



Selection of MCB for Motor Circuits

Motor Loads present the most complex type of transient inrush current. The starting phenomenon takes place in two stages, a transient and a steady-state stage. The two stages of the motor starting currents:

- a) An initial peak Inrush current 2.8 times the r.m.s value of the motor's locked rotor current (I_{start}) or 15 times x Full Load Current lasting for less than two main cycles (0.04 sec).
- b) The second stage where the motor starting current decays to about 7.5 times x Full Load Current which may last for 5 to 15 seconds.

The motor finally takes the steady running current at maximum value equal to Full Load Current.

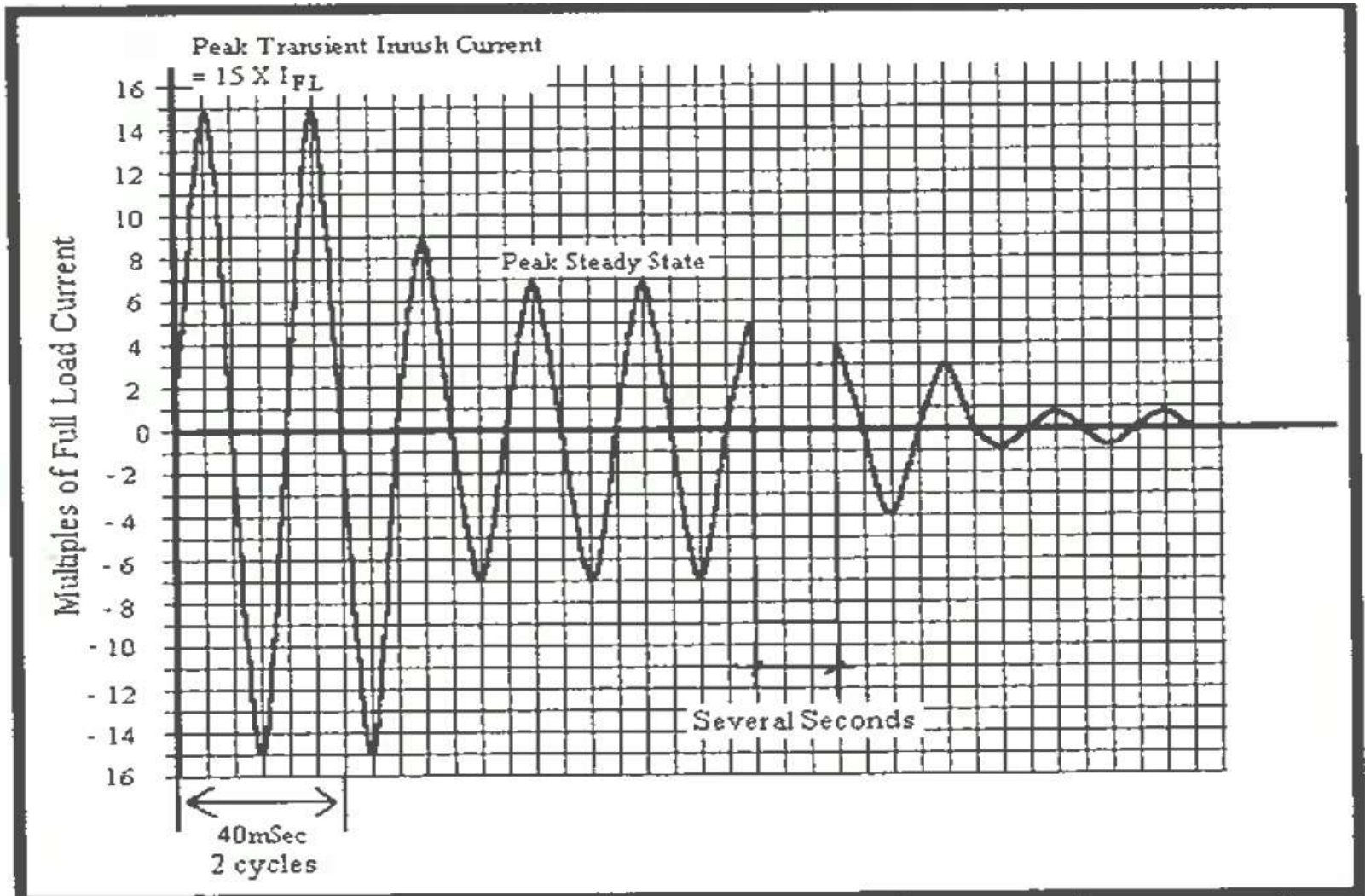


Figure 4.a.1 Motor Inrush Current



Selection of MCB for Motor Circuits

- a) As the initial peak last for about 0.04 seconds, it may cause the magnetic trip to trip.
- b) Whereas the second stage starting current which may last for 5 to 15 seconds and may cause the thermal element to trip.

To overcome these kinds of unnecessary tripping, the following design approach has been used quite satisfactorily;

- a) Rated thermal trip rating or normal rating (I_n) of circuit breakers are selected larger to avoid unnecessary tripping.

For motor with Full Voltage Starting or Direct-on-line Starting, I_n is selected between $2 \times I_{\text{Full Load}}$ and $2.5 \times I_{\text{Full Load}}$.

For motor with Reduced Voltage starting, I_n is selected between $1.5 \times I_{\text{Full Load}}$ and $2 \times I_{\text{Full Load}}$.



Selection of MCB for Motor Circuits

- b) Magnetic trip element or type no. are selected to ensure that magnetic trip element will not operate at Inrush current.

