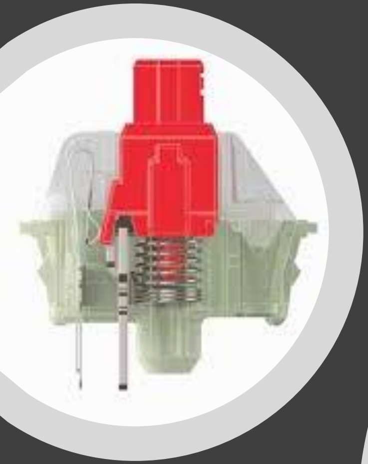
Electrical Drive & Actuation System

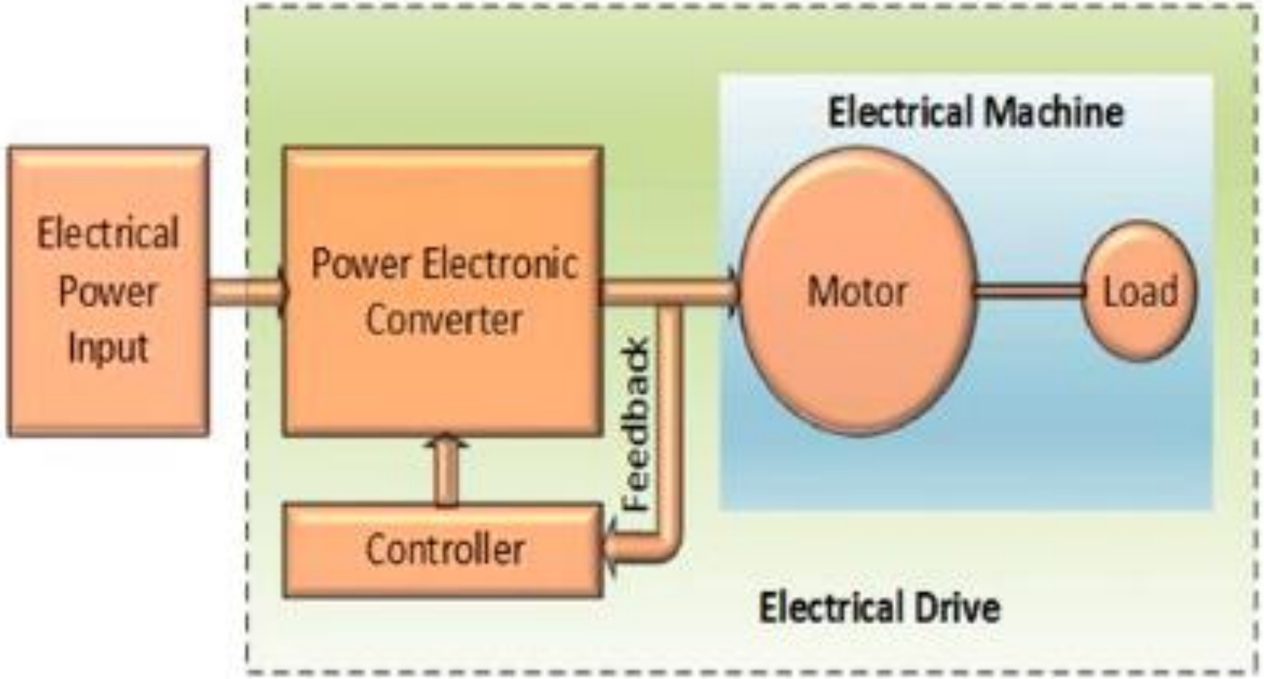
- Electrical systems
- Solenoids operation
- Direct On-Line starter
- Star-Delta starter
- Soft starter
- Variable frequency Drive



Electrical Drive & Actuation System

Electric Drives

- An electric drive is defined as a form of machine equipment designed to convert electrical energy into mechanical energy and provide electrical control of this process.



Electrical Drive & Actuation System

Advantages of Electric Drives

- It is simple in construction and has less maintenance cost.
- Its speed control is easy and smooth.
- It is neat, clean and free from any smoke or flue gases.
- It requires less space.
- It can be installed at any desired convenient place.
- It has comparatively longer life.
- It can be started immediately without any loss of time.
- Transmission of power from one place to other can be done with the help of cables in stead of long shaft etc.
- It can be remotely controlled.

Electrical Drive & Actuation System

Parts of Electric Drives

- Electric drive has three important parts namely.

1. Load 2. Motors 3. Control Unit

Load

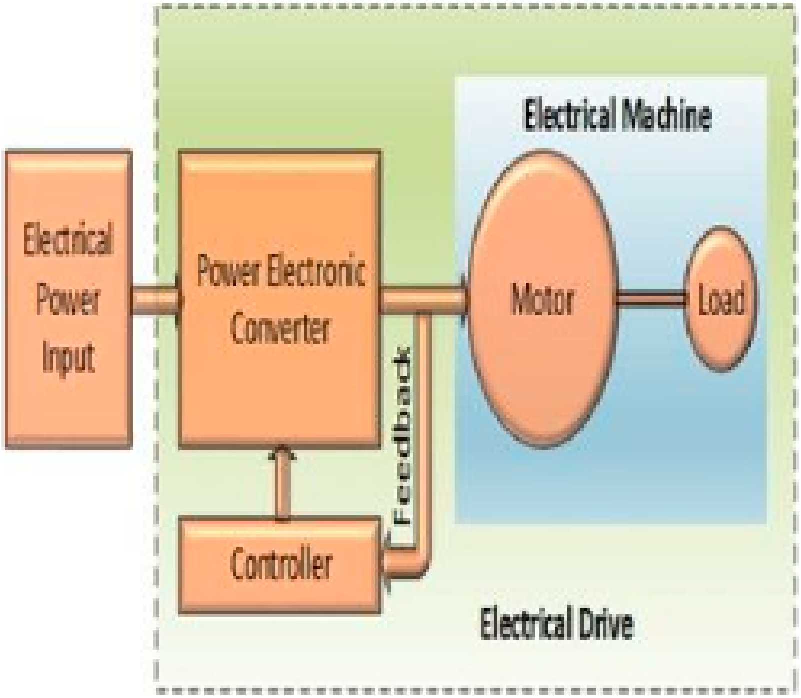
- The load which connects with the shaft of electric motor is called mechanical load. The load is connected with the motor shaft either through direct, or belt, or chain, or gear.

Motor

- The motor may be selected as per the load requirements. Motors commonly used in electric drives are D.C motors, Synchronous Motor or Brushless D.C motors etc

Control Unit

- In modern electric drives, automatic operations are performed, i.e starting, Stopping, Speed control of motors, braking's, reversing are automatic for these electronic circuits used. When the control is complex, now a days programmable logic controllers (PLC) are used.



Electrical Drive & Actuation System

Types of Electric Drives

- The electric drives are classified into three types. They are

1. Individual drive 2. Group drive 3. Multi motor drive

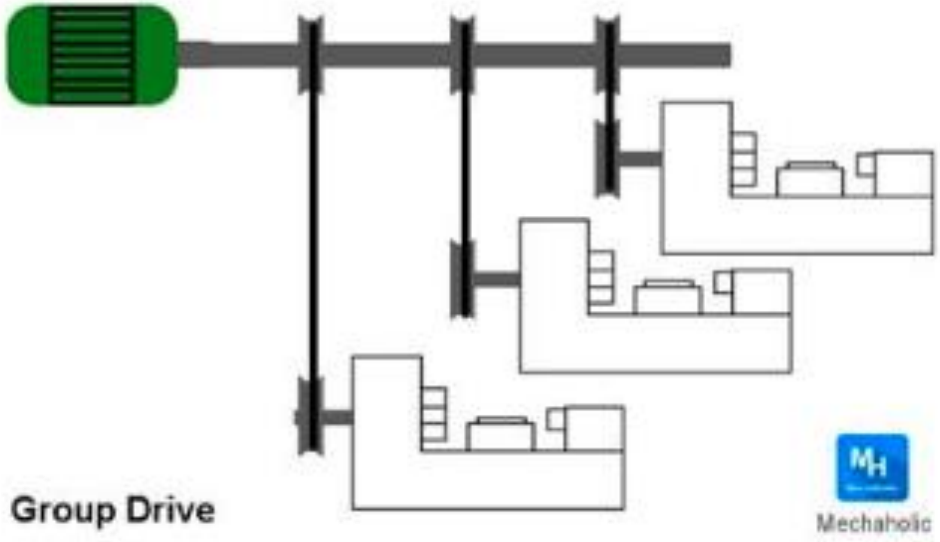
1. Individual Drive

- In individual drive single electric motor is used to drive one individual machine.
- Most of the industries use this type of drive.

Electrical Drive & Actuation System

2. Group Drive

- A single motor drives a number of machines. The motor is mechanically connected to a long shaft.
- It is also called line shaft drive. The line shaft is fitted with multistepped pulleys and belts.
- The driven machines are connected to these pulleys and belts for their required speed.



Electrical Drive & Actuation System

3. Multi motor Drive

- In multi motor drives separate motors are used for operating different parts of the same mechanism. E.g., in case of an overhead crane, different motors are used for hoisting, long travel motion and cross travel motion.
- Such drive is also essential in complicated metal – cutting machine tools, paper making machines, rolling mills.

Electrical Drive & Actuation System

Introduction to Motor Starter:

Motor starters are one of the major inventions for motor control applications. As the name suggests, a starter is an electrical device which controls the electrical power for starting a motor. These electrical devices are also used for the purpose of stopping, reversing and protecting electric motors. The following are the two major components of a starter:

1.Contactor: The main function of the contactor is to control the electric current to the motor. A contactor can make or break power to the circuit.
2.Overload Relay: Overheating and drawing too much current can cause the motor to burn out and become practically useless. Overload relays prevent this from happening and protect the motor from any potential danger.
A starter is an assembly of these two components, which allows it to turn on or off an electric motor or motor controlled electrical equipment. The starter also provides the necessary overload protection to the circuit.

