MOTOR STARTER

(NOTES)

1.0 INTRODUCTION

A.C. Induction motors are traditionally started and stopped by applying and removing the A.C. supply. In some cases, a full voltage start is acceptable, but in many situations, the start current must be reduced, and so a reduced voltage starter is employed. For that reasons, we need a starter to start the A.C Motor. BS 7671: 1992 states that every electric motor having a rating exceeding 0.37 kW shall be provided control equipment incorporating means of protection against overload of the motor.

The simplest form of motor starter for the induction motor comprises a switch and an overload protection relay. The switch may be a manually operated load break switch, but more commonly it would be an electromagnetic contactor that can be opened by the thermal overload relay. Typically, the contactor will be controlled by separate Control Circuit which is consist of start and stop buttons, and an auxiliary contact is used as a hold in contact.

According to IEE regulation, electrical motor starter must contain:

- Start-Stop Control
- Overload protection
- Isolator

1.1 Components in Control Circuit

1.1.1 Biased Switch / Push Button

- A Push Button switch contains a spring that returns the switch actuator to their original state immediately after being depressed. Push button is used as a control element in Control Circuit, to manually opens and closes the circuit.
- Symbol

- Two distinct colors for identification. Red indicates Push Button Stop and Green indicates Push Button Start.
- To operate the switches, an external force must be exerted to the buttons. The button will return to its normal position when the external force is removed.

Push-button switch

1.1.2 Mechanical Latching Switch

- The mechanical latching switch is a type of switch that maintains the selected position without a current draw. Latching Switch is used as a control element in Control Circuit to manually opens and closes the circuit. The contact is mechanically latched closed or opened.
- Symbol

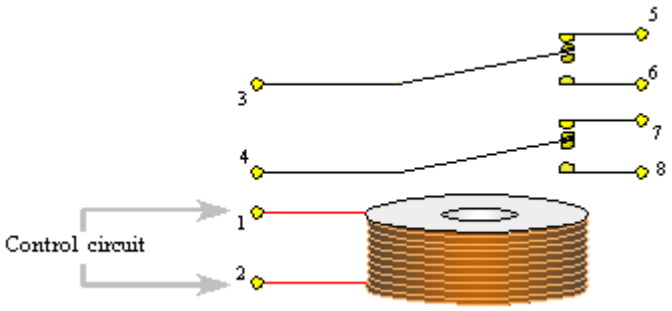
Latching Switch

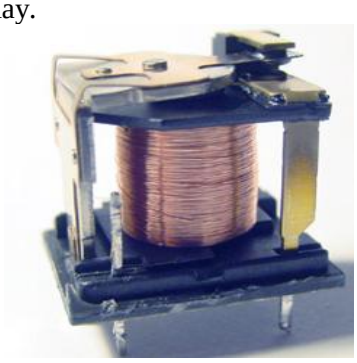
- Two distinct colors for identification. Red indicates Push Button Stop and Green indicates Push Button Start.
- To operate the switch, an external force must be exerted to the button. The button will return to its normal position when the button is twisted to remove the latch.

Latching switch

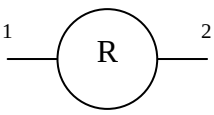
1.1.3 Relay

- A relay is an electrical switch that opens and closes under the control of another electrical circuit. It allows a low current control circuit to make or break an *electrically isolated* high current circuit path. A basic relay consists of a coil and a set of contacts. The most common relay coil is made of a length of copper wire wrapped around a metal core. When voltage is applied to the coil, current passes through the wire and creates a magnetic field. This magnetic field pulls the contacts together and holds them there until the current flow in the coil has stopped. The diagram below shows the parts of a simple relay.

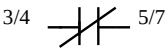




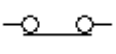
Symbol



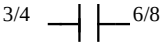
Relay Coil

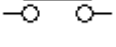


or



Normally Closed contact

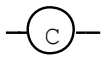




Normally Opened contact

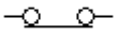
1.1.4 Contactor

- A contactor is an electrically controlled switch (relay) used for switching a power circuit. A contactor is activated by a control input that is a lower voltage or current than that of the contactor is switching. Contactors come in many forms with varying capacities and features.
- Symbol:

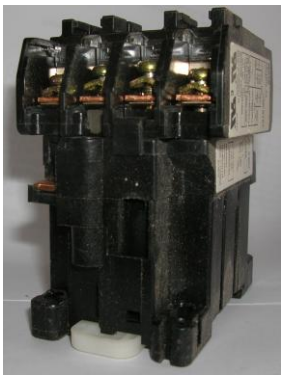


Contactor Coil

Contactor Contact (Normally Opened / N.O)



Contactor Contact (Normally Closed / N.C)



Contactor

- A basic Contactor contains a Coil and multiple Contacts.
- There are two types of contact:
  - Main Contacts – Normally opened contact type with high current rating (30A ~ 40A). Behave as an electromagnetic latched switch in a main circuit.
  - Auxiliary Contacts – Have a lower current rating (>5A). Behave as an electromagnetic latched switch in a control circuit. Divided into two types; Normally Opened (NO) and Normally Closed (NC) contacts and could be added according to the application needs.