Example: If $I_{\text{inrush}} < 3 \times I_n$ (or maximum current that will definitely not trip magnetic trip of Type B)

Then Type B will be selected.

If $I_{\text{inrush}} < 5 \times I_n$ (or maximum current that will definitely not trip magnetic trip of Type C)

Then Type C will be selected.



Example in selection of MCB

Eg 4.3

Determine the appropriate current rating of MCB for a 3-phase, 400V, 50Hz 4.5kW Motor with an efficiency 85% and power factor 0.8. Assuming that the motor is started by Direct-On-Line starter (D.O.L.).

$$\text{a) Input } I_{F.L} \text{ Power (kW)} = \frac{\text{Output power}}{\text{Efficiency}}$$

$$= \frac{4.5\text{kW}}{85\%} = 5.3\text{kW}$$

$$\text{Therefore, Design Circuit Current, } I_b = I_{F.L} = \frac{P}{1.732 \times V_L \times \text{p.f.}}$$

$$= \frac{5300\text{W}}{1.732 \times 400 \times 0.8}$$

$$= 9.56\text{A}$$



Eg 4.3

As the motor is started by D.O.L starter, to allow for the starting current , the MCB current rating is sized larger at 2.5 times $\times I_{F.L}$

$$2.5 \times I_{F.L} = 2.5 \times 9.56A = 23.9A$$

Since , the next available MCB current rating is = 30A.

A 30A triple pole (TP) MCB is selected.

b) Determine of magnetic trip rating

$$\begin{aligned}\text{Calculate } I_{\text{inrush}} &= 15 \times I_{F.L} \\ &= 15 \times 9.56A \\ &= 143.4A \text{ (Peak) which last for 0.04 seconds}\end{aligned}$$



Eg 4.3

c) Determination of magnetic trip and type no.

$$\text{Since } \frac{\text{Inrush Current}}{\text{Trip Rating, } I_n} = \frac{143.4\text{A}}{30\text{A}} = 4.78 \text{ times}$$

And a 30A Type B MCB may trip on magnetic trip at $3 I_n$, Type B is not suitable

And a 30A Type C MCB may trip on magnetic trip at $5 I_n$, which is large than $4.78 I_n$, a 30A Type C MCB is selected.