Motor Starter Types:

1) Direct Online Starter
2) Star- Delta Starter
3) Soft Starter
4) Variable frequency Drive

Electrical Drive & Actuation System

❖ Motor Starter Methods:

1) Direct On-Line starter:

The direct-on-line starter is the simplest form of motor starter, other than a manual starter. The controller of this starter is typically a simple push button (but could be a selector switch, limit switch, float switch, etc.). Pressing the start button closes the contactor (by energizing the contactor coil) connected to the main supply and motor. This provides the supply current to the motor. To turn the motor off, a stop button is provided. To protect it from over current, the control circuit is wired through a normally closed auxiliary contact of the overload relay. When the overload relay trips, the normally closed auxiliary contact opens, and de-energizes the contactor coil, and the contactor main contacts open.

The Advantages of Using Direct-On-Line Motor Starters:

•They have a compact design.

•They are cost-effective.

•They have a simple construction.

Electrical Drive & Actuation System

- Motor Starter Methods:

Electrical parts Required for Making Direct On-Line starter:

A) *Magnetic contactor.*

B) Thermal overload Relay

C) MCCB

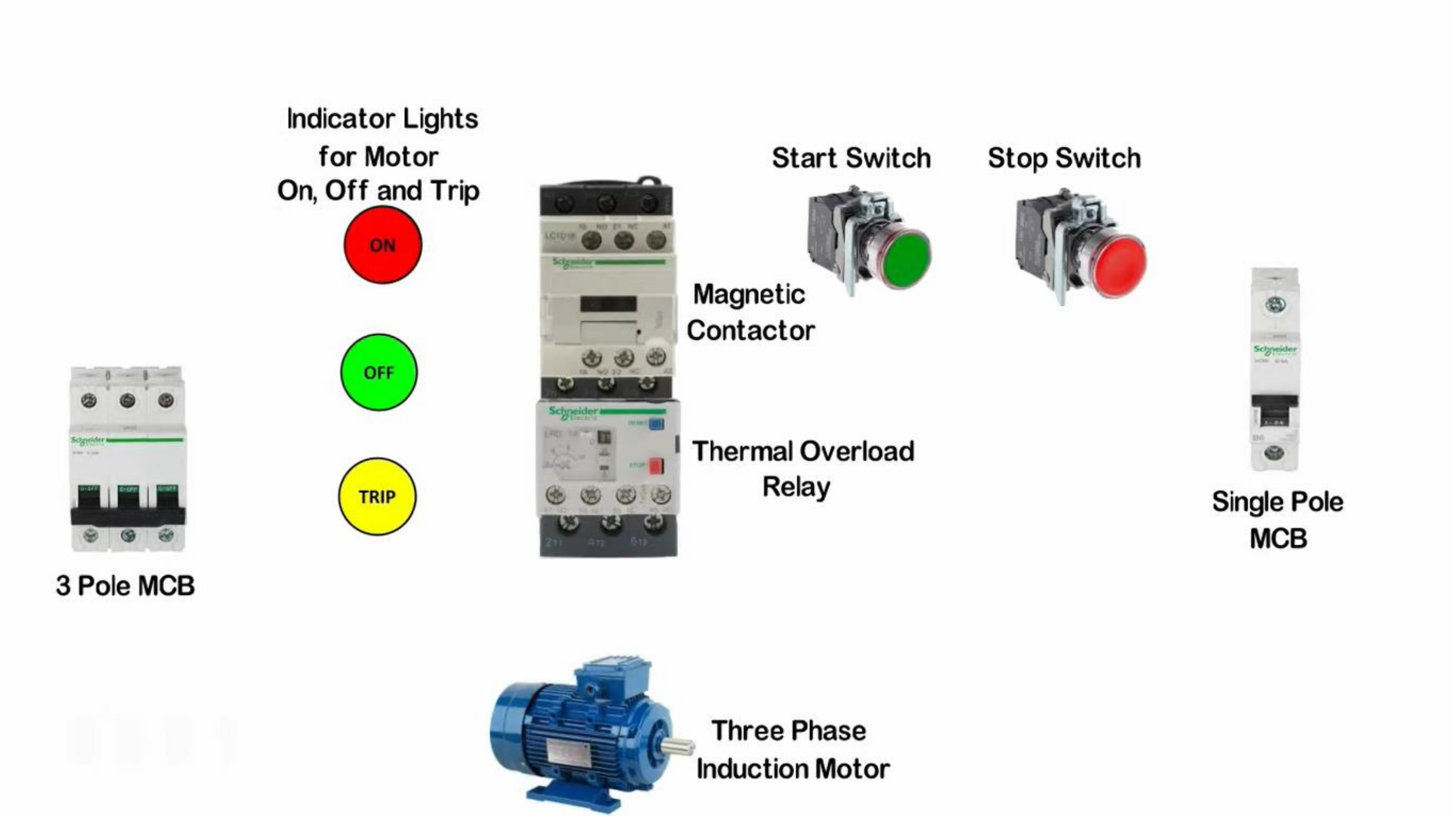
D) Start/ Stop Push Button

E) Indicator lights

Electrical Drive & Actuation System

❖ Motor Starter Methods:

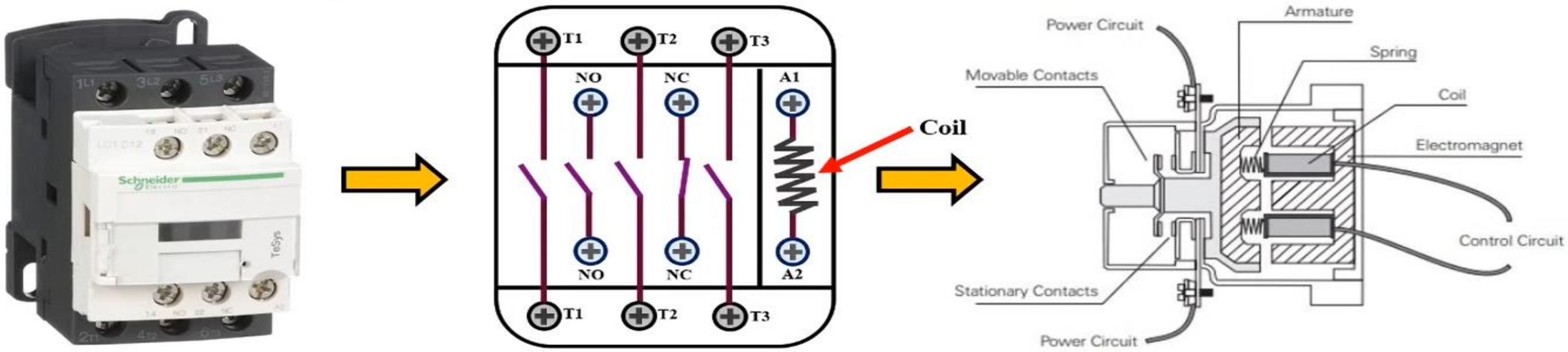
Electrical parts Required for Making Direct On-Line starter:



Electrical Drive & Actuation System

- ❖ Motor Starter Methods:
- ❖ **Electrical parts Required for Making Direct On-Line starter:**

Magnetic Contactor



NC – Normally Closed
NO – Normally Open

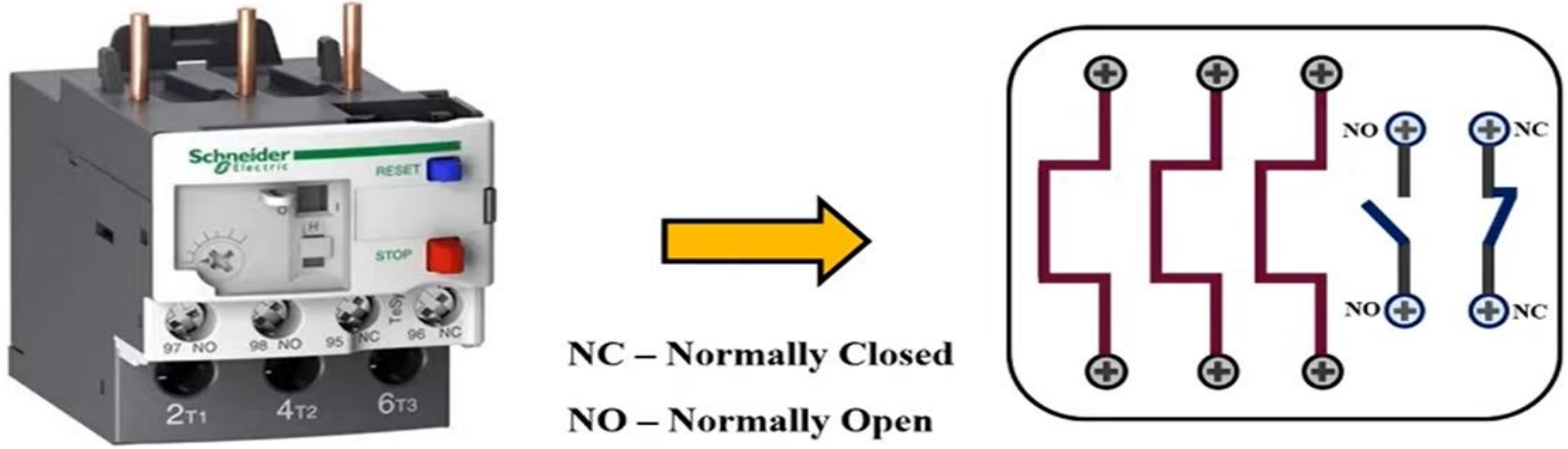
- ❖ When power is supplied to the coil from the control circuit, a magnetic field is produced, magnetizing the electromagnet.
- ❖ The magnetic field attracts the armature to the magnet, which in turn closes the contacts. With the contacts closed, current flows through the power circuit from the line to the load.

