaces.

Manual Circuit Breaker



Cam Switches

- A cam switch has a group of fixed contacts and equal number of moveable contact.
- The contact can be made to open and close in a preset by rotating handle or knob.
- Cam switches are used to control the motion and position of hoist, callenders, machine tools and so on.

Cam Switches

Pushbuttons

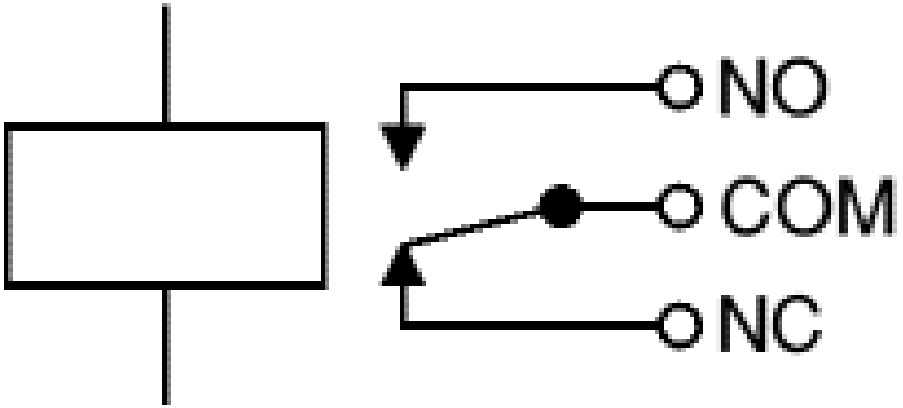
- A pushbutton is a switch activated by finger pressure.
- Two or more contacts are open or closed when the button is depressed.
- Pushbuttons are usually spring loaded so as to return to their normal position when pressure is removed.

Push buttons

Control Relays

- Control relays is an electromagnetic switch that opens and closes a set of contacts when the relay coil is energized.
- The relay coil produces a strong magnetic field which attract a moveable armature bearing the contacts.
- Control relays are usually used low power circuits.

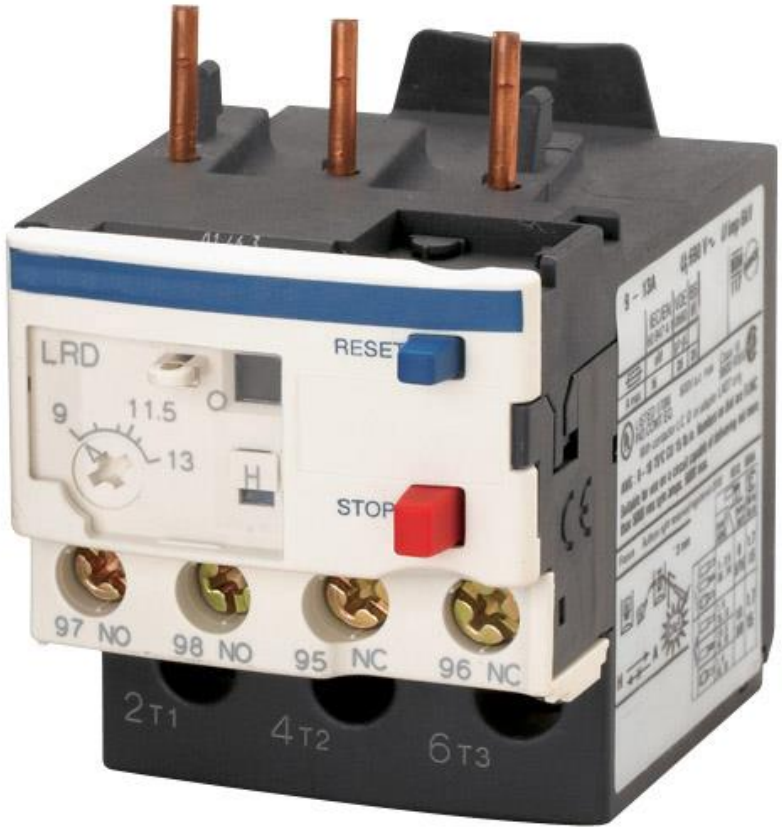
Control Relays



Thermal relays

- A thermal relay is a temperature-sensitive device whose contact open or close when motor current exceed present limit
- The current flow through a small, calibrated heating elements which raises the temperature of the relay.

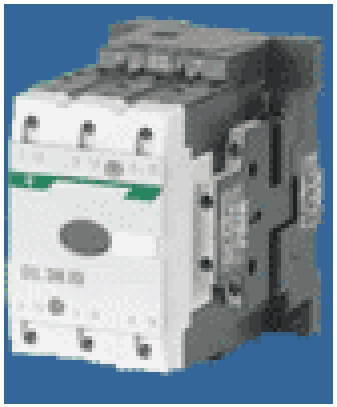
Thermal Relays



Magnetic Contactors

- Magnetic contactors is basically large control relays design to open and close a power circuit.
- It possesses a relay coil and a magnetic plunger, which carry sets of movable contacts.
- Magnetic contactors are used to control motors ranging from 0.5 hp to several hundred hp.

Magnetic Contactors



Proximity detectors

- Sealed devices that can detect object without coming in direct contact with them
- Wire to external Dc source.