Eg 4.3

$$\begin{aligned} I_{\text{start}} &= 7.5 \times I_{\text{F.L}} \\ &= 7.5 \times 9.56\text{A} \\ &= 71.7 \text{ A (Second Stage) which last for 5 to 15 seconds} \end{aligned}$$

The MCB thermal characteristic, shown that at $I_{\text{start}} = 71.7\text{A}$.

30A MCB will operate in about 80 seconds.

Since the starting current only last for about 15 seconds, a MCB with $I_n = 30\text{A}$ (thermal trip rating) is selected.

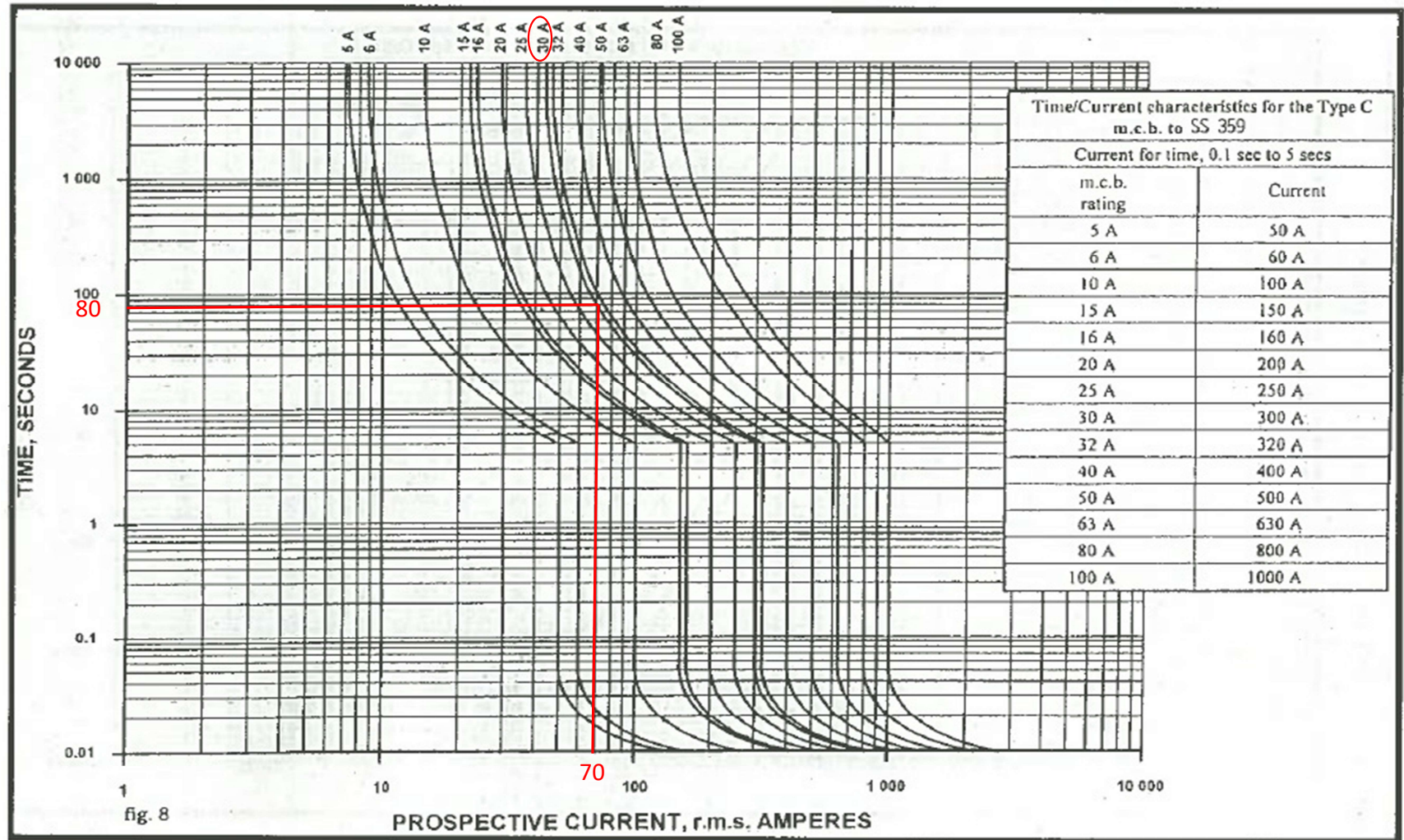


Figure 4.a.2 Time-Current Characteristic in Logarithmic Scales – Type C MCB



Instantaneous Tripping Operating Time

Type	Will NOT trip in 100ms at Current	Will trip in 100ms at current	Typical Application
B	$I < 3 \times I_n$	$I > 5 \times I_n$	General Purpose Use
C	$I < 5 \times I_n$	$I > 10 \times I_n$	High Inrush Current (Motor Circuits)

Table 4.a.3 Instantaneous Trip Operating Time



❑ Moulded Case Circuit-Breakers

Moulded case circuit-breakers (MCCB) are required for installations which have higher fault level or higher current ratings exceeding 125A. This circuit-breaker is defined as an air-break circuit-breaker, designed to have no provision for maintenance, having a supporting and enclosing housing of mould insulating material, forming an integral part of the circuit-breaker. It has basically three main elements, namely, the tripping unit, the switching unit and a current interrupting unit.