Electrical Drive & Actuation System

❖ Motor Starter Methods:

Electrical parts Required for Making Direct On-Line starter:

Thermal Overload Relay



NC – Normally Closed

NO – Normally Open

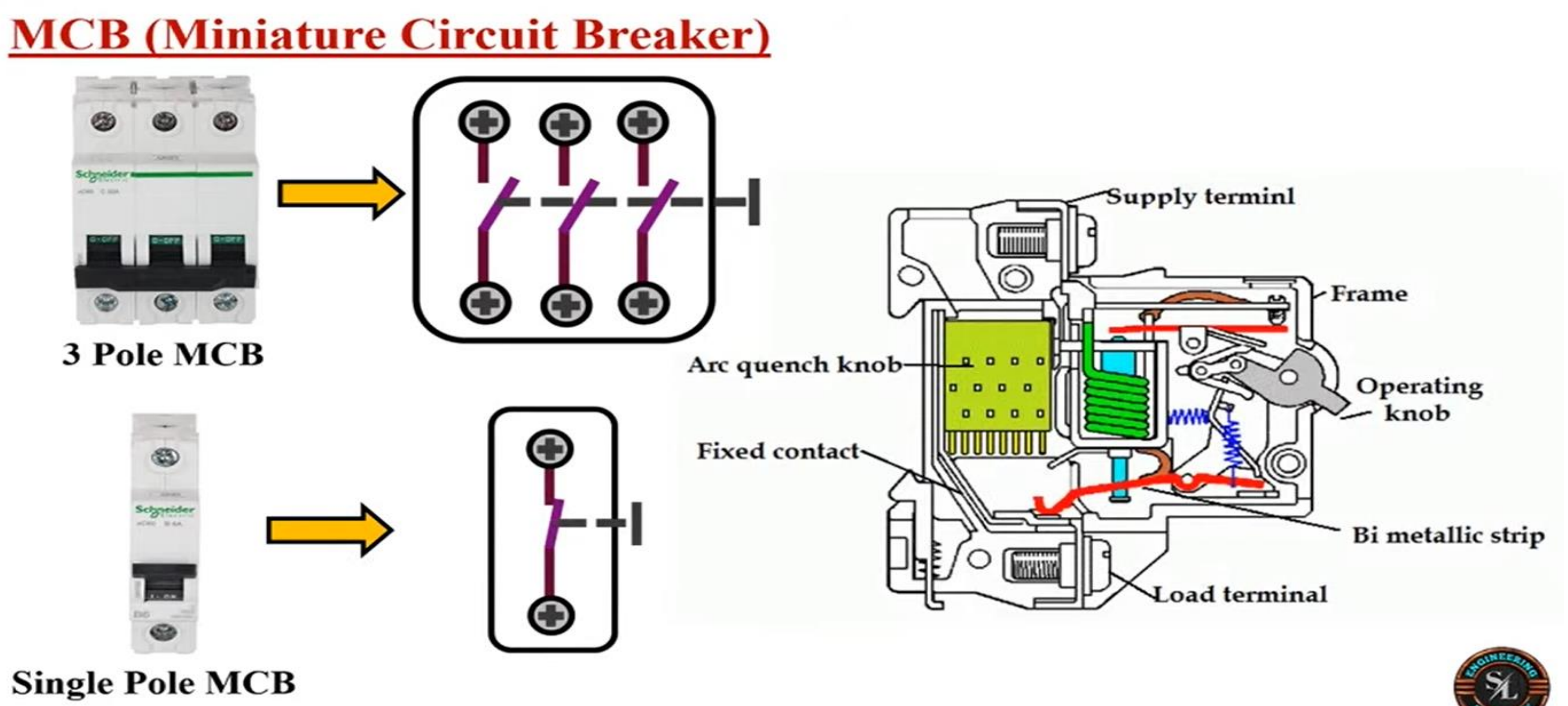
❖ Thermal overload relay is an electromechanical protection device for the main circuit. This device protects the motor in the event of phase failure or overload.

❖ The thermal overload relay does not directly shut down the load. It triggers one or several auxiliary contacts which then disconnect the motor.

Electrical Drive & Actuation System

❖ Motor Starter Methods:

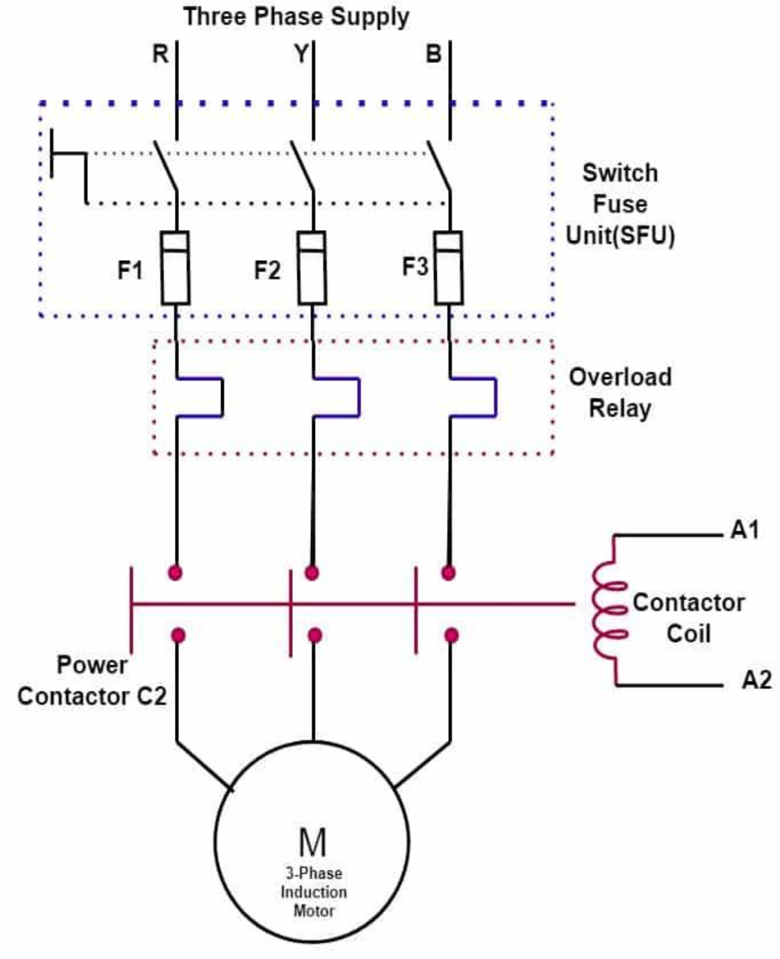
Electrical parts Required for Making Direct On-Line starter:



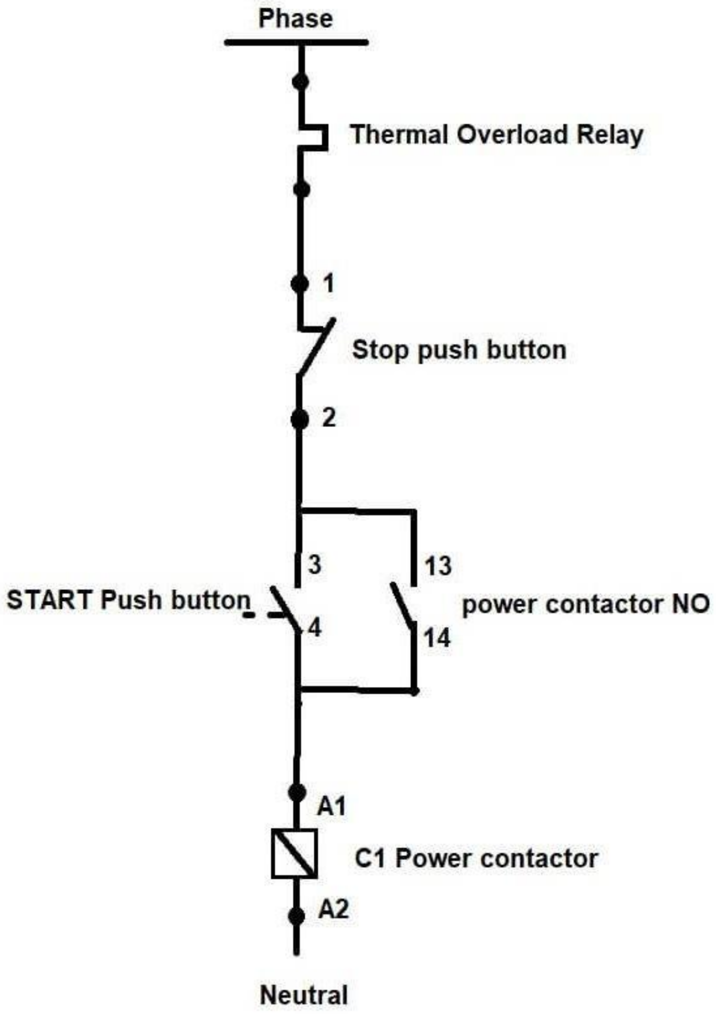
Electrical Drive & Actuation System

❖ Motor Starter Methods:

Power & control circuit diagram of Direct On-Line starter:



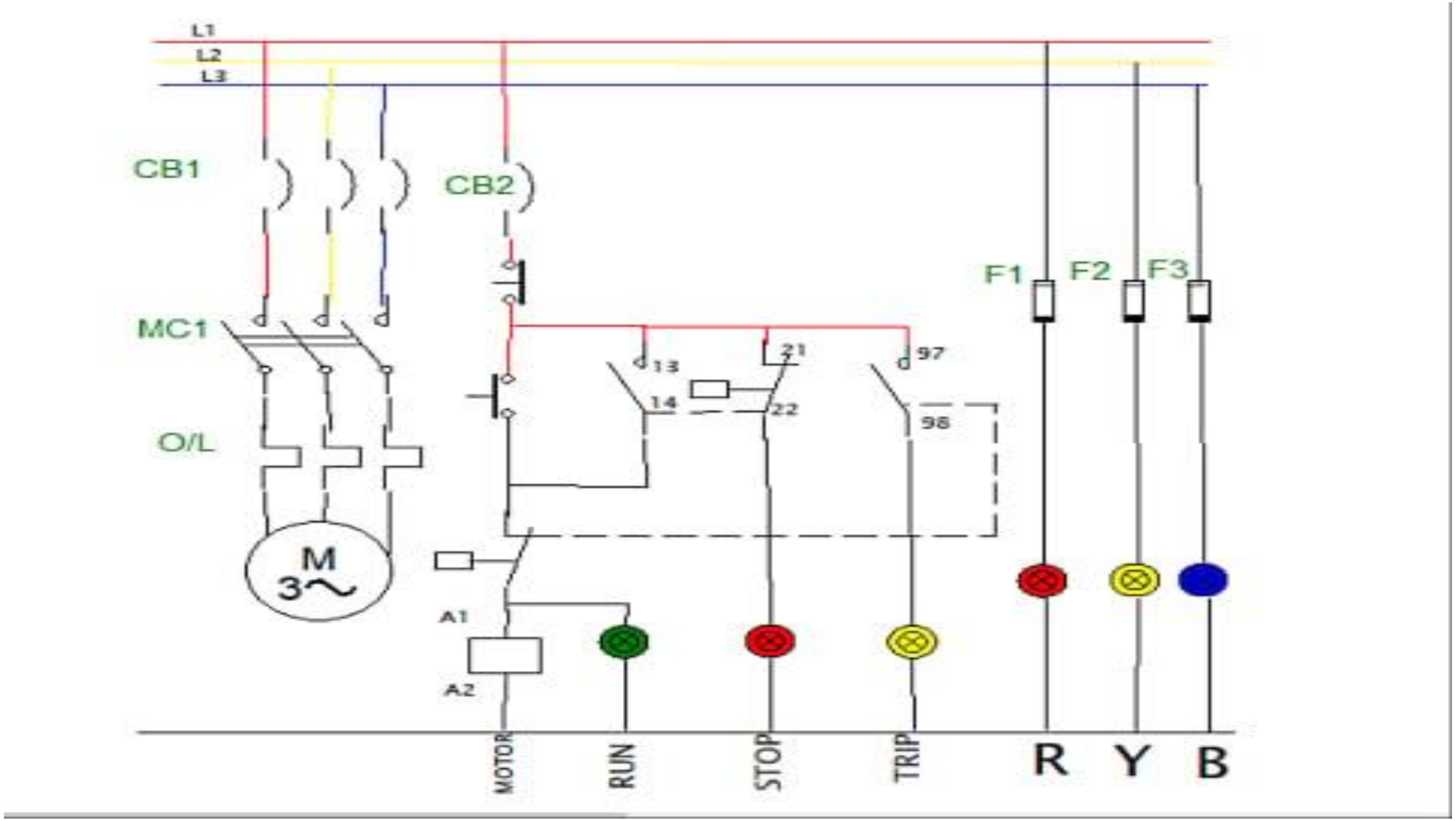
DOL Starter Power Circuit Diagram



Electrical Drive & Actuation System

❖ Motor Starter Methods:

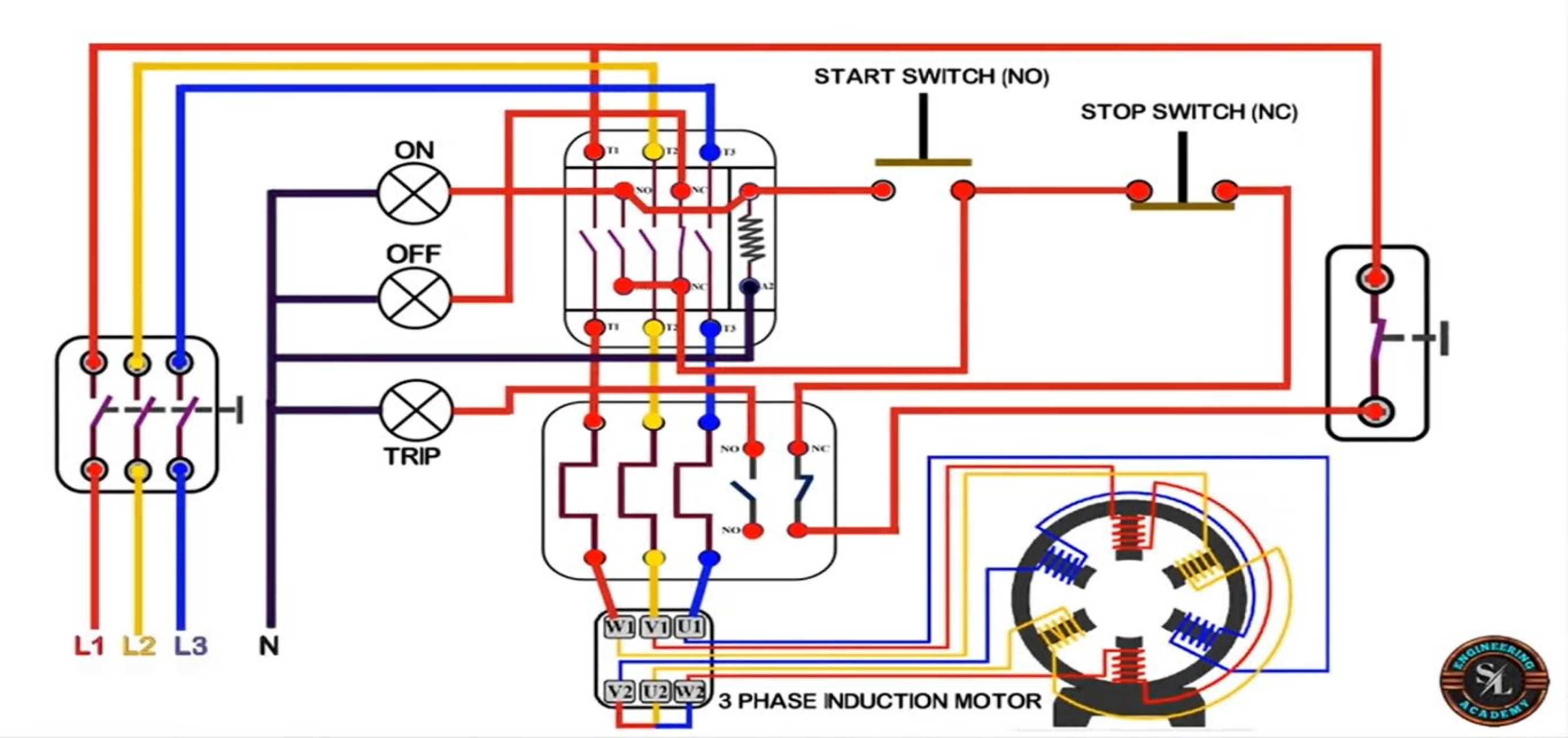
Power & Control Circuit diagram of Direct On-Line starter:



Electrical Drive & Actuation System

❖ Motor Starter Methods:

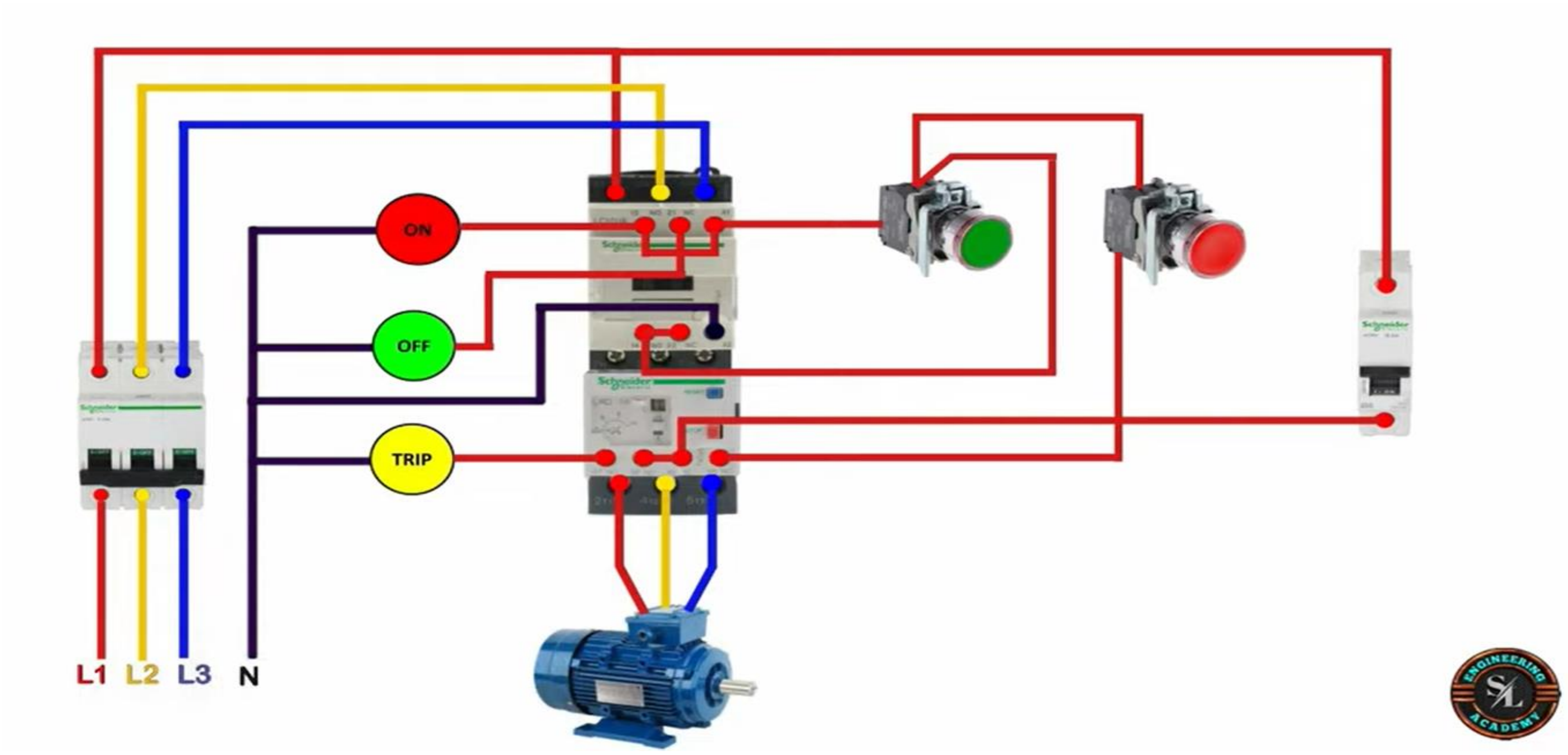
Complete circuit diagram of Direct On-Line starter:



Electrical Drive & Actuation System

- Motor Starter Methods:

Schematic circuit diagram of Direct On-Line starter:



Electrical Drive & Actuation System

❖ Motor Starting Methods:

1) Star - Delta starter:

Compared to the other types of starters, the star delta starter is used on a large scale. As the name suggests, the three windings are connected in a star connection in the star delta starters. A certain time is set by the timer or any other controller circuit. After this time is passed, the windings are then connected in the delta connection. The phase voltage in the star connection is reduced to 58%, and the total current drawn is 58% of normal current. This results in a reduced torque.

The Advantages of Using Star Delta Motor Starters:

- They are ideal for long acceleration times.
- They have a lower input surge current when compared to other starters.
- They have a simpler construction as compared to other starters.