Control Diagram

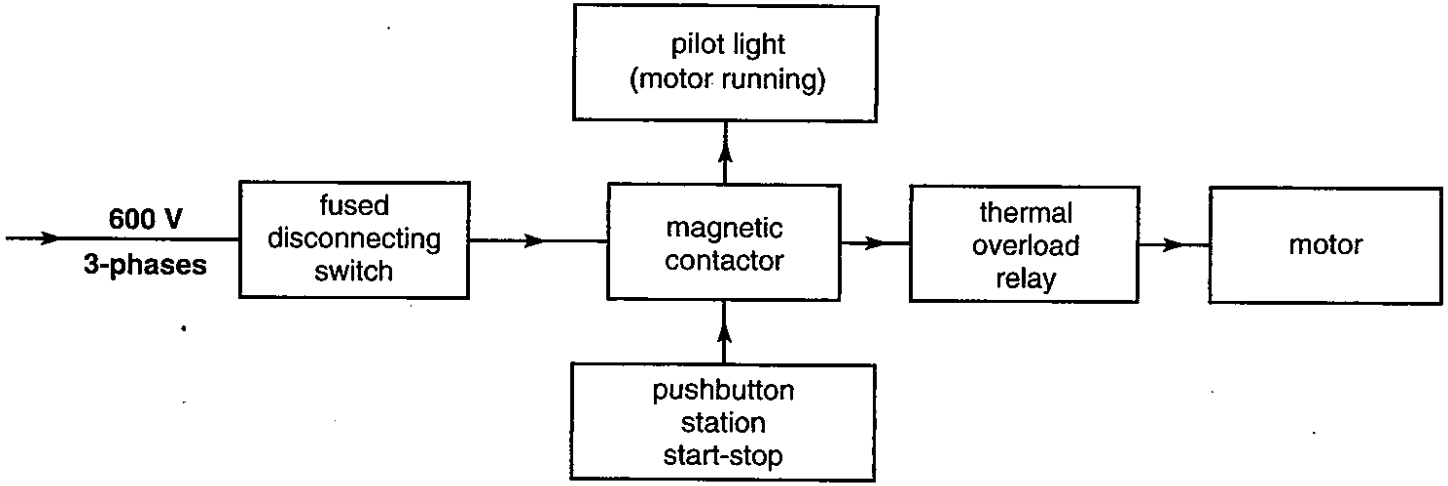
Control Diagram

- Control system can be represented by four types of circuit diagrams.
  - Block diagram
  - One line diagram
  - Wiring diagram
  - Schematic diagram

Block diagram

- Composed of set of rectangular, each representing control device with description of function.
- Connected in arrow to indicate direction of power or signal flow

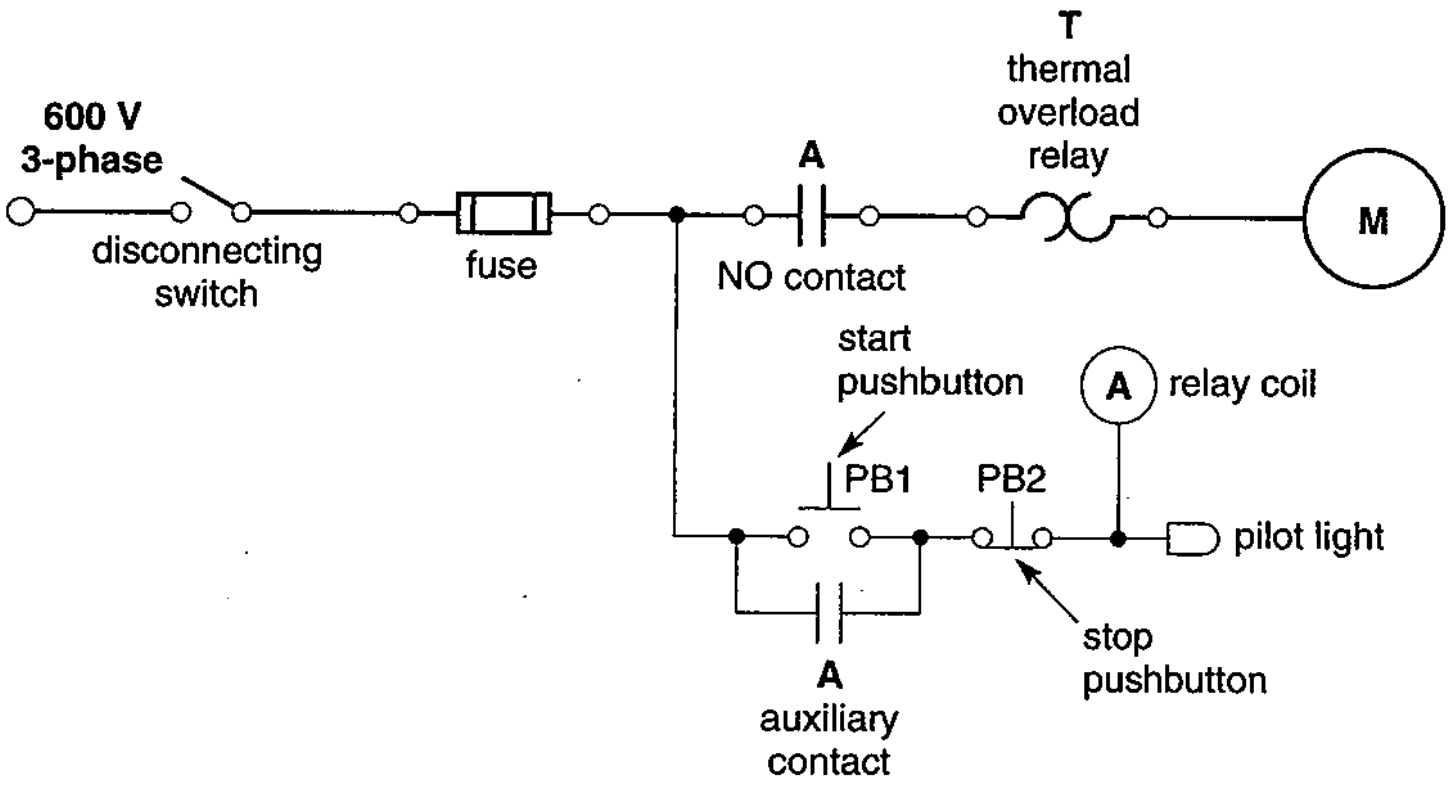
Block Diagram



One line Diagram

- Also call single line diagram
- Similar to block diagram, except components shown by their symbols.
- Consequently one line diagram yield more information