1.1.5 Timer Relay

- Timer Relay is a relay that has timing control mechanism. It is used in applications where functions need to be delayed, or loads need to be maintained for a predetermined period of time.
- Timer relay is made of an electromechanical contacts and time adjustable knob.
- The timer opens and closes a circuit depending on the position of the hands of its clock.
- It has two types of contacts; normally opened and normally closed contacts.
- Symbol:

Timer Coil

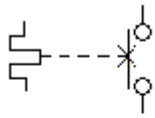
Timer Contact (Normally Opened / N.O)

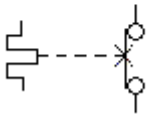
Timer Contact (Normally Closed / N.C)

Timer Relay

1.1.6 Thermal Over load Relay

- Thermal Over load Relay is a type of relay that functions (trips) by means of a thermally responsive system. It is a protective device that protects the motor against dangerous overheating due to current overload, stalled motor and failure to start.
- It is designed to perform its function by opening (trips) the circuit to the motor. The tripping mechanism is normally made of a bi-metal element that is responsive to changes in temperature. The movable contact is mechanically coupled to a main bimetal to operate the electrical switch. Excess heat is generated in the heater elements by an overloaded motor. The bimetals deflect to thermally open the normally closed contact, thereby opening a coil circuit of a magnetic contactor, which disconnects the overloaded motor from the line.
- Symbol:


Normally Open Contact (N.O)


Normally Close Contact (N.C)


Thermal Over load Relay

1.1.7 Circuit Breaker

- A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Unlike a fuse, which operates once and then has to be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation. Circuit breakers are made in varying sizes, from small devices that protect an individual household appliance up to large switchgear designed to protect high voltage circuits feeding an entire city.
- Miniature Circuit Breaker or MCB is rated at not more than 100 A current. Trip characteristics normally not adjustable.
- Tripping mechanism is either Thermal or thermal-magnetic.
- Both 3-phase MCB and 1-phase MCB will be used in a control circuit and a main circuit respectively
- Abbreviation: MCB SP – for single phase MCB
  MCB TP – for three phase MCB
- Symbol:

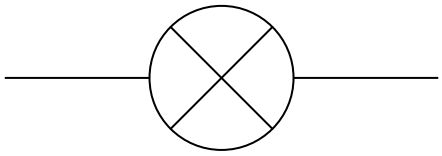

Circuit Breaker


3-phase MCB


Single-phase MCB

1.1.8 Indicator Lamp

- Multiple lamps to indicate the state of operation of the circuit.
- Green or yellow indicates that the circuit is running in a normal mode.
- Red indicates that there is an overload or tripping in the circuit. In this situation, the main circuit has been cut off from the main power supply.
- Symbol:



Indicator Lamp

1.2 Measuring Instrument for Trouble Shooting

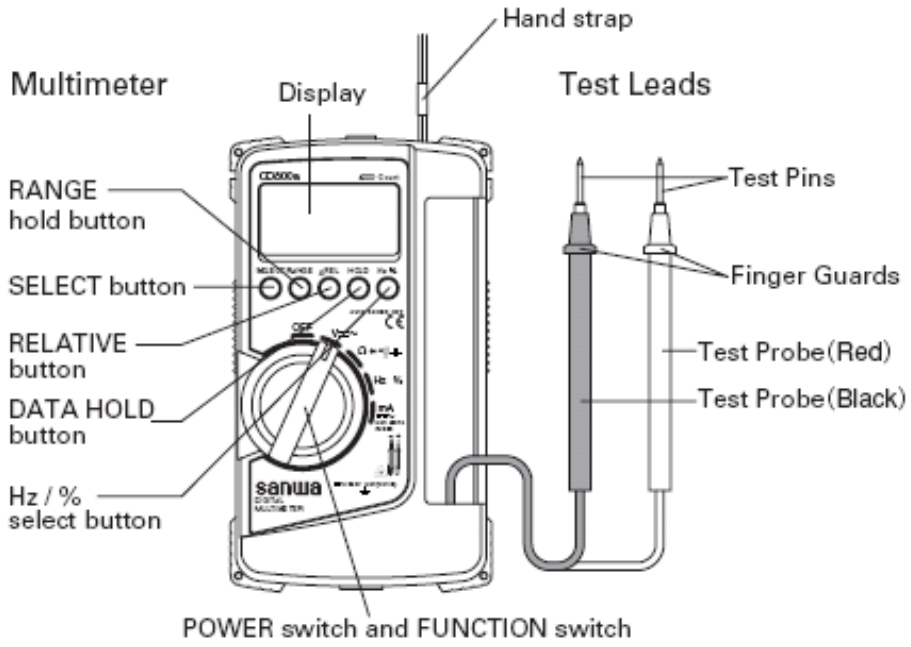
1.2.1 Digital or analog Multimeter.

