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# INDUSTRIAL AUTOMATION WITH PLC

## DOL STARTER WITH CONTACTOR

# Direct On-Line (DOL) Motor Starter

Different starting methods are employed for starting induction motors because Induction Motor draws more starting current during starting. To prevent damage to the windings due to the high starting current flow, we employ different types of starters.

The simplest form of motor starter for the induction motor is the Direct on Line starter. The Direct on Line Motor Starter (DOL) consists of an MCCB or Circuit Breaker, Contactor and an overload relay for protection. Electromagnetic contactor which can be opened by the thermal overload relay under fault conditions.

Typically, the contactor will be controlled by separate start and stop buttons, and an auxiliary contact on the contactor is used, across the start button, to hold in contact. I.e. the contactor is electrically latched closed while the motor is operating.

## Principle of Direct On Line Starter (DOL):

To start, the contactor is closed, applying full line voltage to the motor windings. The motor will draw a very high inrush current for a very short time, the magnetic field in the iron, and then the current will be limited to the Locked Rotor Current of the motor. The motor will develop Locked Rotor Torque and begin to accelerate towards full speed.

As the motor accelerates, the current will begin to drop, but will not drop significantly until the motor is at a high speed, typically about 85% of synchronous speed. The actual starting current curve is a function of the motor design, and the terminal voltage, and is totally independent of the motor load.

The motor load will affect the time taken for the motor to accelerate to full speed and therefore the duration of the high starting current, but not the magnitude of the starting current.

Provided the torque developed by the motor exceeds the load torque at all speeds during the start cycle, the motor will reach full speed. If the torque delivered by the motor is less than the torque of the load at any speed during the start cycle, the motor will stop accelerating. If the starting torque with a DOL starter is insufficient for the load, the motor must be replaced with a motor that can develop a higher starting torque.

The acceleration torque is the torque developed by the motor minus the load torque and will change as the motor accelerates due to the motor speed torque curve and the load speed torque curve. The start time is dependent on the acceleration torque and the load inertia.

DOL starting has a maximum start current and maximum start torque.

This may cause an electrical problem with the supply, or it may cause a mechanical problem with the driven load. So this will be inconvenient for the users of the supply line, always experience a voltage drop when starting a motor. But if this motor is not a high power one it does not affect much.