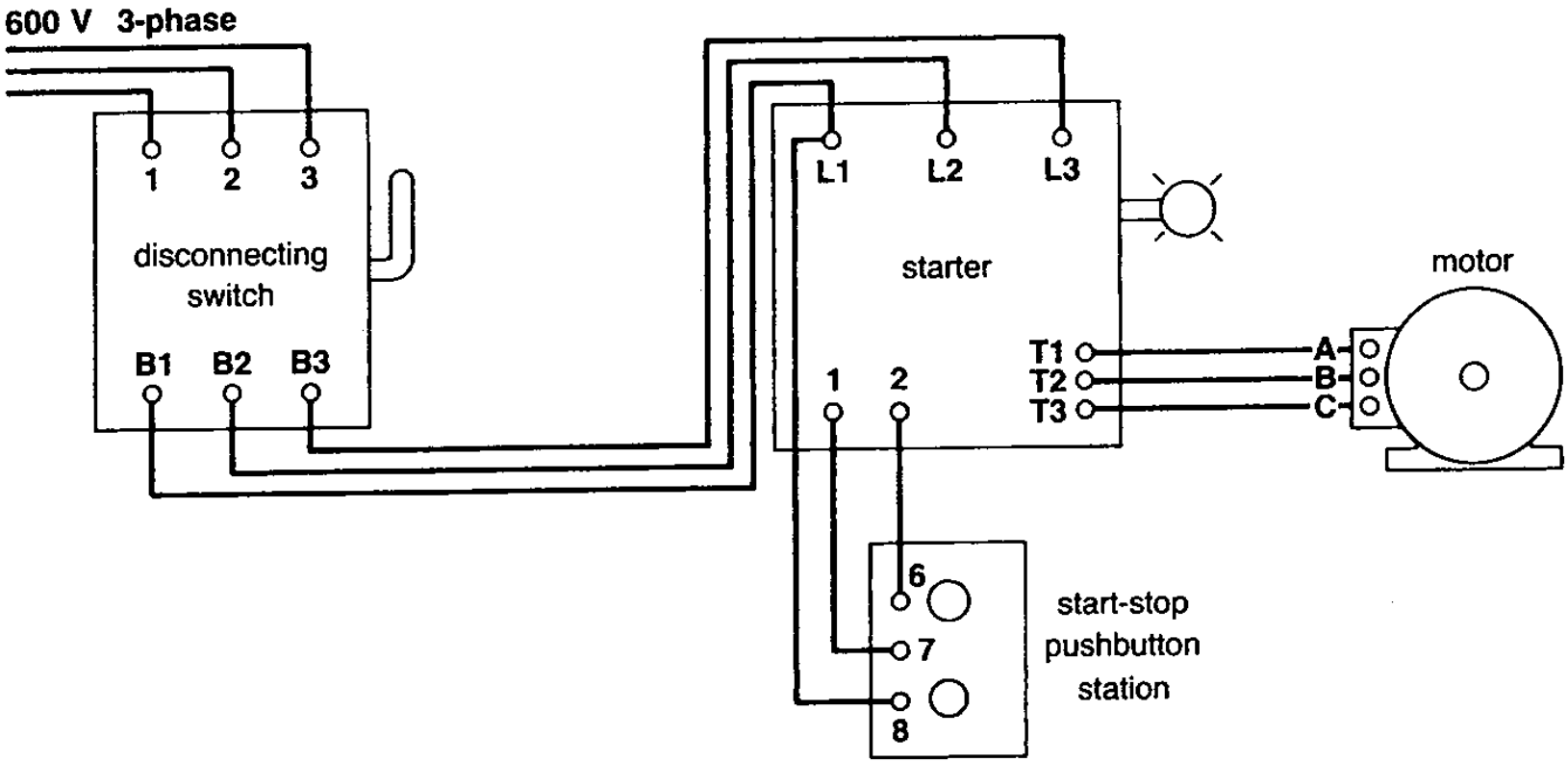
One line diagram



Wiring Diagram

- A wiring diagram show the connection between components , taking into account physical location.
- These diagrams are employed when installing equipments.

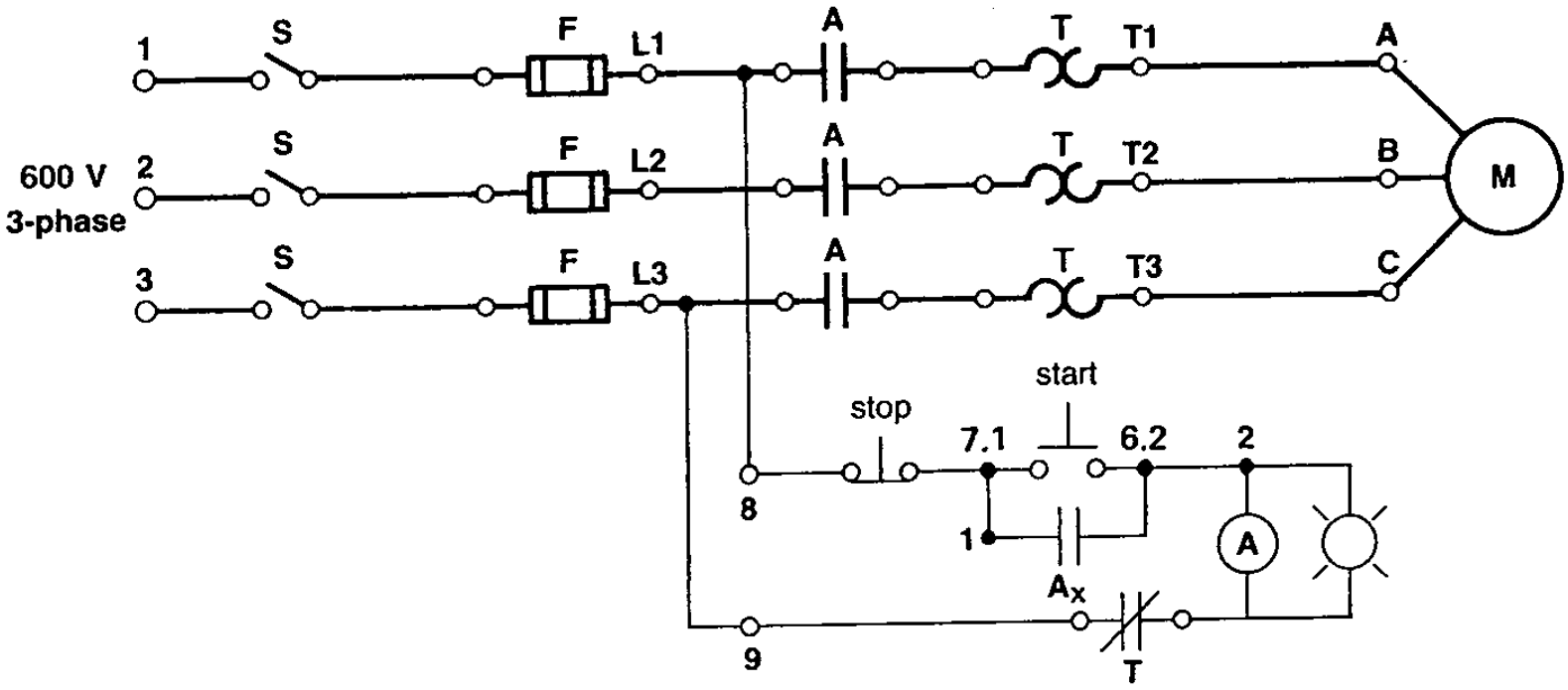
Wiring Diagram



Schematic Diagram

- Show all the electrical connection between components, without regards their physical location or terminal arrangements.
- Show all the details of connection and components.

Schematic Diagram



Starting Method

Starting of 3 Phase Induction Motor

- Methods of starting 3-phase induction motor
  - Direct on line (DOL)
  - Stator resistance starting
  - Autotransformer starting
  - Star-delta starting
  - Rotor resistance starting

Direct On Line Starting (DOL)

- Motor started by connecting directly to 3 phase supply.
- Impedance of the motor at standby is relatively low and when connected to power supply system, the starting current will be high(4 to 10 time of full load current) and low power factor.
- This method of starting suitable for relatively small machines (up to 7.5kW)

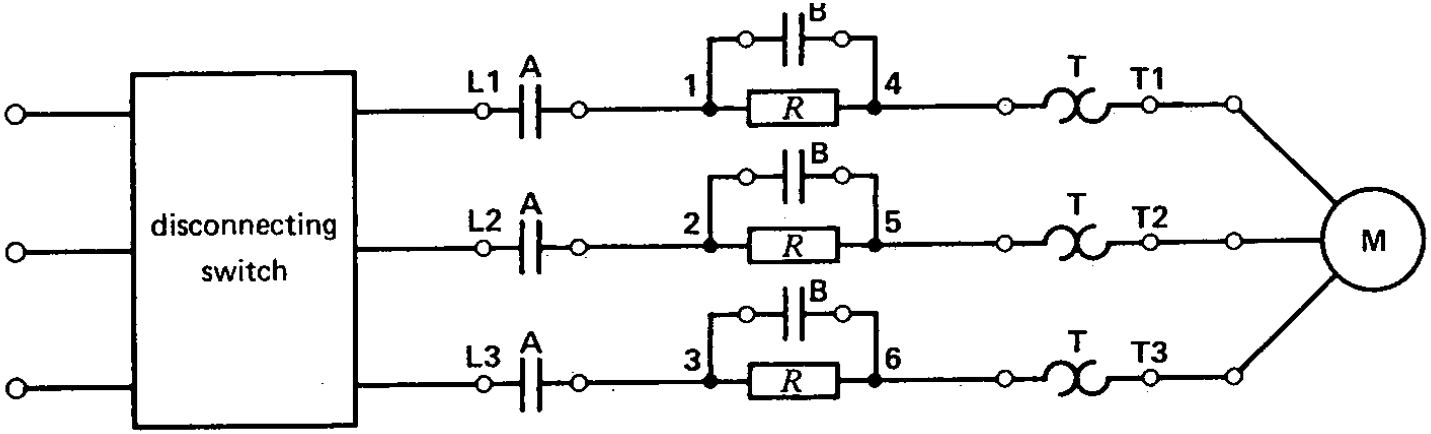
Stator resistance starting

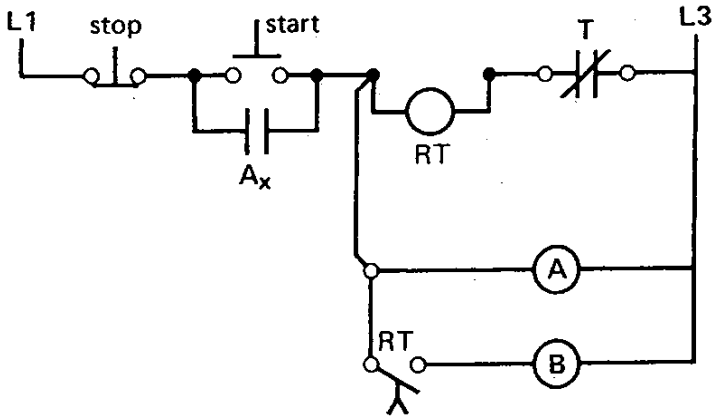
- In this method external resistances are connected in series with each phase of stator winding during starting.
- This cause voltage drop across the resistance so that voltage available across motor terminals is reduced and hence thence the starting current
- The starting resistance are gradually cut out in steps (two or more steps) from the stator circuit as motor picks up speed.