- **The Disadvantages of Using Star Delta Motor Starters:**

- Increased cost and complexity.
- Longer starting time.
- Reduced torque during starting.

Electrical Drive & Actuation System

❖ Motor Starting Methods:

Electrical parts Required for Making Star- Delta starter:

A) *Magnetic contactor.*

B) Thermal overload Relay

C) MCCB

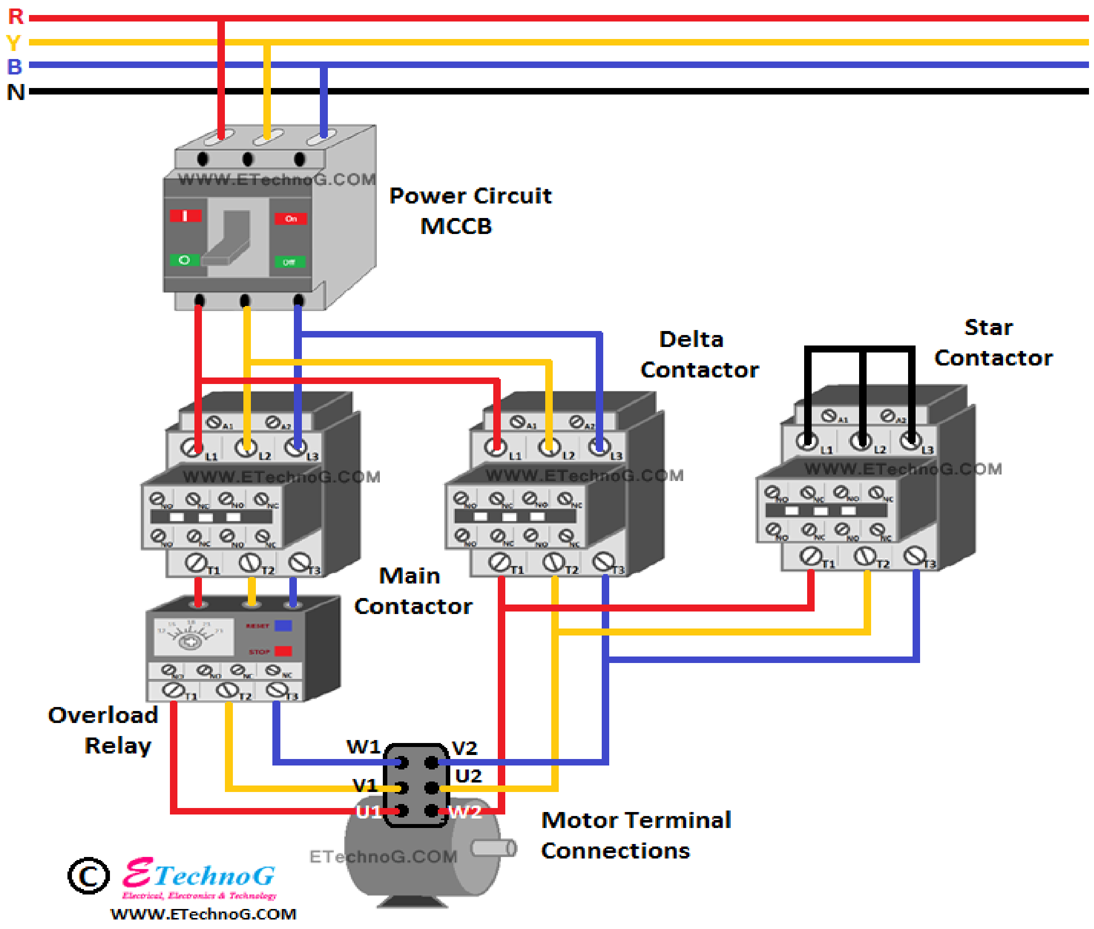
D) Start/ Stop Push Button

E) Indicator lights

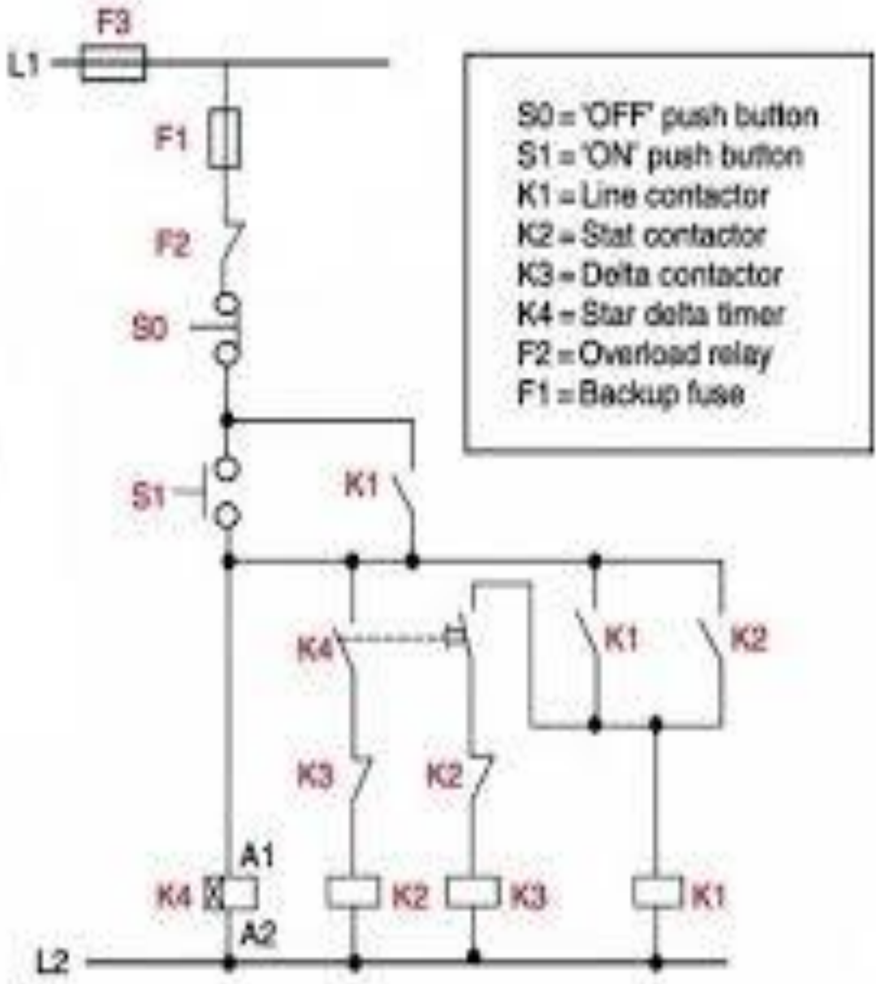
F) Timer

Electrical Drive & Actuation System

Circuit diagram of Star-Delta starter

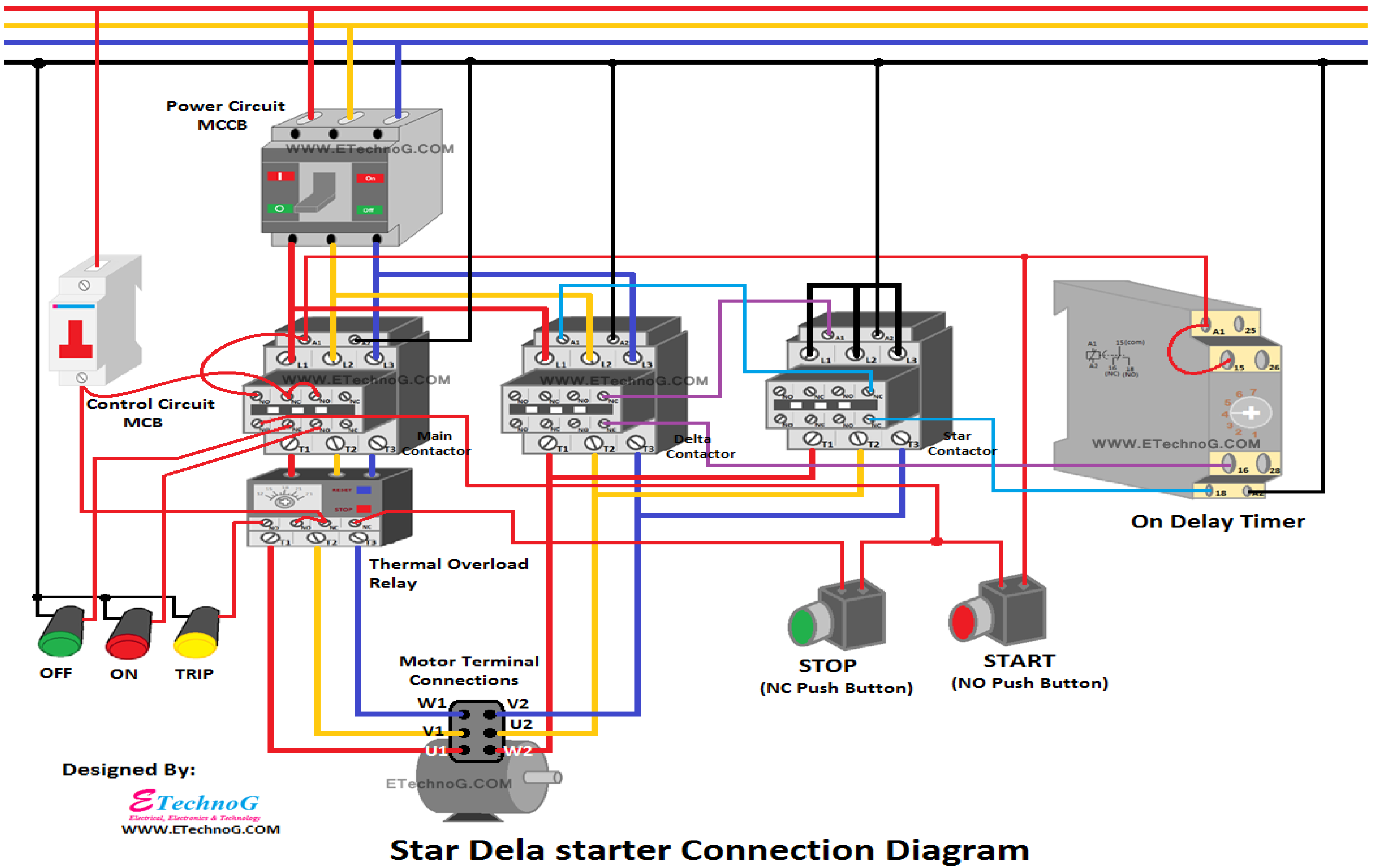


Star Delta Starter Wiring Diagram



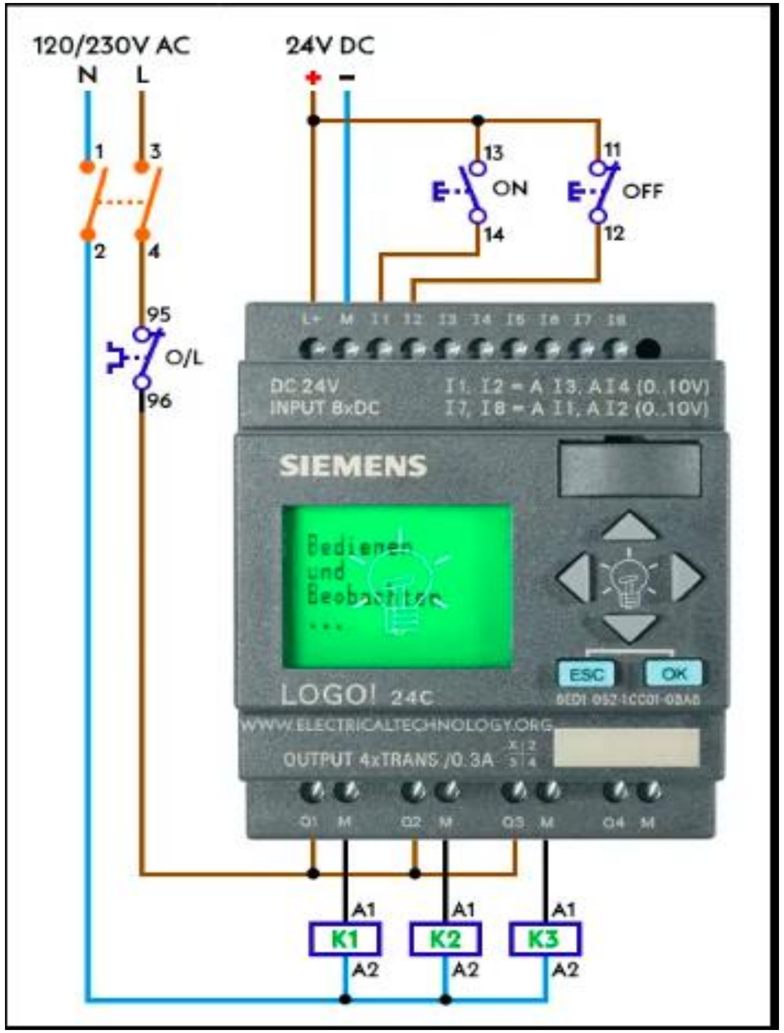
Electrical Drive & Actuation System