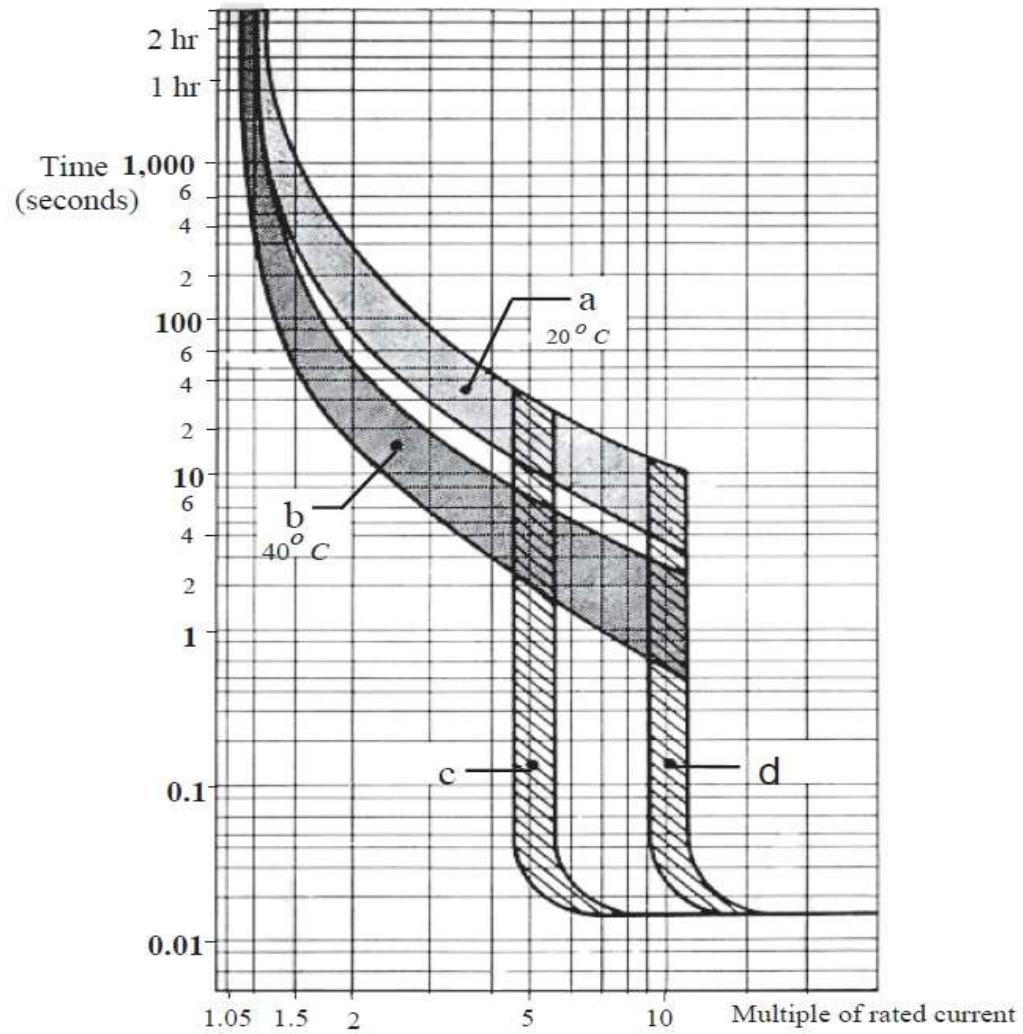


Figure 4.a.4 Time-current characteristic of a typical MCCB



Conventional Tripping Current

1.45 I_N O/L tripping → IEC 60898-1 (MCB)

1.3 I_N O/L tripping → IEC 60947-2 (MCCB)

IEC 60502-1 Rated Conductor Temperature

Cable Type	Rated Temperature (°C)	Overload Temperature (°C)	Critical Temperature (°C)
PVC-insulated	70	95	160
Cross-linked	90	130	250



Selection of Moulded Case Circuit Breaker

For motor circuit, the motor branch circuit protective devices is allowed to be larger such that it will not operate during starting. The trip rating of the MCCB shall be selected as follows:

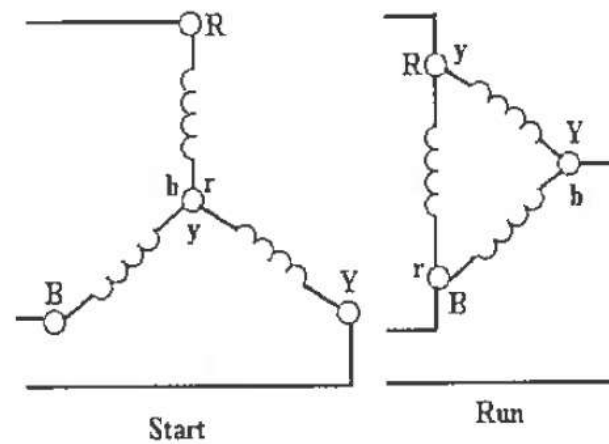
- a) Full Voltage Starting (i.e. with Direct on line Starter) circuit breaker trip rating shall be selected between **2 x Full Load Current and 2.5 x Full Load Current.**
- b) **Reduce Voltage Starting** (i.e. with Star/Delta0 circuit breaker trip rating shall be selected between **1.5 x Full Load Current and 2 x Full Load Current.**

As the circuit breaker for motor has been selected higher to avoid nuisance tripping by motor starting current, the circuit breaker is no longer effective in providing overload protection.