Stator resistance starting

- When the motor attain rotor speed, the resistances are completely cut out and full line voltage is applied to the motor.
- This method suffer from two drawbacks
  - Reduced voltage applied to the motor during the starting period lowers the starting torque and hence increase the accelerating times.
  - Lot of power is wasted in the starting resistance
- Therefore this method usually to start small motors only

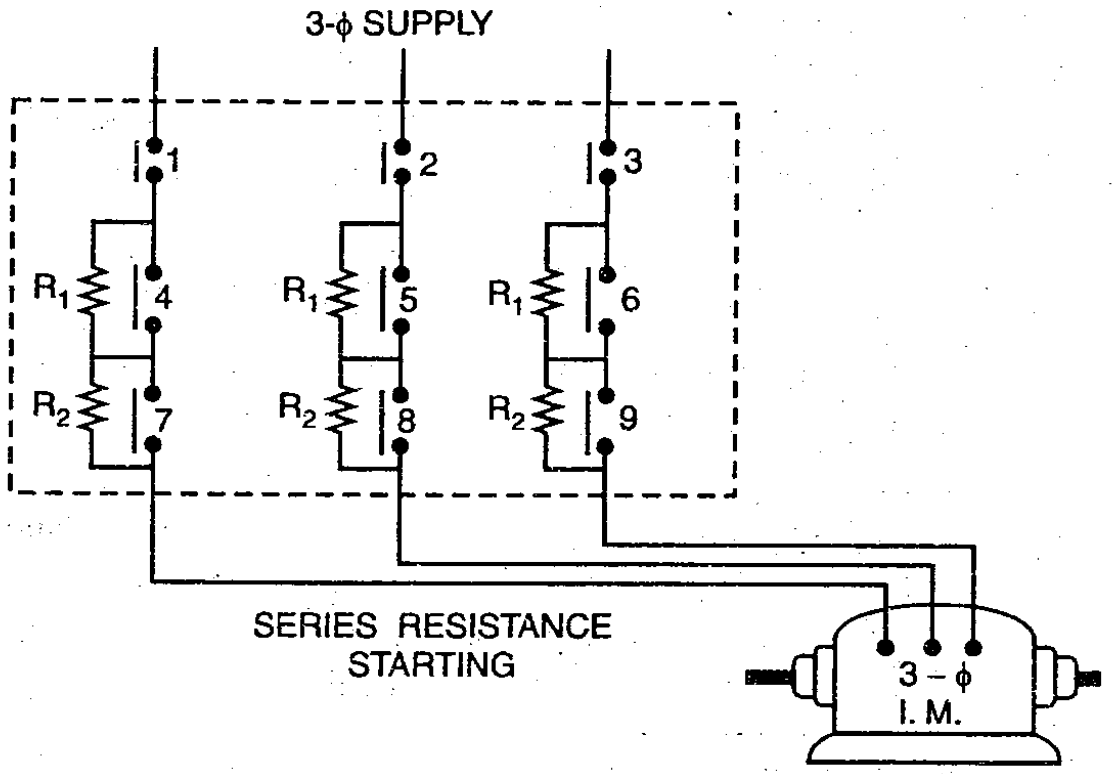
Stator resistance starting





Stator resistance starting

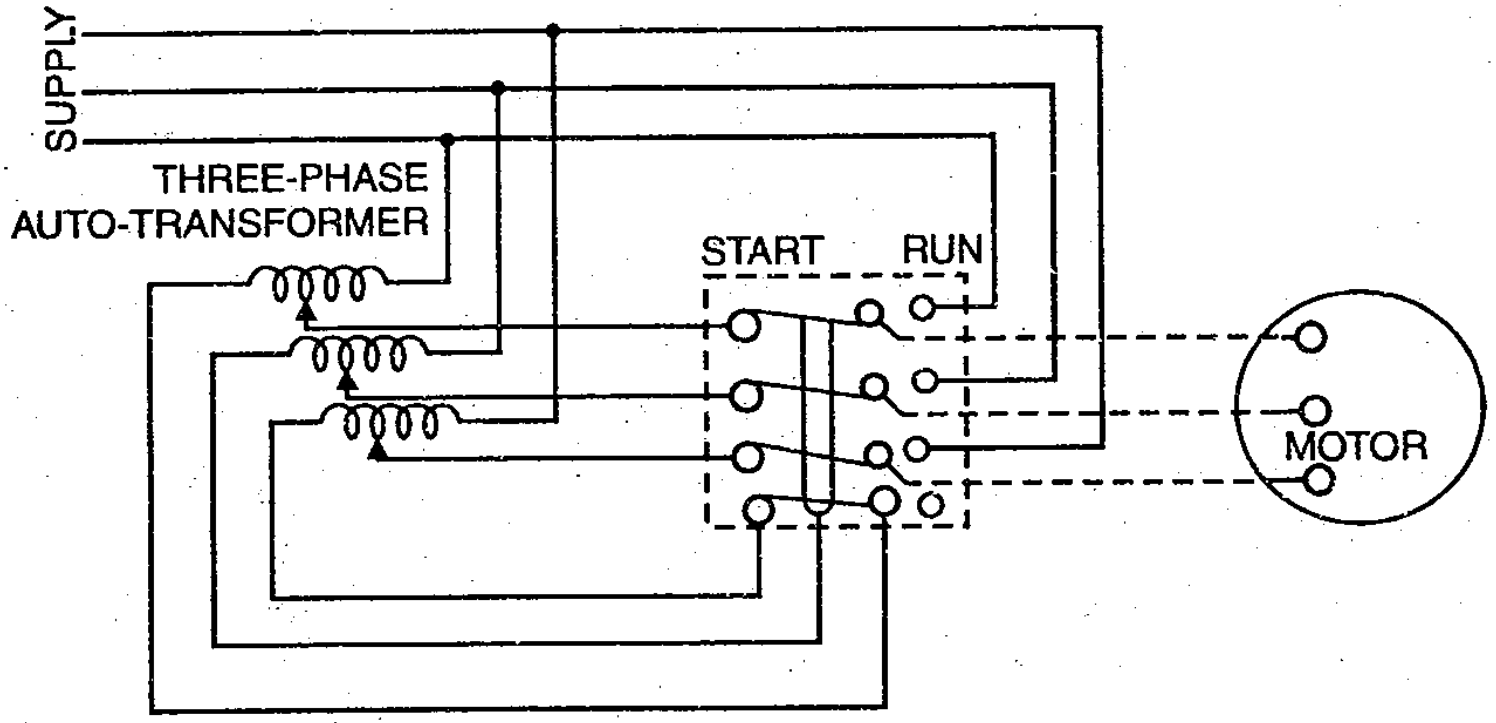
Start : Close 1-2-3
Next : Close 4-5-6
Finally : Close 7-8-9