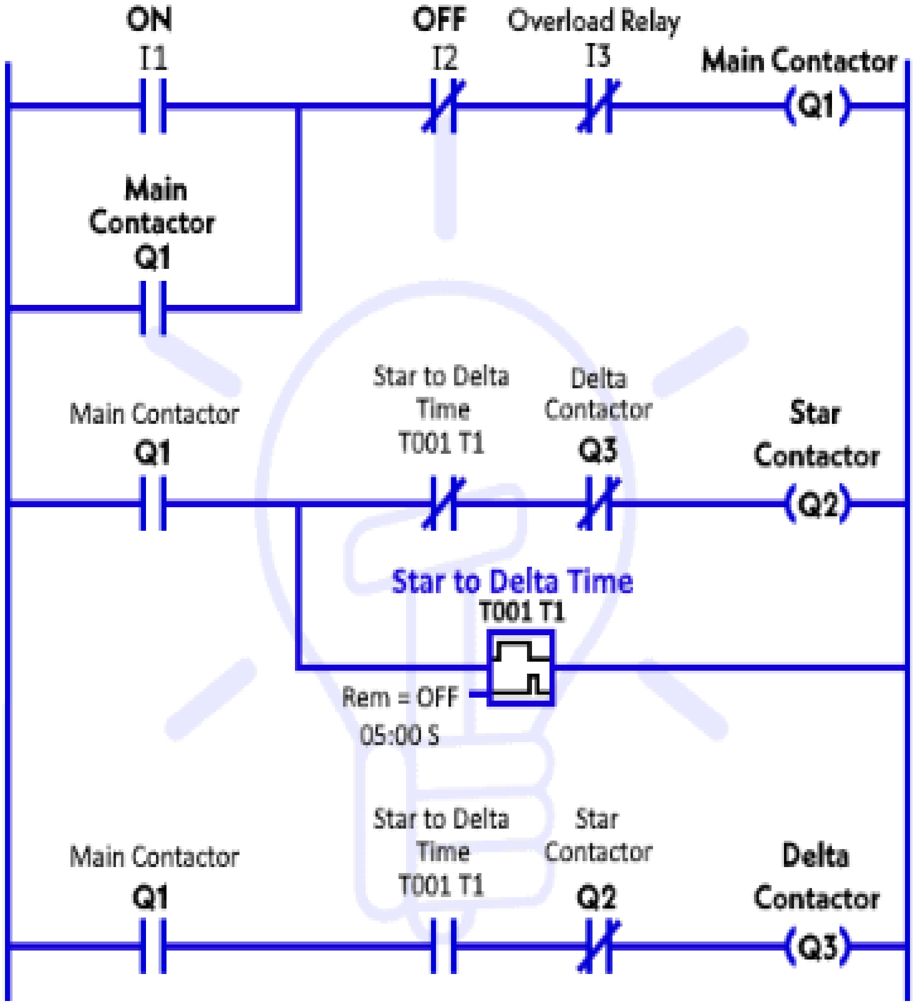
Circuit diagram of Star-Delta starter



Electrical Drive & Actuation System

Star-Delta starter using PLC and Ladder logic diagram





Electrical Drive & Actuation System

Soft Starter

Electrical Drive & Actuation System

Soft Starter:

3-phase induction motors need a high current load to start (between 3 and 15 times the nominal current), something that can end up damaging the motor and other components in the long term.

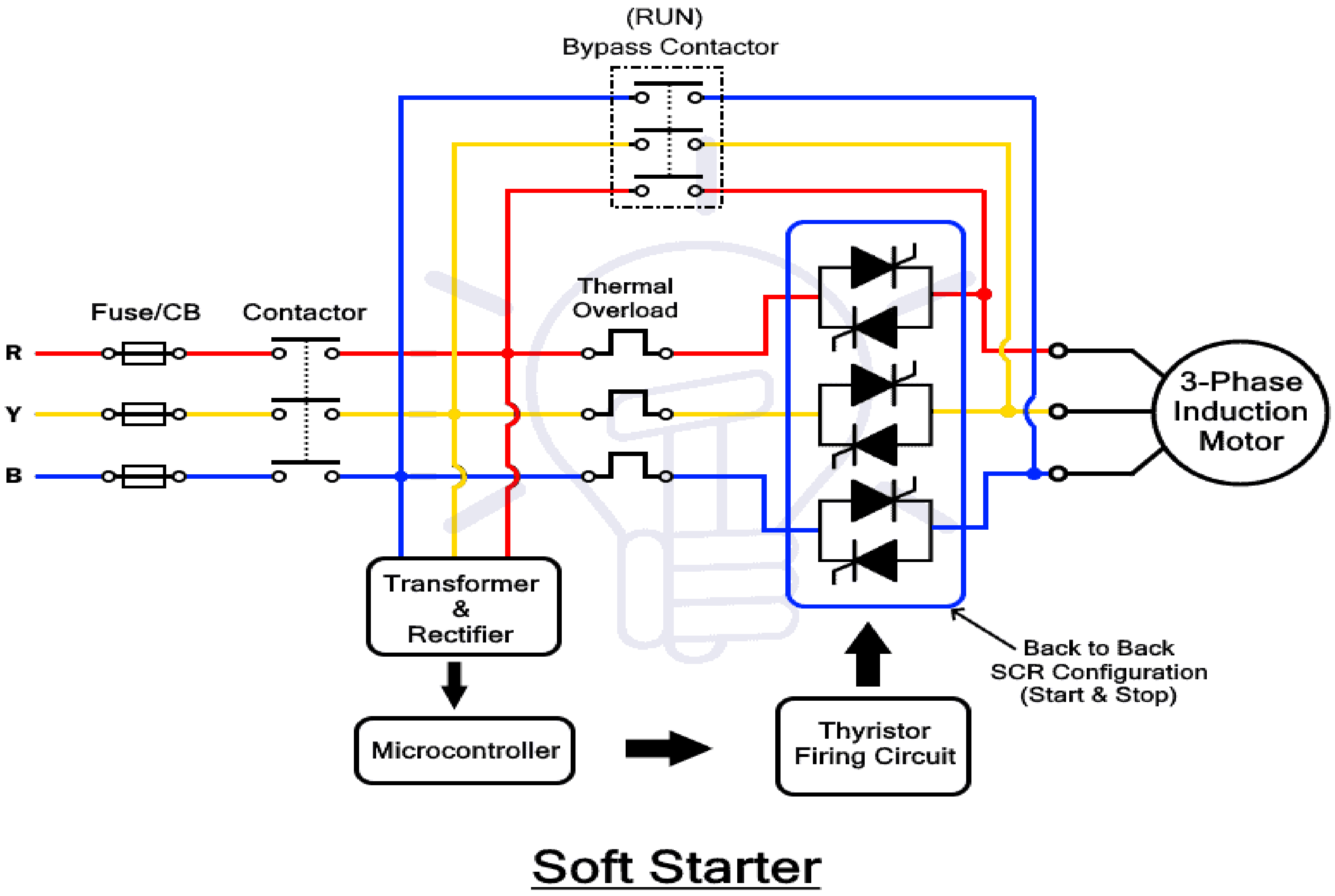
Basically, soft starters allow the voltage to be controlled more effectively by supplying the current gradually until it reaches the nominal current required by the motor to run at its maximum speed.