- The functions of Multimeter are as follows:
  i. AC/DC Voltage Measurement
  ii. AC//DC Current Measurement
  iii. Resistance Measurement
  iv. Continuity Test
  v. Diode Test
  vi. Capacitance Measurement
  vii. Signal Frequency Measurement

- Below is the specification of **Sanwa** Multimeter **Model CD800a**

DC Voltage Range	400mV, 4V, 40V, 400V, 600V
AC Voltage Range	4V, 40V, 400V, 600V
DC Current Range	40mA, 400mA
AC Current Range	40mA, 400mA
Resistance Range	400Ω, 4kΩ, 40kΩ, 400kΩ, 40MΩ
Continuity	Audible Buzzer. Open voltage: Approx. 0.4V
Capacitance Range	50nF, 500nF, 5μF, 50μF, 100μF
Frequency Range	5Hz ~ 100kHz
Diode Test	Open voltage: Approx. 1.5V

- Description of Function



i. Function Knob
Turn this Knob to turn on and off the power and to select the multimeter functions.

ii. SELECT: Measurement Function Select
When the SELECT button is pressed , the functions changes as required.

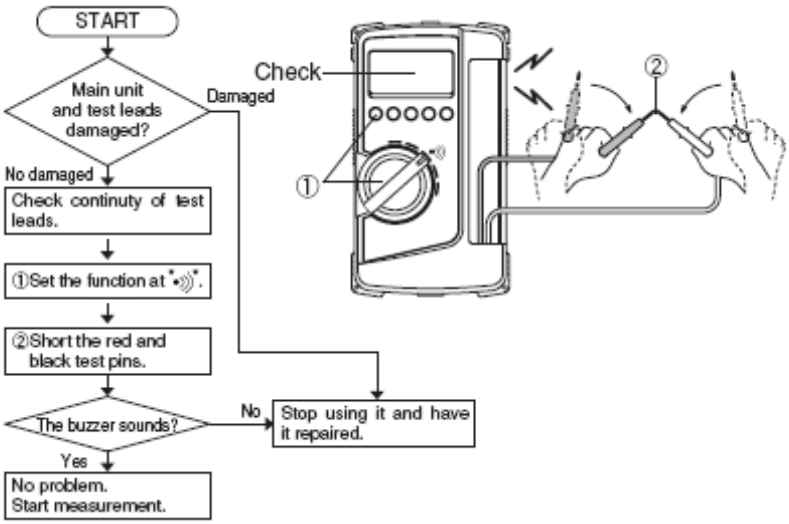
iii. RANGE: Range Hold
Press the RANGE button momentary to set the manual range mode, then 'AUTO' disappears in the display. In manual range mode, press the button again to step through the ranges. To return to the auto mode, press the button for 1 sec. or more, then 'AUTO' is shown.
Note. Manual mode is not available in , Hz, duty measurement, diode check, cont. buzzer functions.

iv. △REL: Relative Mode
Relative zero allows the user to offset the meter consecutive measurements with the displaying reading as the reference value. Press the △REL button momentarily to activate and to exit relative zero mode.

v. HOLD: Data Hold
When the HOLD button is pressed, the display is hold ('DH' is shown on the display). The display will not be changed while the function is active. Press the button again to cancel the function.('DH' on the display disappears.)
Note. DATA HOLD function does not work when measuring frequency.

vi. Hz/% : Frequency and duty cycle select button
Frequency and duty cycle measurement functions are activated alternatively by pressing the button. In the case of the mode change as Hz →%

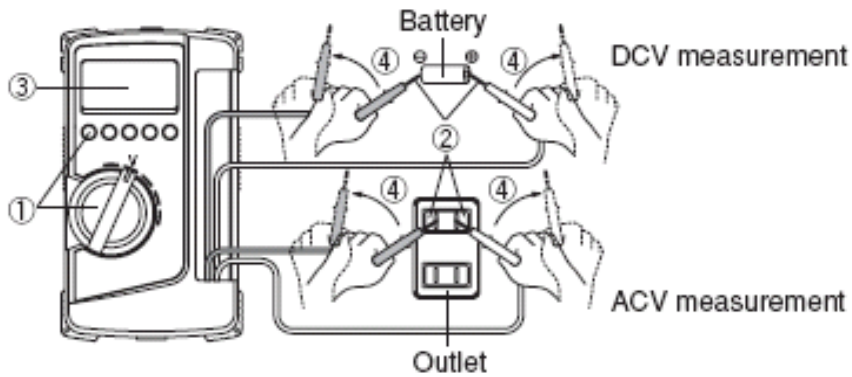
- Start-up/Inspection procedure



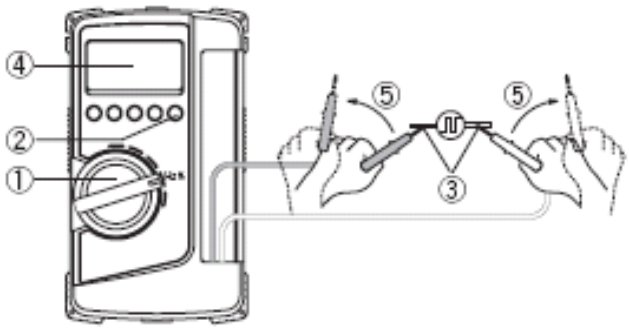
WARNING !

Never apply an input signal exceeding the maximum rating input value. Be sure to disconnect the test pins from the circuit when changing the function. Always keep your fingers behind the finger guards on the probe when making measurements. Use caution when working above 60Vdc or 30Vac. DO NOT use the meter if the meter or test probes is damaged

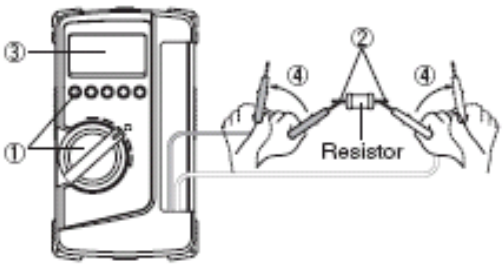
- Voltage measurement procedure
  i. Set the function knob to voltage (V)
  ii. Push the Select button for AC or DC type voltage
  iii. Probe the circuit using the red and black test probes.
  iv. For unknown voltage, first set voltage range to the highest range. Change the range until a satisfactory reading is obtained
  v. For DC voltage, apply the black test pin to the negative potential side and the red test pin to the positive potential side of the measured circuit.

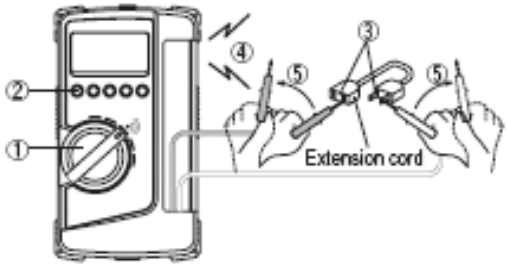


- Frequency and duty cycle measurement
  i. Set the function knob at Hz/%
  ii. Select Hz or duty-cycle by pressing the Hz/% button
  iii. Probe the measured circuit and read the display

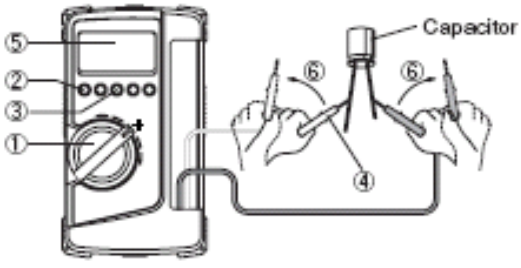


- Resistance and Continuity measurement
  i. Set the Function knob and SELECT button to the desired resistance or continuity position
  ii. Remove power supply from the circuit under test
  iii. Probe the device and read the display
  iv. For Resistance: Value will be displayed
  v. For Continuity: Buzzer sounds continuously

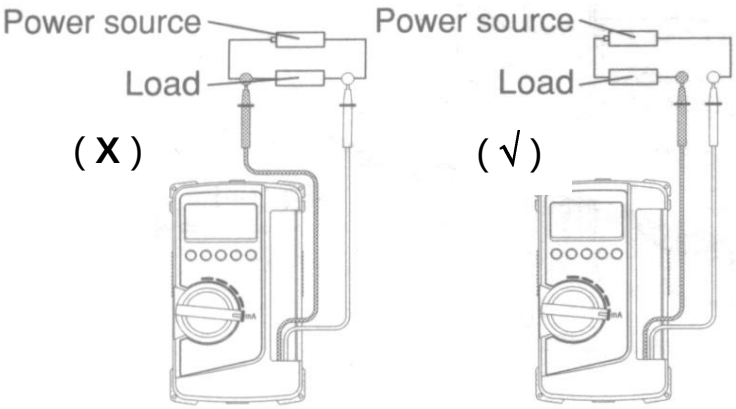




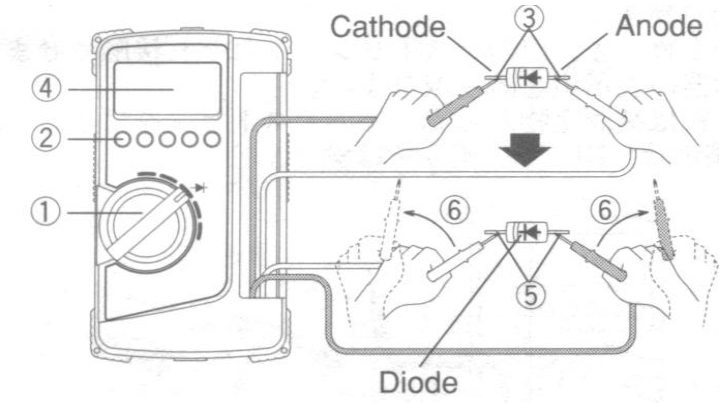
- Capacitance measurement
  i. Set the function/range to the desired capacitance position
  ii. Remove power supply from the circuit under test
  iii. Probe to the test capacitor and read the display