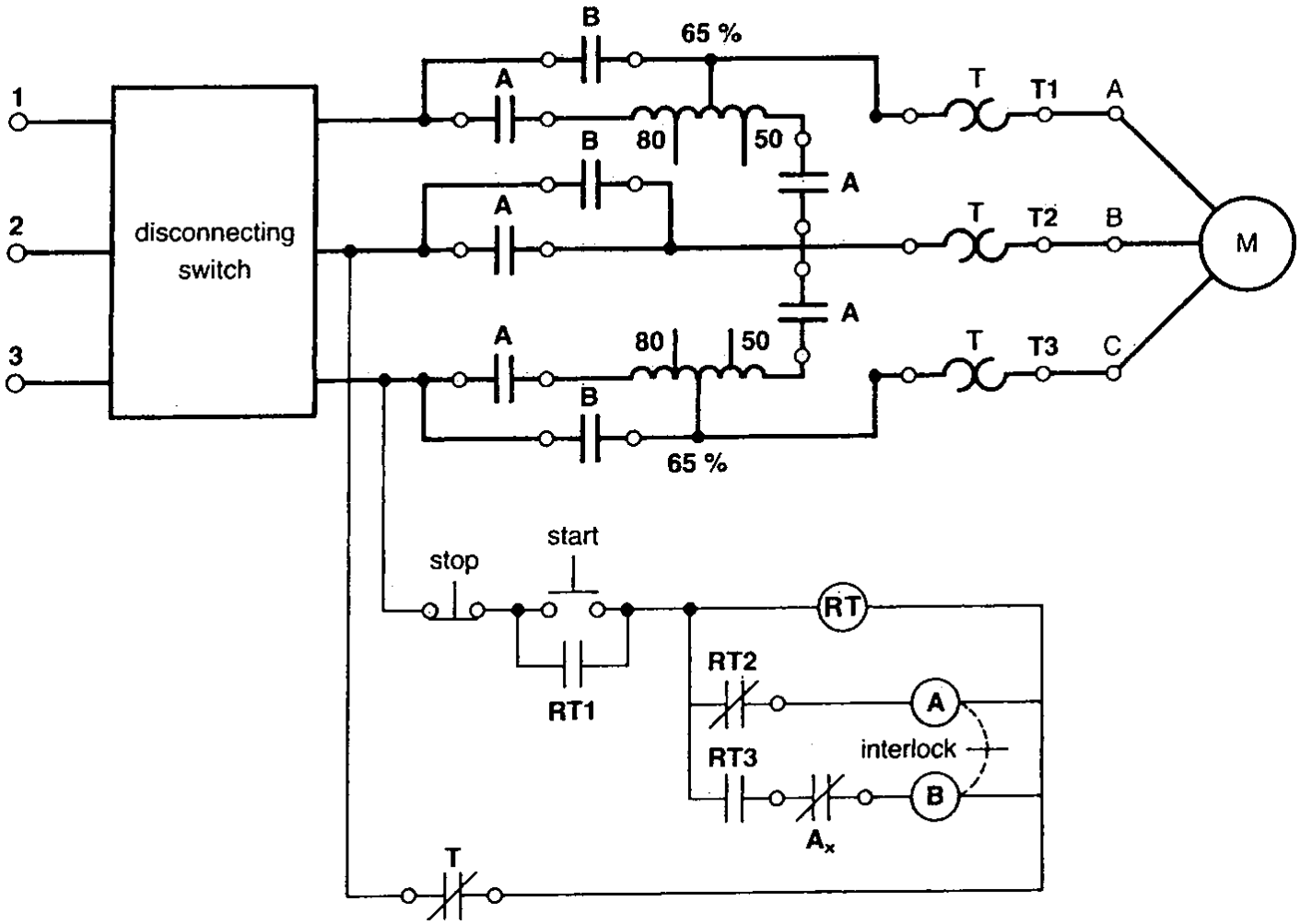
Autotransformer starting

- Aim in connecting induction motor to reduced power supply at starting and full voltage at sufficient speed.
- Example of autotransformer starting is 3-phase system where is 45%, 75% and 100% of line voltage.
- The circuit condition for voltage is control by the tapping position

Autotransformer starting



Autotransformer starting



Autotransformer starting

- At instant of starting , the change over thrown to start position. This put autotransformer in the circuit and thus reduced the voltage applied to the circuit.(Current limited to safe value)
- When motor takes 80% of normal speed, the change over switch thrown to “run” position.
- This take out autotransformer from the circuit and put the motor to line voltage