The starter has additional protection features including:

- Overload
- Input phase failure
- Output phase failure
- Load short-circuit
- Starting limiting overtime
- Over-voltage
- Under-voltage

Electrical Drive & Actuation System

Circuit diagram of Soft starter



Electrical Drive & Actuation System

Advantages of Soft Starter

- **Smooth Startup:**

Unlike conventional motor starter, it provides very gradual increase of voltage thus speed that results in a very smooth startup.

- **Acceleration & Deceleration Control:**

It offers a fully adjustable acceleration & deceleration of the motor. Varying the firing angle slowly or quickly can control the acceleration during startup & deceleration during stopping of motor. This is used in application where startup acceleration needs to be adjusted.

No Power Surges: Since the conventional motor starter allows full voltage across the motor, a huge inrush current start flowing into the motor that cause a power surge in the circuit. the soft starter limits such current thus preventing the power surges.

Multiple Startups: Some applications require the motor to start & stop multiple times in small period. such motor if used with a conventional starter will experience overheating due to high starting current. However, soft starters drastically increases the number of startups for a motor in a specific duration.

Reduction of Overheating: The motor overheating is a very serious problem. It occurs due to the high winding current during its startup. The soft starter allows a very small amount of starting current which prevents the overheating of motor.

Electrical Drive & Actuation System

- **Increased Life Span:** The soft starter as compared to a conventional starter improves the lifetime of the motor. it is due to the smooth operation & absence of electrical & mechanical stress on the motor.

- **Less Maintenance:** Due to its smooth operation, the induction motor is less likely to have any mechanical faults, which is why it require less maintenance as opposed to conventional motor starter.

- **Efficiency:** A conventional motor starter supply full voltage (very high inrush current) to the motor that consumes too much energy. A soft starter significantly reduces it & allows a gradual increase in energy consumption. Also, the power switches are controlled using very low voltage level. It improves the overall efficiency of the motor .
- **Compact & Small Size:** The soft starter has a very compact design that takes up very small space. Unlike other motor starters, it has very small size.
- **Low Cost:** compared to other starters such as VFD, this sure does cost cheaper.

Electrical Drive & Actuation System

Disadvantages of Soft Motor Starter:

- **No Speed regulation:** The soft starter only allows the control of input voltage supply i.e. from 0 volts to line voltage with a fixed line frequency. Since the frequency is constant the motor speed is constant & only regulates by the load connected with it. The speed of induction motor is regulated by varying the supply frequency below or above the line frequency according to the need. Such feature is only available in VFD (variable frequency drive).

- **Heat dissipation:** The semiconductor switches inside the soft starter dissipates some energy in the form of heat. Therefore, it also requires heat sinks for cooling the power switches.

- **Reduced starting Torque:** Since it reduces the input voltage that corresponds to the input current which is directly proportional to the starting torque of the induction motor, it significantly reduces the starting torque. This is why Soft starters are used for low or medium starting torque application.

Electrical Drive & Actuation System

Variable Frequency Drive (VFD) :

Electrical Drive & Actuation System

Variable Frequency Drive (VFD) :

Electrical Drive & Actuation System

Variable Frequency Drive (VFD) :

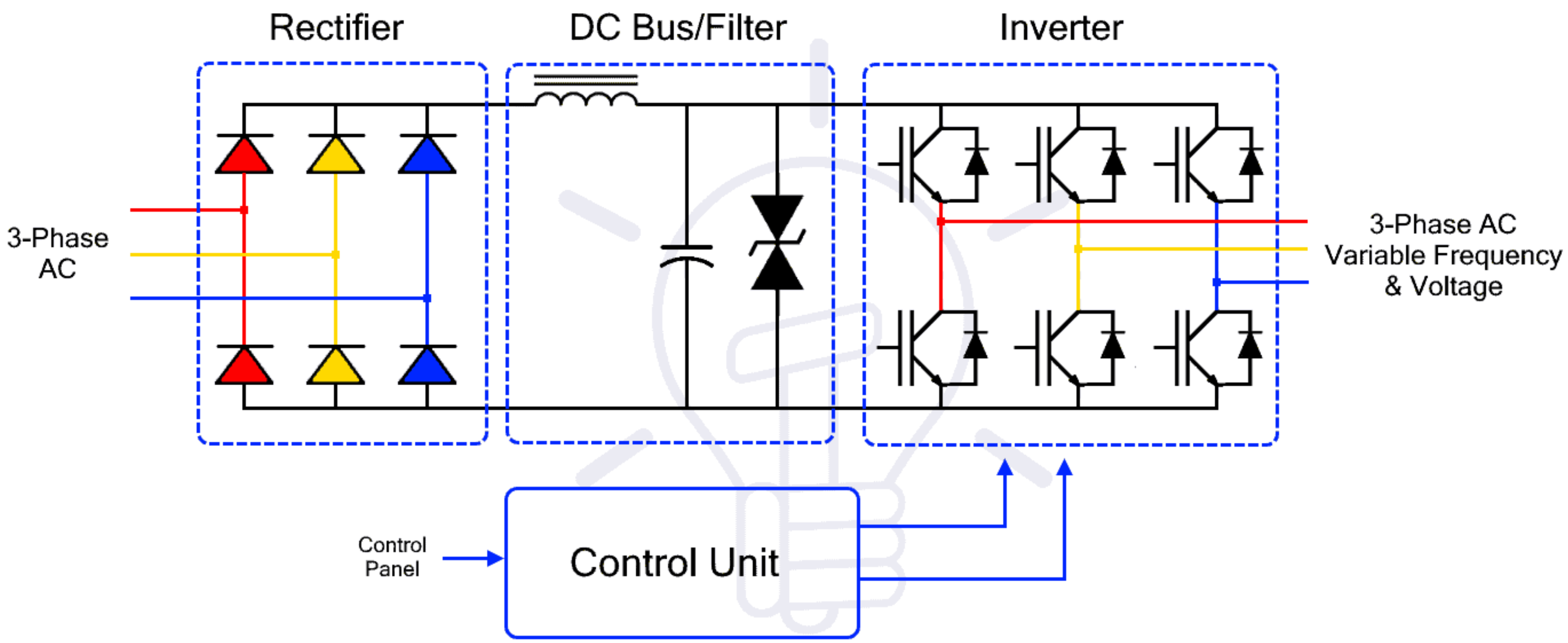
What is VFD: A frequency converter provides a significant reduction in power consumption by regulating the speed of the motor because the motor is not running at rated speed and not at full power. In the absence of a frequency converter, it is possible to use only one speed and rated power regardless of the load of the system at the time. This is particularly evident in the case of water head or airflow in a fan. In such cases, the output is controlled by throttling with a damper and the head is controlled by the inlet vanes.

Many HVAC systems in commercial and industrial buildings use single-speed AC motors to operate the fans. The inlet airflow of the fan is controlled by blades or dampers as previously mentioned. An alternative method of control is to use a frequency converter, which will provide motor speed control that will remove the damper, thereby simplifying the system design.

All three methods provide the same power consumption at 100% airflow load, but when the load is reduced, the frequency converter allows much less energy to be consumed. At 50% load reduction in HVAC systems, tests have shown that the IF uses 21% of the rated power consumption, with vane control the power consumption is 65%, and with a damper, the power consumption is 87%.

Electrical Drive & Actuation System

Variable Frequency Drive working Principle:



Variable Frequency Drive

Electrical Drive & Actuation System

Danfoss VFD Local control Panel (LCP):

A. Display area.

B. Display menu keys.

C. Navigation keys and indicator lights.

D. Operation keys and reset.

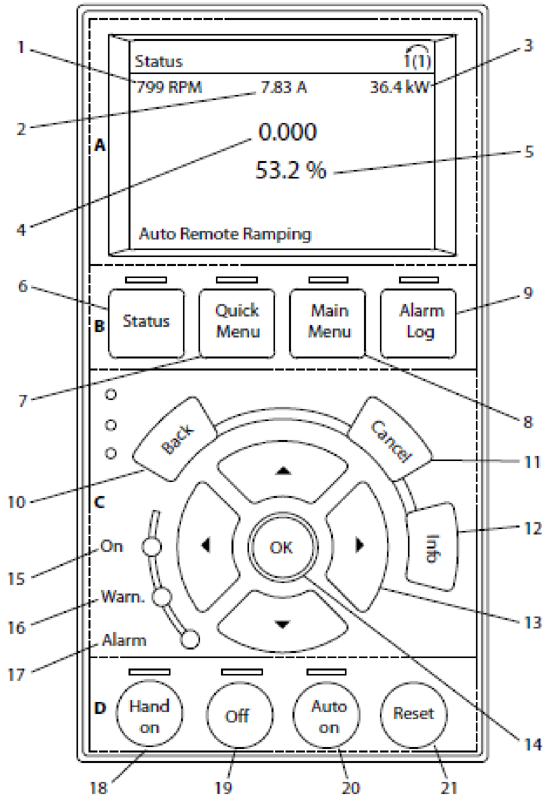


Illustration 5.1 GLCP

Electrical Drive & Actuation System

VFD parameter setting Procedure :

Parameters	Name	Unit Setting	Setting Range	Initial Value	Application
Pr.0	Torque boost	0.10%	0 to 30%	6/4/3/2%	Increase starting torque When the engine is loaded but not running
Pr.1	Maximum frequency	0.01Hz	0 to 120Hz	120Hz	Set maximum output frequency
Pr.2	Minimum frequency	0.01Hz	0 to 120Hz	0Hz	Set minimum output frequency
Pr.3	Base frequency	0.01Hz	0 to 400Hz	60Hz	Setting according to motor frequency
Pr.4	Multi-speed setting (high speed)	0.01Hz	0 to 400Hz	60Hz	Set when you want to change the preset frequency for each switch RH, RM, RL
Pr.5	Multi-speed setting (middle speed)	0.01Hz	0 to 400Hz	30Hz	Set when you want to change the preset frequency for each switch RH, RM, RL
Pr.6	Multi-speed setting (low speed)	0.01Hz	0 to 400Hz	10Hz	Set when you want to change the preset frequency for each switch RH, RM, RL
Pr.7	Acceleration time	0.1/0.01s	0 to 3600/360s	5/10/15s	Set acceleration time
Pr.8	Deceleration time	0.1/0.01s	0 to 3600/360s	5/10/15s	Set deceleration time
Pr.9	Electronic thermal O/L relay	0.01A	0 to 500A	Rated inverter current	Motor overheating protection
Pr.79	Operation mode selection	1	0, 1, 2, 3	0	0: Switch mode between PU and EXT 1: Fixed in PU . Mode 2: Fixed in EXT . Mode 3: PU/EXT combo mode
Pr.125	Terminal 2 frequency setting gain frequency	0.01Hz	0 to 400Hz	60Hz	Set the frequency to the maximum value that the potentiometer can change
Pr.126	Terminal 4 frequency setting gain frequency	0.01Hz	0 to 400Hz	60Hz	Set the frequency to the maximum value that the current input can change
Pr.160	User group read selection	1	0, 1, 9999	0	0: Show all parameters 1: Displays only parameters registered to the user group 9999: Show only parameter of simple mode
AllClr	Delete all parameters	1	0, 1	0	Select 1 to return all parameters except for the initial values
PrClr	Delete parameters	1	0, 1	0	Choose 1 to return all parameters to their original values

Electrical Drive & Actuation System

Industrial Panel Board:

Electrical Drive & Actuation System

Danfoss VFD Fault Troubleshooting:

Number	Description	Warning	Alarm/ trip	Alarm/ trip lock	Parameter reference
1	10 volts low	X	–	–	–
2	Live zero error	(X)	(X)	–	*Parameter 6-01 Live Zero Timeout Function*
3	No motor	(X)	–	–	*Parameter 1-80 Function at Stop*
4	Mains phase loss	(X)	(X)	(X)	*Parameter 14-12 Function at Mains Imbalance*
5	DC-link voltage high	X	–	–	–
6	DC-link voltage low	X	–	–	–
7	DC overvoltage	X	X	–	–
8	DC undervoltage	X	X	–	–
9	Inverter overloaded	X	X	–	–
10	Motor ETR overtemperature	(X)	(X)	–	*Parameter 1-90 Motor Thermal Protection*
11	Motor thermistor overtemperature	(X)	(X)	–	*Parameter 1-90 Motor Thermal Protection*
12	Torque limit	X	X	–	–
13	Overcurrent	X	X	X	–
14	Ground fault	X	X	–	–
15	Hardware mismatch	–	X	X	–
16	Short circuit	–	X	X	–
17	Control word timeout	(X)	(X)	–	*Parameter 8-04 Control Word Timeout Function*
20	Temp. input error	–	X	–	–
21	Param error	–		X	–

Electrical Drive & Actuation System

Danfoss VFD Fault Troubleshooting:

Number	Description	Warning	Alarm/ trip	Alarm/ trip lock	Parameter reference
22	Hoist mech. brake	(X)	(X)	–	*Parameter group 2-2* Mechanical Brake*
23	Internal fans	X	–	–	–
24	External fans	X	–	–	–
25	Brake resistor short-circuited	X	–	–	–
26	Brake resistor power limit	(X)	(X)	–	*Parameter 2-13 Brake Power Monitoring*
27	Brake chopper short-circuited	X	X	–	–
28	Brake check	(X)	(X)	–	*Parameter 2-15 Brake Check*
29	Heat sink temp	X	X	X	–
30	Motor phase U missing	(X)	(X)	(X)	*Parameter 4-58 Missing Motor Phase Function*
31	Motor phase V missing	(X)	(X)	(X)	*Parameter 4-58 Missing Motor Phase Function*
32	Motor phase W missing	(X)	(X)	(X)	*Parameter 4-58 Missing Motor Phase Function*
33	Inrush fault		X	X	–
34	Fieldbus communication fault	X	X	–	–
35	Option fault	–	–	X	–
36	Mains failure	X	X	–	–
37	Imbalance of supply voltage		X	–	–
38	Internal fault		X	X	–
39	Heat sink sensor		X	X	–
40	Overload of digital output terminal 27	(X)	–	–	*Parameter 5-00 Digital I/O Mode, parameter 5-01 Terminal 27 Mode*
41	Overload of digital output terminal 29	(X)	–	–	*Parameter 5-00 Digital I/O Mode, parameter 5-02 Terminal 29 Mode*
42	Ovrld X30/6-7	(X)	–	–	–
43	Ext. supply (option)	X	–	–	–
45	Ground fault 2	X	X	–	–
46	Pwr. card supply	–	X	X	–
47	24 V supply low	X	X	X	–
48	1.8 V supply low	–	X	X	–
50	AMA calibration failed	–	X	–	–
51	AMA check U_{nom} and I_{nom}	–	X	–	–
52	AMA low I_{nom}	–	X	–	–
53	AMA motor too big	–	X	–	–
54	AMA motor too small	–	X	–	–

Electrical Drive & Actuation System

Difference between soft starter and VFD

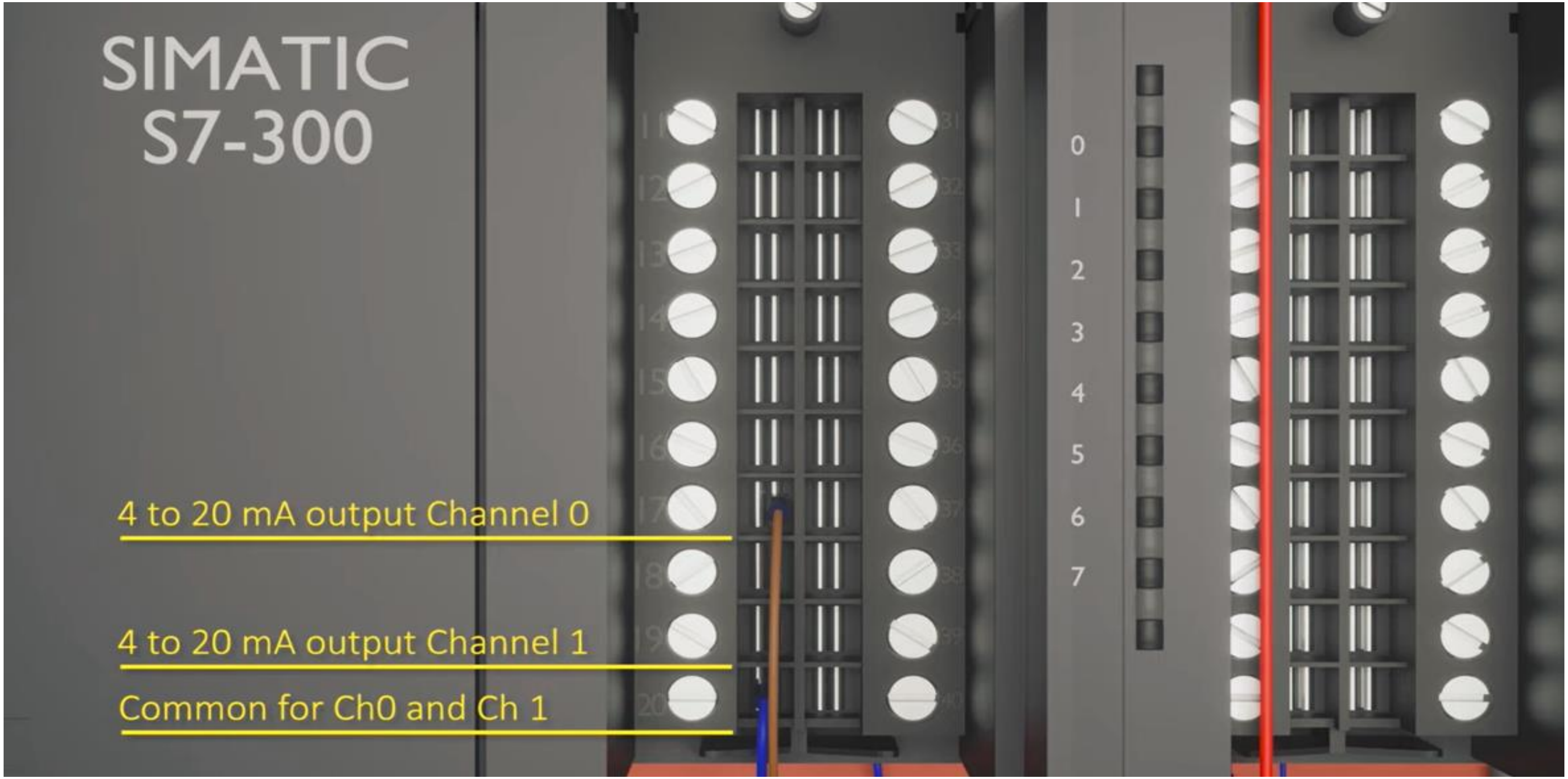
Soft Starter	VFD
Soft starters are used only for motor start and stop control.	VFD's are used for start, stop, and speed control of motor.
Soft starters will be bypassed after motor reaches its full speed.	VFD controls the motor throughout it's operation.
Soft starters do not inject any harmonic noises.	VFD may induce harmonic noises, so extra filters will be needed to reduce these harmonics.
Less expensive.	More expensive.
Space requirement is less.	Space requirement is more.
Energy saving is less.	Energy saving is more.

Electrical Drive & Actuation System

VFD signal connection to PLC:

Electrical Drive & Actuation System

VFD signal connection to PLC:



Electrical Drive & Actuation System

VFD signal connection to PLC:

Electrical Drive & Actuation System

Energy saving calculation from VFD:

Cost Savings Example

Let's say we have a fan with a 60-horsepower (hp) motor that supplies air for 15 hours a day,

300 days a year, and the energy cost is $ 0.1177 per kilowatt-hour (assumed).

The operational cost is calculated with the following formula:

Cost = Power (kW) × Running Time × Cost/kWh

So, the cost of operation for running a motor at different speeds for different durations with VFD and without VFD is shown in table 1:

Control	Speed (%)	Power (hp)	Duration (%) / hours	Cost ($) per year
Without VFD (A)	100	60	100/4500	23,707.13
With VFD (B)	100	60	30 / 1350	7,112.14
	75	25.3125	55 / 2475	5,500.79
	50	7.5	15 / 675	444.51
Annual savings per year by using VFD				$ 10,649.69

Table 1: cost of operation for running a motor with VFD and without VFD

To calculate the payback period of investing in an AC Drive, we can use the following formula:

$$\frac{\text{(Cost of drive)}}{\text{(annual savings)}} \times 12$$

So, if our 60hp Drive costs $15000 (assumed), the payback period would be around 17 months, i.e., less than two years!