- Current measurement
  i. Set the Function/Range/SELECT to the desired Current (mA) position
  ii. NEVER apply any voltage to the input terminals and DO NOT exceed the maximum rated current.
  iii. Connect the probes and be sure it is in SERIES connection to load
  iv. For unknown current, first set current range to the highest range. Change the range until a satisfactory reading is obtained
  v. For DC current, apply the black test pin to the negative potential side and the red test pin to the positive potential side of the measured circuit..



- Diode measurement
  i. Set the Function/SELECT to the desired diode testing position
  ii. Remove power supply from the circuit under test
  iii. Apply the black test pins to the cathode of the diode and the red test pin to the anode and read the diode forward voltage drop from the display.



- Clamp Meter

  A clamp meter is a type of ammeter that measures AC current without the need to disturb the wiring through which the current is flowing. Clamp meter is also known as **tong tester** or **Amprobes** (after Amprobe Instrument Company).

  Beside its basic function to measure AC current, other functions of clamp meter are:

  i. AC Voltage measurement
  ii. Resistance measurement

Kyoritsu clamp meter

- Specification of Kyoritsu clamp meter

Test Current	Frequency	Accuracy
AC 200A	50-60Hz	1.5% + 4dgt
	40-1kHz	2.0% + 5dgt
AC 600A	50-60Hz	1.5% + 3dgt
	40-1kHz	2.0% + 5dgt

WARNING !

Never use on a circuit with voltage above 600VAC. DO NOT measure current above 600A. It will damage the instrument. Remove any test leads when make current measurement

- Current measurement

  i. Set the range switch to desired position
  ii. Press trigger to open transformer jaw
  iii. Clamp onto a conductor and closed the transformer jaw.
  iv. Read the display

1.2.3 Insulation tester

- The Insulation Resistance Test is a safety test required by the electrical safety testing standards. The Insulation Resistance Test consists in measuring the Insulation resistance of a device under test, while phase and neutral are short-circuited together.

- Specification of insulation tester Kyoritsu model 3165

Test Voltage	500VDC	1000VDC
Measuring Range	0-1000MΩ	0-2000MΩ
Terminal Voltage	500V +20%, -0% from 0.5MΩ to ∞	1000V +20%, -0% from 1MΩ to ∞
Output Short Circuit Current	1.4mA	1.6mA
Usage	General purpose Natural installation Electronics components	High voltage installation
Acceptable Insulation Resistance	>1MΩ	>1MΩ

- Insulation measurement
  i. Remove power supply from the circuit under test
  ii. Connect the crocodile clip: Black – Earth, Red – Phase or Neutral
  iii. Press test button and the "Power On" lamp will light
  iv. Read the meter

Kyoritsu insulation tester model 3165

1.3 Direct On-Line Starter (D.O.L)

The simplest form of motor starter for an induction motor is the **D**irect **O**n **L**ine or the full voltage starter. It is the easiest method to employ, has the lowest equipment costs, and is the most reliable. This method utilizes a control to close a contactor and apply full line voltage to the motor terminals. This method will allow the motor to generate its highest starting torque and provide the shortest acceleration times. However, it also has several drawbacks

- the high starting torque may cause mechanical problem to the driven load.
- when a large motor is started using direct-on-line method, it causes voltage dip of the main supply lines due to a large starting current surge. This voltage disturbance may cause the malfunction of other electrical equipment connected to the same supply.

The DOL starter is normally comprises of a switch and an overload protection relay. D.O.L is suitable for 1 kW to 2 kW motors.

Direct On Line starter sequence:

- Figure 1 shows a Control Circuit and Main Circuit of Direct On Line Motor Starter.
- When start button is pressed, it connects the supply to contactor coil C1.
- Coil C1 is energized. Contactor's main and auxiliary contact C1 will close.
- The auxiliary contact holds its closed position even though the start button returns to its normal position. This contact serves as a *holding contact* for the circuit. At this stage, run light illuminates.
- The motor is now connected directly to a 3-phase power supply.
- When the stop button is pressed, the supply to coil C1 is cut off. The coil C1 is de-energized and all the contacts return to their normal position. The supply to the motor will cut off and the motor stopped.
- Under overload condition, the supply to motor will be cut off when the overload current is sensed by the thermal overload relay. The normally closed contact will open and cut the power off the contactor coil. The normally opened contact will close and trip light is turned on.

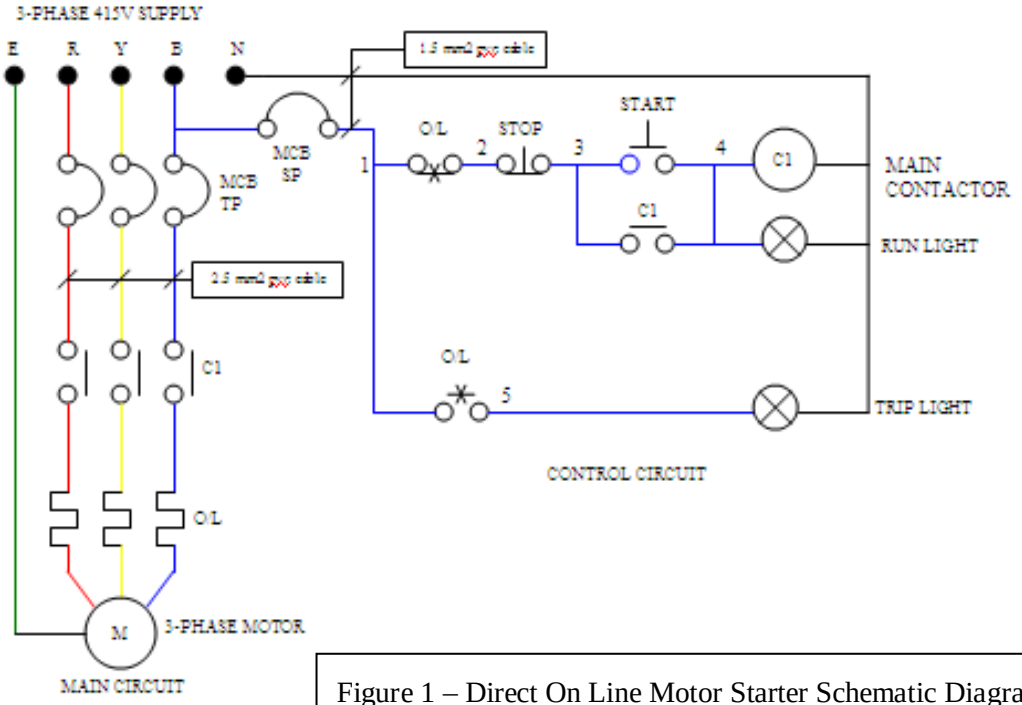


Figure 1 – Direct On Line Motor Starter Schematic Diagram

1.4 Direct On Line Forward-Reverse Motor Starter

Figure 2 shows the connection of DOL motor starter with forward-reverse function. Two contactors are required. The forward function is denoted as *F* or *FWD* whilst the reverse function is *R* or *REV* for main circuit and control circuit respectively.

FWDSTART start button is used to allow line current through the FWD contactor coil. While REVSTART start button is used to permit line current through the REV contactor coil. STOP button cuts power supply to the control circuit. The two normally closed contacts for FWD and REV contactors are serves as an *interlocking device* to prevent any simultaneous operations. Noted that the two phases of the 3-phase power supply are switched during each operation and any simultaneous operations will cause danger due to a short circuit of the phases.

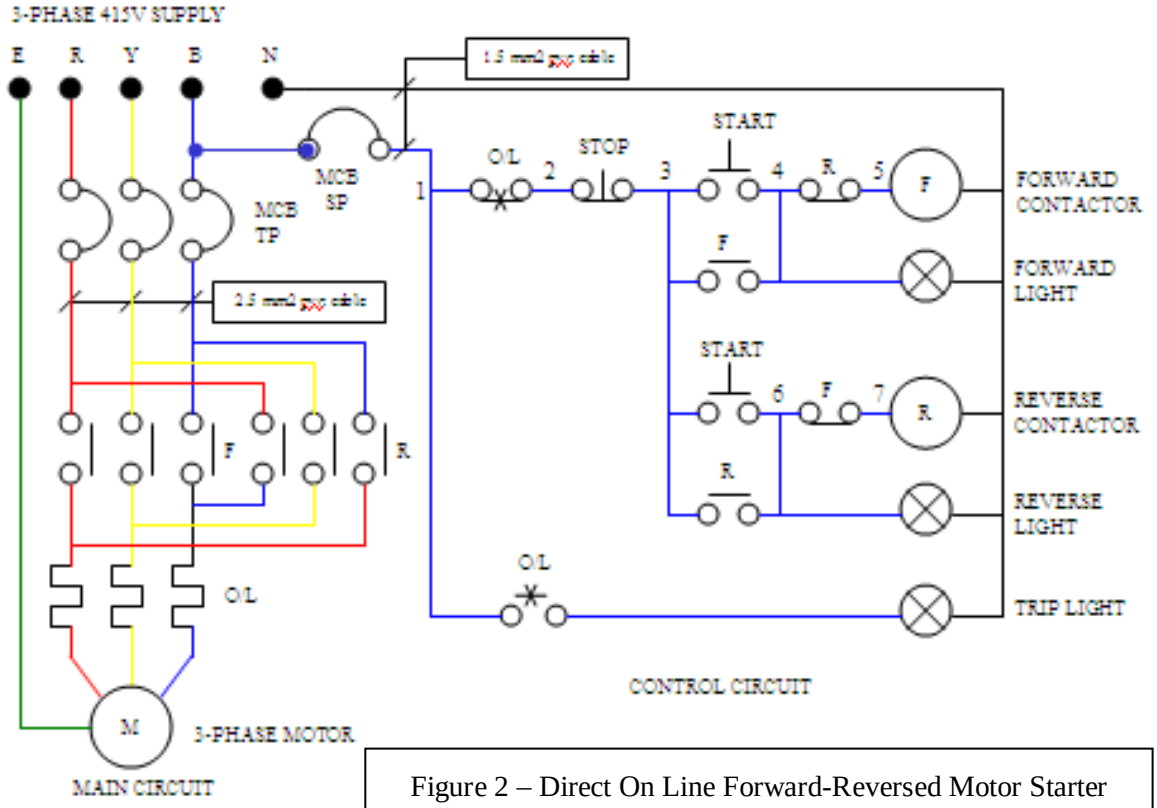


Figure 2 – Direct On Line Forward-Reversed Motor Starter Schematic Diagram

1.5 Star-Delta Motor Starter

The Star-Delta starter can only be used with a motor that is rated for connection in delta operation at the specified line voltage. The utilization of this starter is to reduce the motor starting current. Under this connection, the voltage across each winding is $1/\sqrt{3}$ of line voltage and the resultant current flowing in each winding is also reduced by this amount.

During the startup operation, the motor accelerates to 75% of its maximum speed within 5 sec. The transition to full voltage occurs when the star connection is opened and the contactor changed the motor windings terminal connection to delta connection.

Figure 3 shows the connection of Star-Delta motor starter.