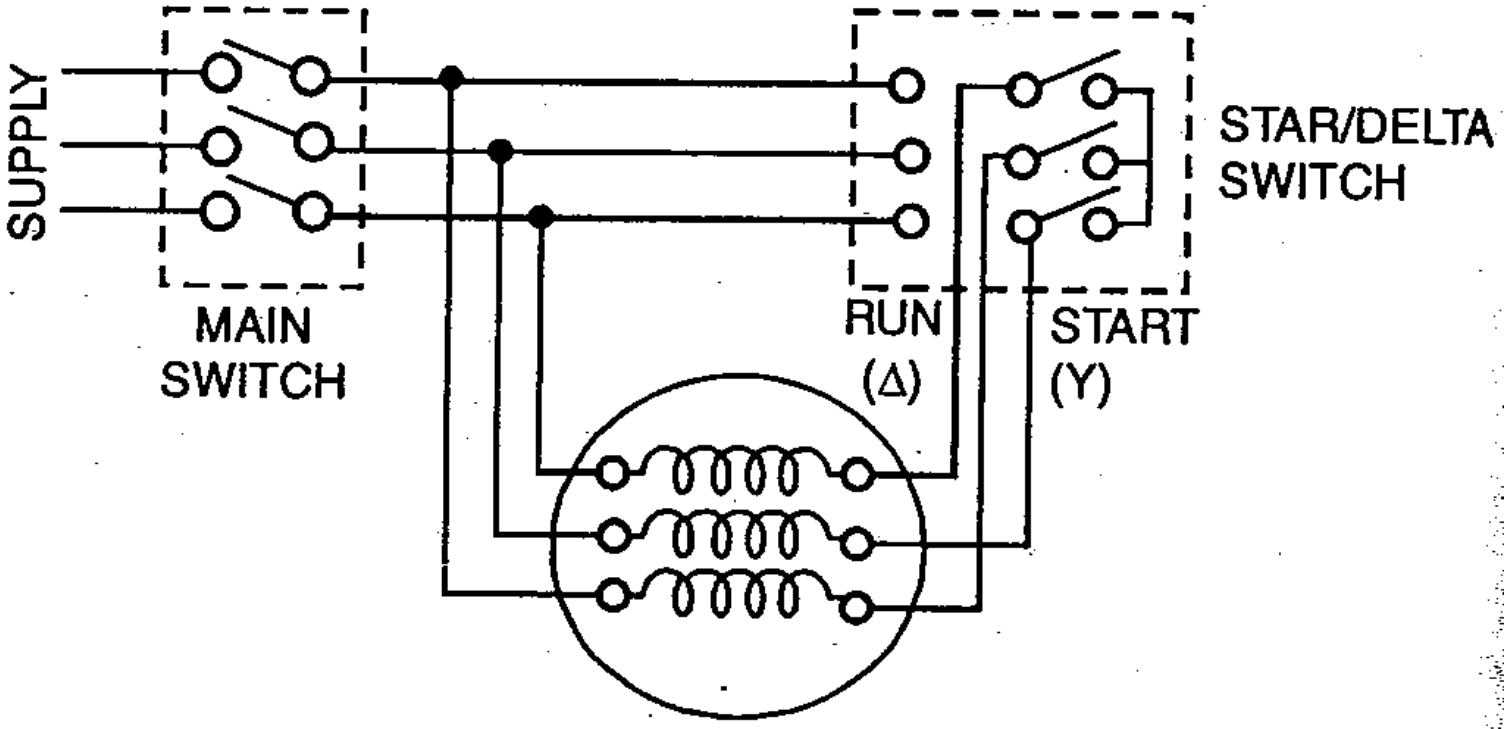
Autotransformer starting

- Autotransformers starting has several advantages
  - Low power loss
  - Low starting current
  - Less radiated heat
- This method of starting usually used large machines (over 25 HP). This method can be used for both star or delta connected motors.

Start Delta starting

- The stator winding is designed for delta operation.
- During starting stator is connected in star mode.
- When machine is up to the speed the connection is changed to delta connection.

Star Delta Connection



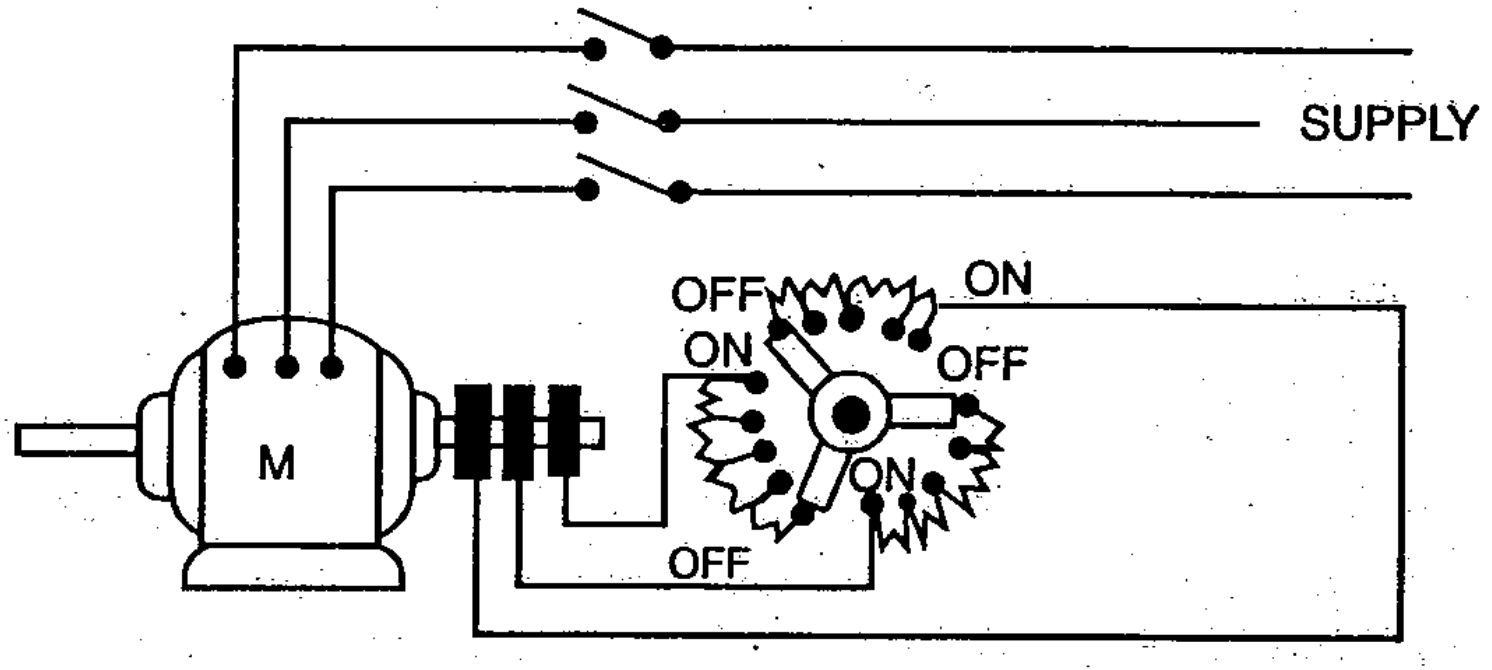
Star delta connection

- Six leads of stator winding are connected to the change over switch.
- Starting point, change over switch is in star position.
  - Stator phase voltage is $1/\sqrt{3}$ times of line voltage. Also starting torque is $(1/\sqrt{3})^2$ compare to delta connection.
  - Then after exceeding the nominal speed the connection will be change to delta connection for full load current
- This method usually used for medium size machines (up to 25 HP)

Rotor resistance starting

- This method is used to start slip ring motor.
- In this method , a variable star connected rheostat is connected in the rotor circuit through slip ring and full voltage applied to the stator winding.