# Parts of DOL Starters:

## Contactors & Coil:

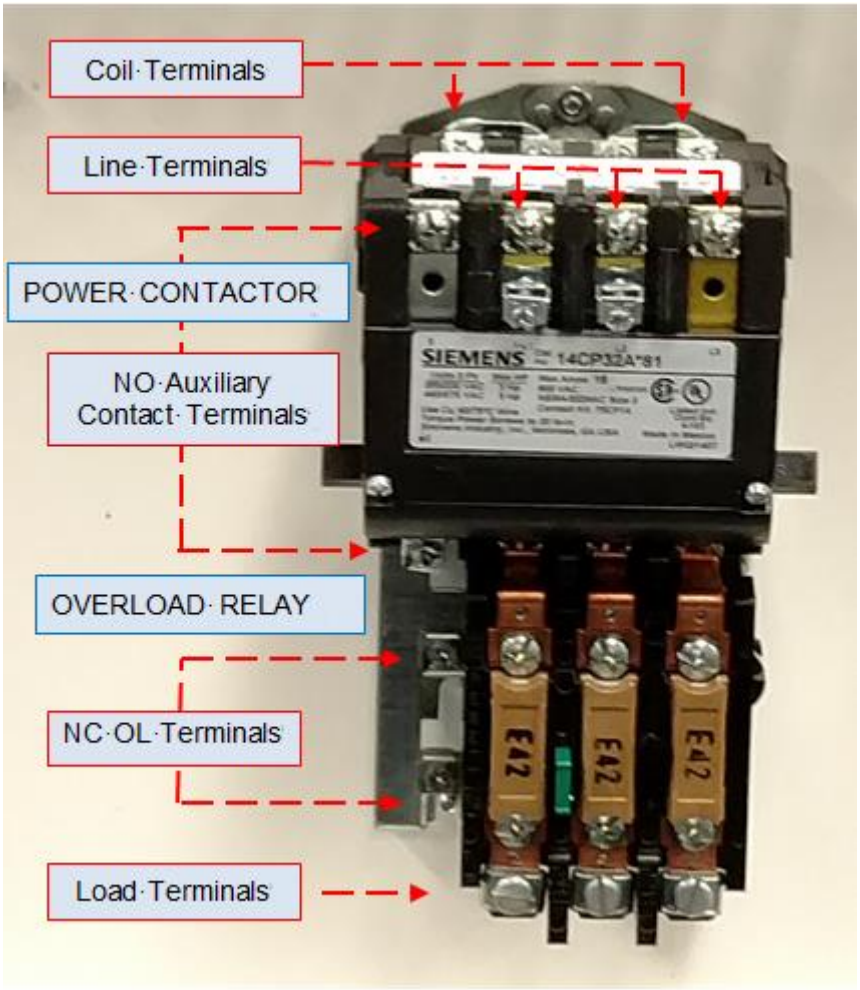


**Fig: Contactor**

Magnetic contactors are electromagnetically operated switches that provide a safe and convenient means for connecting and interrupting branch circuits.

Magnetic motor controllers use electromagnetic energy for closing switches. The electromagnet consists of a coil of wire placed on an iron core. When a current flows through the coil, the iron of the magnet becomes magnetized, attracting an iron bar called the armature. An interruption of the current flow through the coil of the wire causes the armature to drop out due to the presence of an air gap in the magnetic circuit.

Line-voltage magnetic motor starters are electromechanical devices that provide a safe, convenient, and economical means of starting and stopping motors, and have the advantage of being controlled remotely. The great bulk of motor controllers sold are of this type.

Contactors are mainly used to control machinery which uses electric motors. It consists of a coil that connects to a voltage source. Very often for Single-phase Motors, 230V coils are used

and for three-phase motors, 415V coils are used. The contactor has three main NO contacts and lesser power rated contacts named Auxiliary Contacts [NO and NC] used for the control circuit. A contact is conducting metal parts that complete or interrupt an electrical circuit.

- NO-normally open
- NC-normally closed

## Over Load Relay (Overload protection):

Overload protection for an electric motor is necessary to prevent burnout and to ensure maximum operating life.

Under any condition of overload, a motor draws excessive current that causes overheating. Since motor winding insulation deteriorates due to overheating, there are established limits on motor operating temperatures to protect a motor from overheating. Overload relays are employed on motor control to limit the amount of current drawn.

The overload relay does not provide short circuit protection. This is the function of overcurrent protective equipment like fuses and circuit breakers, generally located in the disconnecting switch enclosure.

The ideal and easiest way for overload protection for a motor is an element with current-sensing properties very similar to the heating curve of the motor which would act to open the motor circuit when full-load current is exceeded. The operation of the protective device should be such that the motor is allowed to carry harmless over-loads but is quickly removed from the line when an overload has persisted too long.


**Fig: Thermal Overload Relay**

Normally fuses are not designed to provide overload protection. Fuse is protecting against short circuits (over current protection). Motors draw a high inrush current when starting and conventional fuses have no way of distinguishing between this temporary and harmless inrush current and a damaging overload. Selection of Fuse is dependent on motor full-load current, would "blow" every time the motor is started. On the other hand, if a fuse were chosen large enough to pass the starting or inrush current, it would not protect the motor against small, harmful overloads that might occur later.

The overload relay is the heart of motor protection. It has inverse-trip-time characteristics, permitting it to hold in during the accelerating period (when inrush current is drawn), yet providing protection on small overloads above the full-load current when the motor is running. Overload relays are renewable and can withstand repeated trip and reset cycles without the need for replacement. Overload relays cannot, however, take the place of overcurrent protection equipment. The overload relay consists of a current-sensing unit connected in the line to the motor, plus a mechanism, actuated by the sensing unit, which serves, directly or indirectly, to break the circuit.