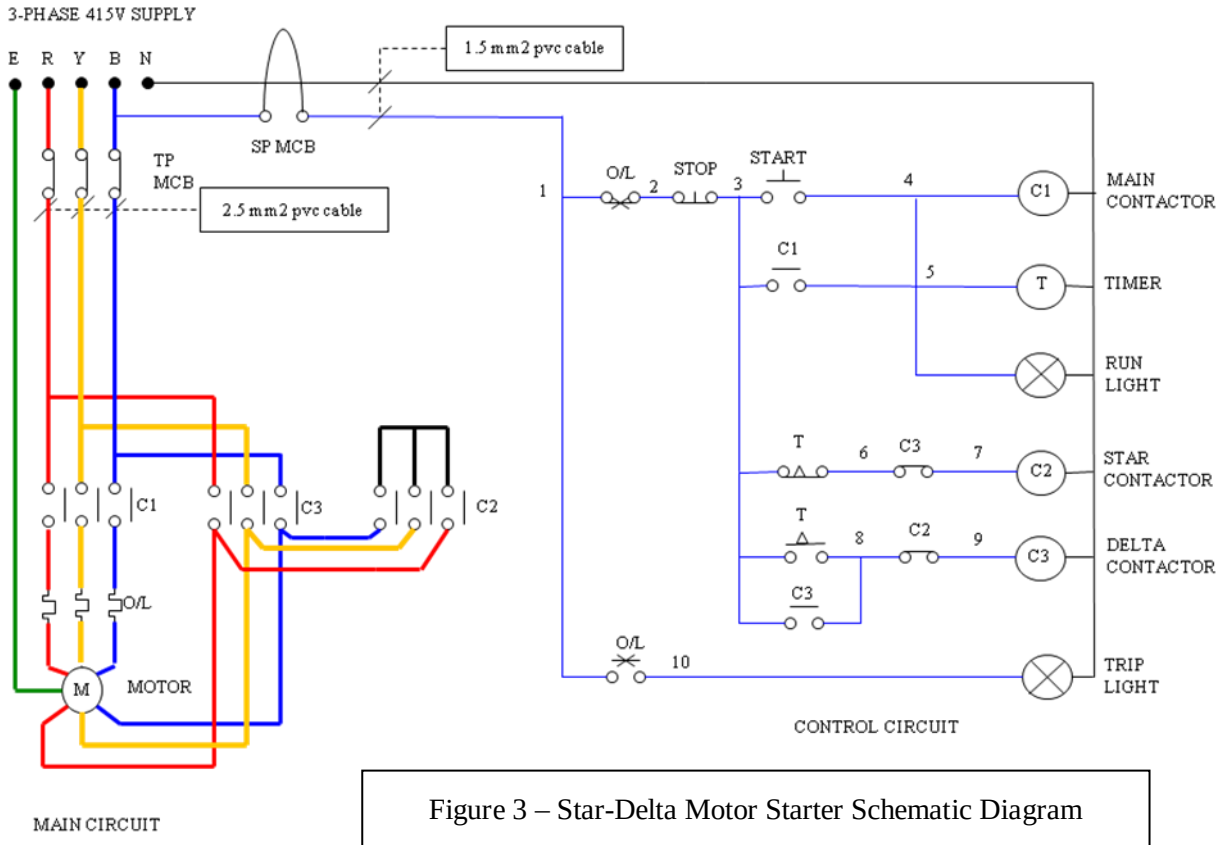


Figure 3 – Star-Delta Motor Starter Schematic Diagram

1.6 Auto Transformer Starter

The auto-transformer starter is more expensive than three types so far described and is generally used only for the larger types of motor. An auto-transformer starter uses an auto transformer to reduce the voltage applied to a motor during starting. Starting a large motor demands a very high current surge from the supply. This causes a severe voltage dip that affects every load on the same system. Reduced voltage starting will limit the starting surge current. One way to reduce the initial voltage supplied to the motor is to step it down using a transformer. The starting conditions depend on the position of the tapping on the transformer winding, i.e. on the secondary voltage. Usually three or more tappings are provided so that there is a choice of starting conditions such as 40, 60 or 75% of line voltage. Then, when the motor has accelerated up to almost full speed, the full mains voltage replaces the reduced voltage. The transformer used in this starter is not the usual type with separate primary and secondary windings. It is an autotransformer type, which uses only one winding for both input and output.

- Auto transformer Starter sequence:

  When the start button is pressed SP contactor coil is energized which closed the main SP contact and SP auxiliary contact. The timer relay coil and TC contactor coil are also energized. The main TC contacts closes, which applies a reduced voltage from the auto-transformer to the motor windings. The motor starts. After 5 seconds, the timer relay opens its normally closed contact and cuts the current flowing through SP contactor coil. Simultaneously, it closes normally opened contact and allows current flowing to LC contactor coil. The star point of the transformer is opened by SP as well as the main TC contacts, which terminates the transformer's task. The stop button or overload relay trips out LC contactor to stop the motor.

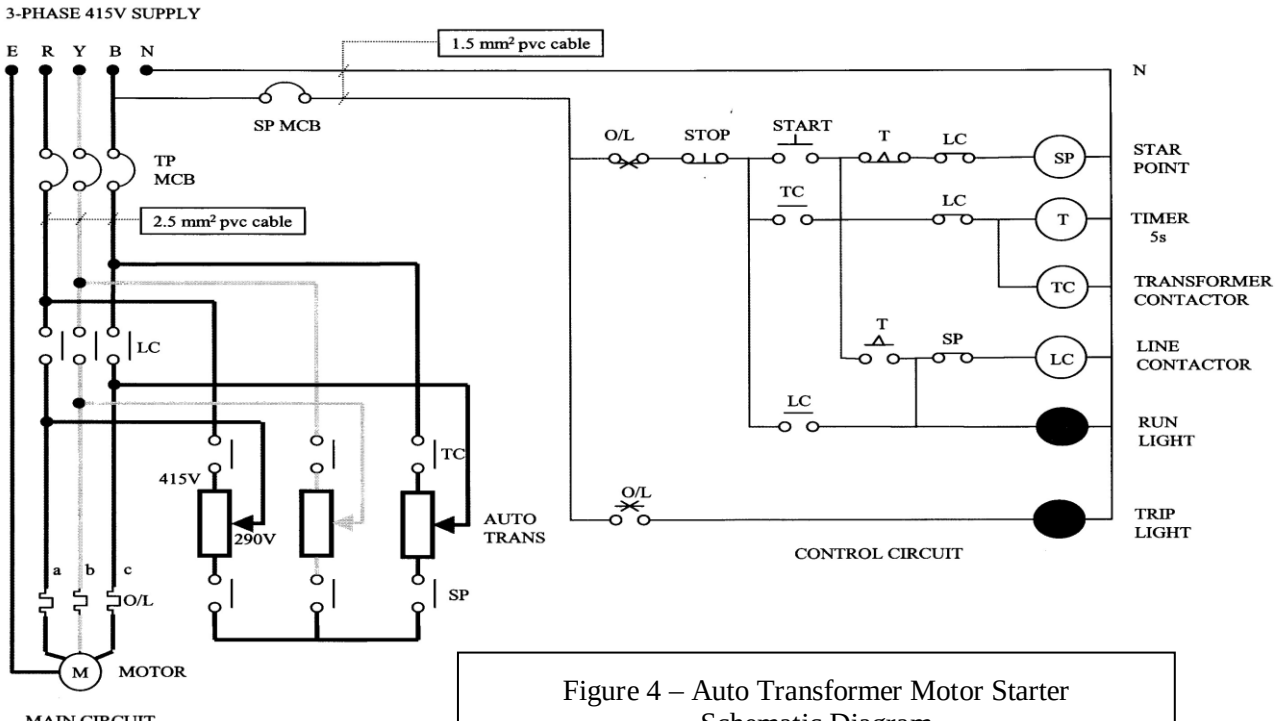


Figure 4 – Auto Transformer Motor Starter Schematic Diagram