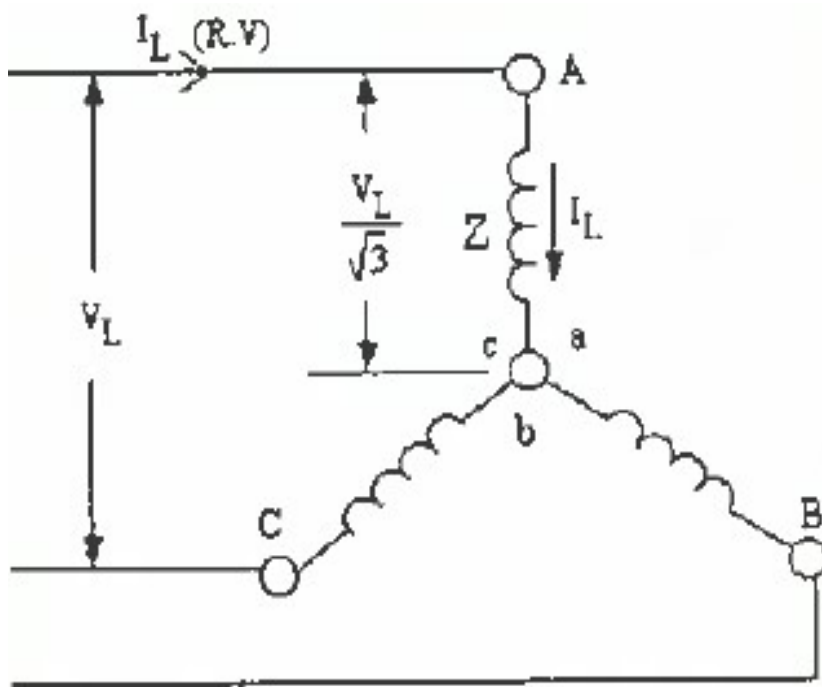
Star-Delta Starters

If Direct switching is not allowed, a method of reduced voltage starting may be used in order to limit the motor starting current. The most popular method of reduced voltage starting is the star-delta due to its economy. The starting current is approximately one third the value of dol starting current.



Motor Winding Connections

Figure 4.a.5 (a) Motor Winding Connections



Motor Winding Connections & Star-Delta Starter

Starting voltage is $V_{\text{start}} = \left[\frac{1}{\sqrt{3}} \right] V_L$

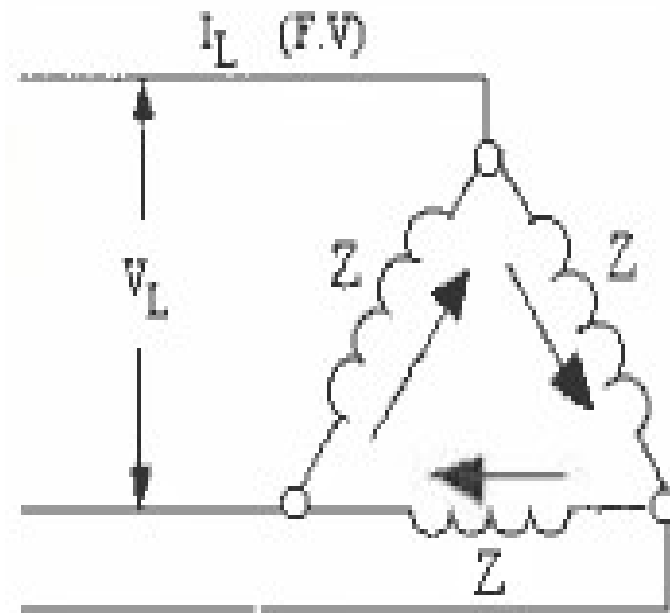
∴, Line Current at reduced starting voltage,

$$I_{\text{st}} = \left[\frac{V_L / \sqrt{3}}{Z} \right]$$

$$I_{\text{st}} (Y) = \left[\frac{1}{\sqrt{3}} \right] \left[\frac{V_L}{Z} \right] \text{-----(1)}$$

Where Z is the impedance of motor winding.

Figure 4.a.5 (b) Motor started in the star configuration (i.e. reduced voltage)



$$V_{\text{run}} = V_L$$

$$I_{\text{phase}} = \left[\frac{V_L}{Z} \right]$$

∴, Line Current at full voltage starting

$$I_L = \sqrt{3} I_{\text{ph}}$$

$$I_L (\Delta) = \sqrt{3} \times \left[\frac{V_L}{Z} \right] \text{ -----(2)}$$

$$\therefore \frac{I_L (Y)}{I_L (\Delta)} = \left[\frac{1/\sqrt{3}}{\sqrt{3}} \right] \left[\frac{V_L/Z}{V_L/Z} \right] = \frac{1}{3}$$

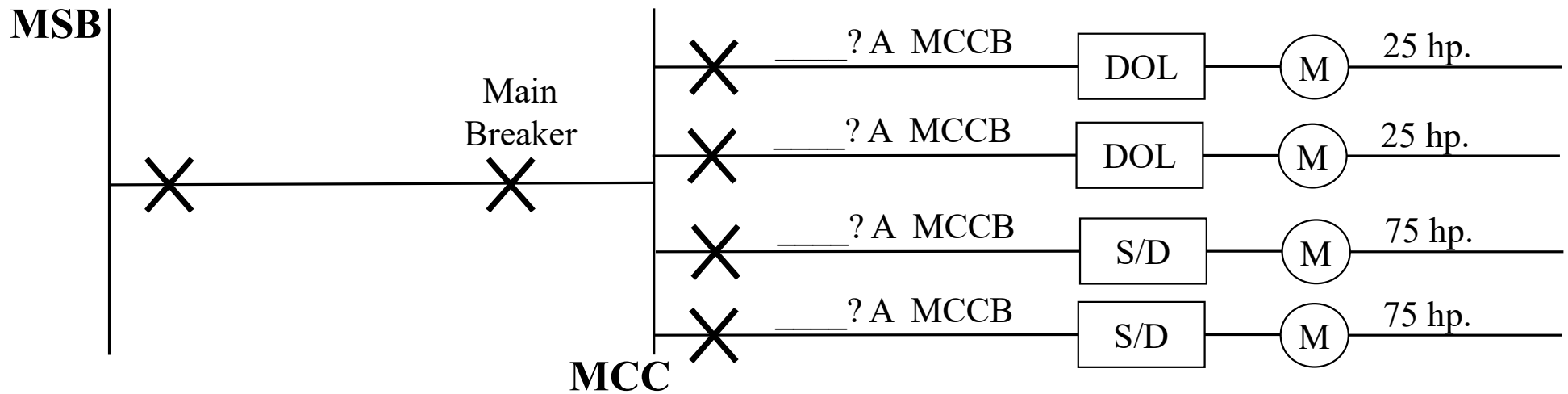
Therefor Motor starting current is reduced by 1/3.

Figure 4.a.5 (c) Motor started in the Delta configuration (i.e. full voltage)



Example in selection of MCCB

Eg 4.4



A motor control center (MCC) supplies the following motor loads:-

- 2 nos. 25 HP 3 phase 400V motor with efficiency 88% and power factor (0.85). The motor is started by Direct-On-Line motor starter.



- b) 2 nos. 75 h.p. 3 phase 400V with efficiency 88% and power factor (0.85). The motor is started by Star-Delta motor starter.
- i. Calculate the full load current and starting current in each case and determine the trip rating of MCCB for each motor.
 - ii. Determine the appropriate trip rating of the main breaker assuming the smallest motor started first and the largest motor started last.



Detail Calculation for (a) 25 h.p. motor

DOL 25HP, efficiency $\eta = 0.88$, p.f = 0.85

$$I_{F.L} = \frac{25 \text{ h.p.} \times 746 \text{ Watt/h.p.}}{\sqrt{3} \times 400 \times 0.88 \times 0.85} = 36\text{A}$$

Select MCCB Current Rating,

$$I_N = 2.5 \times I_{F.L} = 2.5 \times 36 = 90\text{A}$$

Therefore, a 100A Triple-Pole (TP) MCCB is selected.