Rotor resistance starting



Rotor resistance starting

- At starting , the handle of rheostat is set in the OFF position so maximum resistance is placed on each phase of the rotor circuit.
- This reduce starting current and increase torque.
- As motor speed up , the handle of rheostat is gradually moved in the clockwise direction and cuts out the external resistance in each phase of rotor circuit. When motor attain normal speed, the change over switch is ON position and cut off the resistance.

Soft starting

- Motor soft starter is a device used with AC electric motors to temporarily reduce the load and torque in the power train of the motor during startup. This reduce starting current and increase torque.
- Electrical soft starters can utilize solid state devices to control the current flow and therefore the voltage applied to the motor

Soft starting

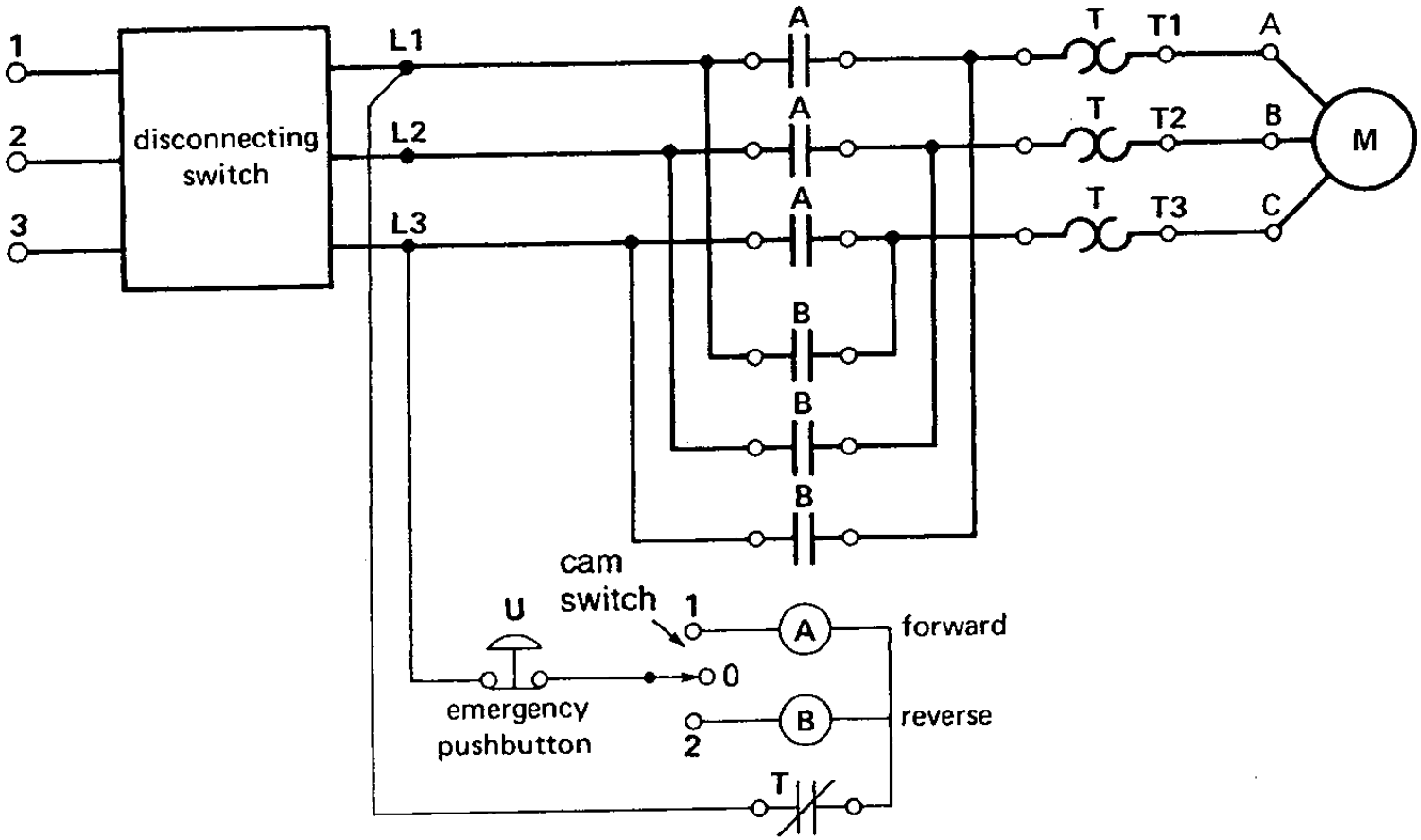
- They can be connected in series with the line voltage applied to the motor, or can be connected inside the delta (Δ) loop of a delta-connected motor, controlling the voltage applied to each winding.
- Typically, the voltage is controlled by reverse-parallel-connected silicon-controlled rectifiers (thyristors), but in some circumstances with three-phase control, the control elements can be a reverse-parallel-connected SCR and diode.

Soft starting

Reversing direction of a rotation

- We can change the rotation of a 3-phase motor by interchanging any two lines.
- This can be done by using two magnetic contactors A and B and 3 position cam switch.

Reversing direction of a rotation



Reversing direction of a rotation

- When contactor A is closed, lines L1, L2 and L3 are connected to terminals A,B,C of the motor.
- When contactor B is closed ,lines L1, L2 and L3 are connected to motor terminals C,B,A.
- This contact is engage by cam swith.
- In forward direction, the cam switch engages contact 1, energize relay coil A
- In reverse direction , the cam switch engages contact 2, energize relay coil B