Overload relays can be classified as being thermal, magnetic, or electronic:

1. **Thermal Relay**: As the name implies, thermal overload relays rely on the rising temperatures caused by the overload current to trip the overload mechanism. Thermal overload relays can be further subdivided into two types: melting alloy and bimetallic.

2. **Magnetic Relay**: Magnetic overload relays react only to current excesses and are not affected by temperature.

3. **Electronic Relay:** Electronic or solid-state overload relays, provide the combination of the high-speed trip, adjustability, and ease of installation. They can be ideal in many precise applications.

## Wiring of DOL Starter

### 1. Main Contact

- A contactor is connecting among Supply Voltage, Relay Coil and Thermal Overload Relay.
- L1 of Contactor Connect (NO) to R Phase through MCCB
- L2 of Contactor Connect (NO) to Y Phase through MCCB
- L3 of Contactor Connect (NO) to B Phase through MCCB.

**NO Contact (-||-):**

- (13-14 or 53-54) is a Normally Open NO contact (closes when the relay energizes)
- Contactor Point 53 is connecting to Start Button Point (94) and 54 Point of Contactor is connected to Common wire of Start/Stop Button.

**NC Contact (-|/|-):**

- (95-96) is a normally closed NC contact (opens when the thermal overloads trip if associated with the overload block)

**2. Relay Coil Connection**

- A1 of Relay Coil is connecting to anyone Supply Phase and A2 is connecting to Thermal over Load Relay's NC Connection (95).

**3. Thermal Overload Relay Connection**:

- T1, T2, T3 are connected to Thermal Overload Relay
- Overload Relay is Connecting between Main Contactor and Motor
- NC Connection (95-96) of Thermal Overload Relay is connecting to Stop Button and Common Connection of Start/Stop Button

## Wiring Diagram of DOL Starter:

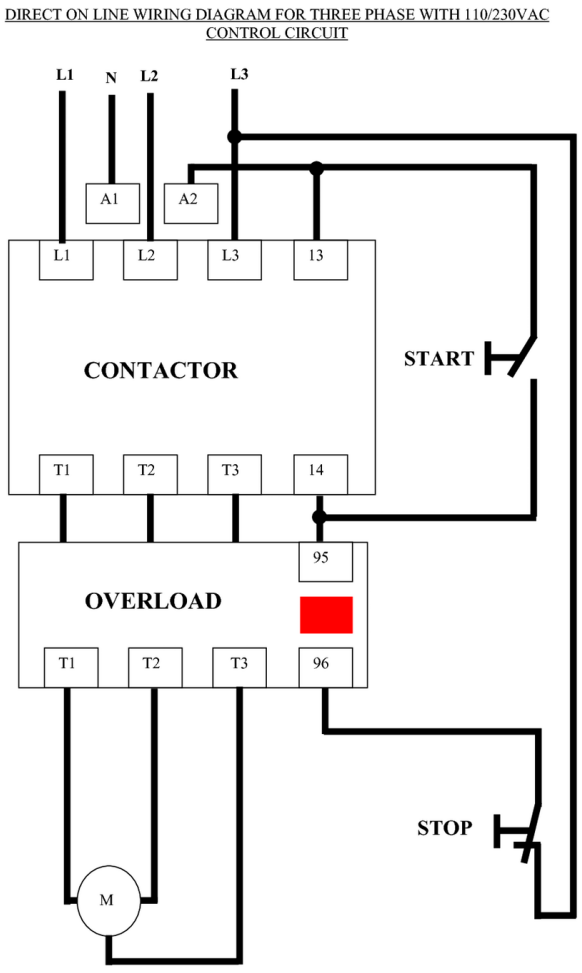


Fig: Direct On Line Starter - Wiring Diagram

## Working principle of DOL Starter:

The main heart of the DOL starter is Relay Coil. Normally it gets one phase constant from incoming supply Voltage (A1). When Coil gets second Phase relay coil energizes and Magnet of Contactor produce electromagnetic field and due to this Plunger of Contactor will move and Main Contactor of starter will close and Auxiliary will change its position NO become NC and NC become NO

### Pushing Start Button:

When We Push the start Button Relay Coil will get the second phase from Supply Phase-Main contactor(5)-Auxiliary Contact(53)-Start button-Stop button-96-95-To Relay Coil (A2). Now coil energizes and magnetic field produce by Magnet and Plunger of Contactor move. The main Contactor closes and the motor gets supply at the same time Auxiliary contact becomes (53-54) from NO to NC.