Check Magnetic Trip

$$I_{inrush} = 15 \times I_{F.L} = 15 \times 36 = 540\text{A}$$

$$\frac{I_{inrush}}{\text{Trip Rating}, I_N} = \frac{540}{100} = 5.4 \text{ times}$$

From graph trip rating of 100A MCCB magnetic trip 4.5 to 5.8 > 5.4 (OK)



Detail Calculation for (a) 25 h.p. motor

Check Thermal Trip

$$I_{\text{start}} = 7.5 \times I_{\text{F.L}} = 7.5 \times 36 = 270 \text{ A}$$

$$\frac{I_{\text{start}}}{\text{Trip Rating}, I_{\text{N}}} = \frac{270}{100} = 2.7 \text{ times}$$

From graph trip rating of 100A MCCB at 40°C, thermal trip 8 sec to 20 sec > 10 sec (D.O.L) (OK)



Detail Calculation for (b) 75 h.p. motor

Star/Delta 75 HP, efficiency $\eta = 0.88$, p.f =0.85

$$I_{F.L} = \frac{75 \text{ h.p.} \times 746 \text{ Watt/h.p.}}{\sqrt{3} \times 400 \times 0.88 \times 0.85} = 108 \text{ A}$$

Motor starting current I_{inrush}

$$I_{\text{inrush}} = \frac{1}{3} \times 15 \times I_{F.L} = \frac{1}{3} \times 15 \times 108 = 540 \text{ A}$$

$$I_{\text{start}} = \frac{1}{3} \times 7.5 \times I_{F.L} = \frac{1}{3} \times 7.5 \times 108 = 270 \text{ A}$$

$$I_N = 1.5 \times I_{F.L} = 1.5 \times 108 \text{ A} = 162 \text{ A}$$

Therefore, a 160A Triple-Pole (TP) MCCB is selected.



Detail Calculation for (b) 75 h.p. motor

Check Magnetic Trip

$$\frac{I_{\text{inrush}}}{\text{Trip Rating}, I_N} = \frac{540}{160} = 3.375 \text{ times}$$

From graph trip rating of 160A MCCB magnetic trip 4.5 to 5.8 > 3.375 (OK)

Check Thermal Trip

$$\frac{I_{\text{start}}}{\text{Trip Rating}, I_N} = \frac{270}{160} = 1.6875 \text{ times}$$

From graph trip rating of 160A MCCB at 40°C, thermal trip 30 sec to 150 sec > 15 sec (OK)



(ii) Main Breaker

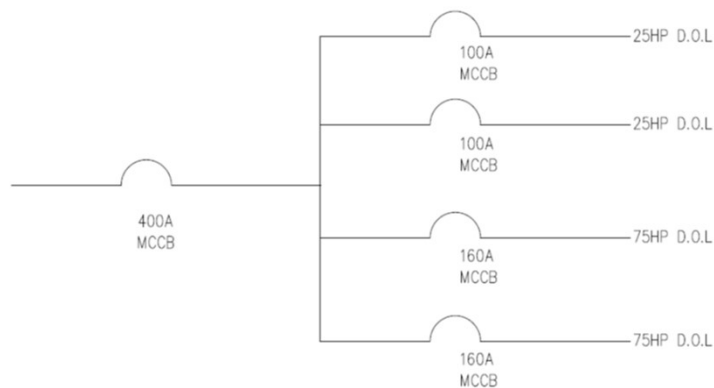
The MCCB main breaker trip rating

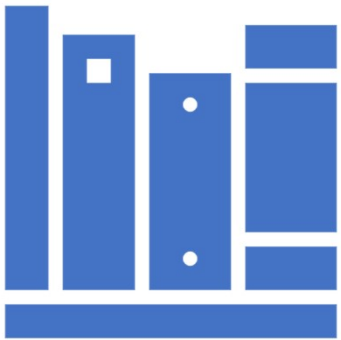
- Trip rating of the MCCB of largest motor in the group + full load current of all other motors

$$= 160 + 108 + (2 \times 36)$$

$$= 340 \text{ A}$$

Therefore , a 400A TP & N MCCB is selected for the main breaker.





Presentation End