### Release Start Button:

Relay coil gets supply even though we release the Start button. When we release Start Push Button Relay Coil gets Supply phase from Main contactor (5)-Auxiliary contactor (53) – Auxiliary contactor (54)-Stop Button-96-95-Relay coil (shown Red / Blue Lines in Diagram). In overload condition of motor will be stopped by the intermission of control circuit at point 96-95.

### Pushing Stop Button:

When we push the Stop Button Control circuit of the Starter will be a break at the stop button and the Supply of the Relay coil is broken, Plunger moves and close contact of Main Contactor becomes Open, Supply of the Motor is disconnected.

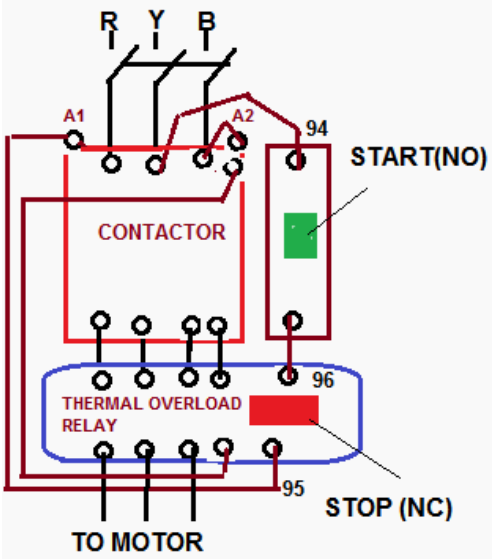


Fig: DOL - Wiring scheme

## Motor Starting Characteristics on DOL Starter:

- Available starting current: 100%.
- Peak starting current: 6 to 8 Full Load Current.
- Peak starting torque: 100%

## Advantages of DOL Starter:

1. Most Economical and Cheapest Starter
2. Simple to establish, operate and maintain
3. Simple Control Circuitry
4. Easy to understand and troubleshoot.
5. It provides 100% torque at the time of starting.
6. Only one set of cable is required from starter to motor.
7. The motor is connected in the delta at motor terminals.

## Disadvantages of DOL Starter:

1. It does not reduce the starting current of the motor.
2. **High Starting Current:** Very High Starting Current (Typically 6 to 8 times the FLC of the motor).
3. **Mechanically Harsh:** Thermal Stress on the motor, thereby reducing its life.
4. **Voltage Dip:** There is a big voltage dip in the electrical installation because of high in-rush current affecting other customers connected to the same lines and therefore not suitable for higher size squirrel cage motors.
5. **High starting Torque:** Unnecessary high starting torque, even when not required by the load, thereby increased mechanical stress on the mechanical systems such as rotor shaft, bearings, gearbox, coupling, chain drive, connected equipment, etc. leading to premature failure and plant downtimes**.**

## Features of DOL starting:

- For low- and medium-power three-phase motors
- Three connection lines (circuit layout: star or delta)
- High starting torque
- Very high mechanical load
- High current peaks
- Voltage dips
- Simple switching devices

### Direct on Line Motor Starter (DOL) is suitable for:

- A direct on line starter can be used if the high inrush current of the motor does not cause an excessive voltage drop in the supply circuit. The maximum size of a motor allowed on a direct online starter may be limited by the supply utility for this reason. For example, a utility may require rural customers to use reduced-voltage starters for motors larger than 10 kW.
- DOL starting is sometimes used to start small water pumps, compressors, fans and conveyor belts.

### Direct on Line Motor Starter (DOL) is NOT suitable for:

- The peak starting current would result in a serious voltage drop on the supply system
- The equipment being driven cannot tolerate the effects of very high peak torque loadings
- The safety or comfort of those using the equipment may be compromised by sudden starting as, for example, with escalators and lifts.

## Wiring diagram followed in the video: