Control elements, accessories - layout of control cabinet

Objectives: At the end of this lesson you shall be able to
- **explain the layout marking methods and necessity**
- **state the methods of marking, cutting, drilling, fixing of accessories and components**
- **explain the methods of mounting and wiring the accessories**
- **state the various control elements used for control panel board**
- **list the different wiring accessories used in control panel wiring.**

Introduction

Preperation of layout drawing and marking on control cabinet is very much essential, we must have a clear vision of mounting components and their location on panel board/ control cabinet.

There is no such important method inpratice to make the layout on control cabinet. However a neat layout on control cabinet is very much required.

The display and indicating instruments should be selected on the top position of the cabinet. Heavy and rare operated devices such as fuse breaker etc; are to be fixed on the bottom of the cabinet.

The components and fixtures should have sufficient space in between to carryout future repair (or) replace requirements. But too much space should not be provided, that will increase the size of the cabinet unnecessarily. While finalising the layout plan the relevent IE rulers to be followed for better result.

Layout marking

Wiring diagrams for power and control circuit should be developed for sequence of operation of automatic star - delta starter with forward and reverse. Types of protection, control, indication and measuring accessories needed should be finalized.

To wire up the above starter in a control panel the well designed and easily understandable layout should be finalized. Layout of the finalized wiring diagram should developed keeping important features of the control panel in mind. While designing the control panel the outside dimensions, the swing area of cabinet doors and area required for maintenance and tools kit have to be considered.

Control panel may be often used near the process area with high temperature, humidity and dust hence the arrangement for cooling fan and dehumidifier along with filters and intake and exhaust vents should be needed.

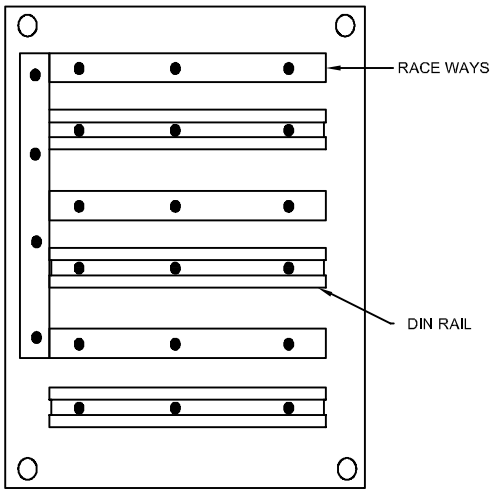
Suitable size of control panel which can accommodate all the controlling, protective, measuring, indicating and wiring accessories required for said wiring should be obtained or fabricated.

While selecting the control and protective accessories of the control panel the full load current of the individual load, total load and duty cycle, simultaneous operation of the load and 25% additional load capacity of the motors have to be considered.

The over load and short circuit protection may be given either ahead of the control panel by calculating the highest rating of the branch circuit or individual motors depends on space available, cost factor and sensitiveness of the operation.

The finalized layout may vary depends the individual design and mind application. However a sample layout marking for the above starter is given in the Fig 1.

Fig 1



TYPICAL LAYOUT MARKINGS

Once the panel layout is designed we must find out where and how to fit the accessories.

The finalized layout of accessories can be marked in the control panel using suitable marking device.

Cutting and drilling

The mounting or fixing holes along with necessary tap or die in suitable size (if any) can be prepared in the front door and inside of the control panel as in Fig 2.

Fig 2

CONTROL PANEL WITH RACEWAYS/DIN RAILS

ELN4217512

Fig 3

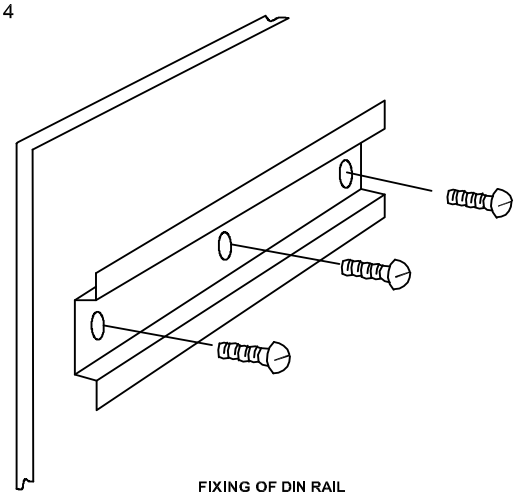
CONTROL PANEL WITH MOUNTING AND FIXING HOLES

ELN4217513

Din rail is a metal rail made from cold rolled carbon steel sheet with zinc plated or chromate bright surface finish used to mount the circuit breakers and control accessories without using screws as in Fig 2. DIN rail being fixed to the chassis before fitted the contactors and other accessories as in Fig 3.

The standard specification of widely available DIN rail is top hat rail EN 50022 which dimension is 35 mm width and a 15 mm or 7.5 mm depth. They can be cut in to the required length and then screwed or bolted inside the panel before mounting any accessories and wiring begins as in Fig 4.

Fig 4



FIXING OF DIN RAIL

ELN4217514

Race way is one form of cable ducting used to carry the wiring between components and keeping the wires neat. The leads wires and cables are laid inside the raceways brought out through the holes / slots in the sides and can be inspected by removing the cover of the raceways.

The minimum spacing between components and raceways should be 100 mm for 415V systems and 50 to 75 mm for less than 415V system. The next stage is to clip the accessories to the rail and wire them.

Mounting and wiring the accessories in control panel

The accessories can be mounted on the DIN rails allowing sufficient space for easy maintenance, wiring and troubleshooting. The mounting should not move or lean in the DIN rail due to vibration or strain due to cables.

Contactor can be either flush mounted to the chassis or DIN rail - mounted . Contactor mounting type over load relay which have three pin connectors engage into the contactor terminals may be used to reduce the mounting and wiring time and labour.

To mount the contactor on rail first place the back top groove on the top of rail and turn it downwards against the lower rail which will cause the spring of the contactor to retract and snap into place behind the rail. There is a slot in the spring clip of the contactor so that the clip can be retracted using small screw driver or connector to remove the contactor if required. To avoid fouling the underneath of the accessories use screws with low profile heads.

The contactor arrangements and terminals are usually labeled which conforms to BS 5583. For example 1 and 2 for NC contacts, 3 and 4 for NO contacts, odd numbers like 1, 3 and 5 for incoming terminals and even numbers like 2, 4 and 6 for outgoing terminals of the main contacts of contactors and OLR.

The conductor should be trimmed OFF to that the conductor does not insert more than the half way through the connectors. Single strand wire should be folded back to give additional thickness. The over tightening of screw have to be avoided otherwise this can crush the strand and give a weak connection.

All the internal wiring should be terminated in the top and external wiring in the bottom of the connectors to avoid the crossover of both wirings. Flexible conduit and cables have to be installed in such a way that the liquid or water if any can drain away from the fitting and grommets.

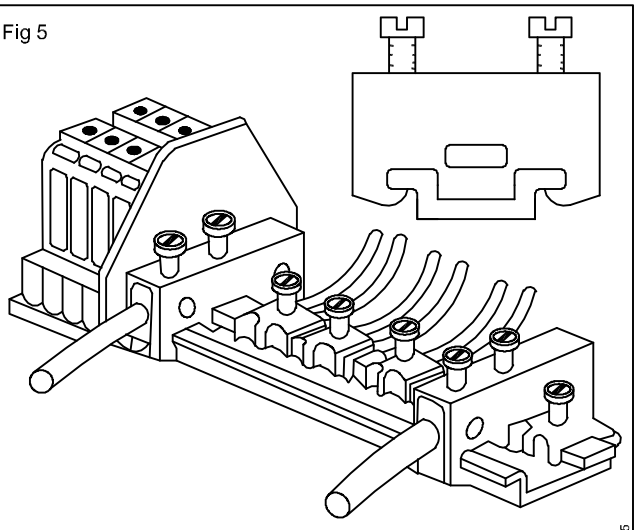
An earth terminal usually green or green yellow to be clamped to the rail and ensure the cabinet and door are earthed properly.

An insulated separator can be used to isolate the high voltage connections from others. End stops are used to clamps the connectors together and close the open

terminals on one end, sometimes the earth terminal will do the same job as in Fig 5.

The control panel should be grounded properly so that control panel should have proper earthing bolts / nuts. If more ground points are used a common earth plate should be fixed inside the cabinet as in Fig 5.

Fig 5



TERMINAL CONNECTORS / EARTH TERMINAL WITH SEPERATOR

ELN4217515

U loops of the cables as long as possible facing down and anchored on each side of the hinged doors and panel with screws or bolts and do not use adhesive. Place the sleeve and spiral flexible conduits of suitable size over the cables running between the hinged doors and panel as in Fig 6.

Fig 6

U LOOP OF CABLES

ELN4217516

The care to be given to the bundle of wires which is mounted on the hinged doors should not restrict the opening and closing of the door or the doors should not damage the wires.

Minimize the use of cable ties if the raceways are used. They may be cut OFF during troubleshooting and rarely replaced.

Routing and bunching

Routing

Conductors and cables should run from terminal to terminal without any intervening joins and cross over. Extra length should be left at connector / terminals where assembly needs to be disconnected for maintenance and servicing. Multi core cable terminations have to be adequately supported to avoid undue strain on the terminals.

Different colour may be used to aid identification of group of controls and functions.

The associated earth and neutral conductor should be routed close to the respective live conductors to avoid undue loop resistance.

Select the race ways to leave some slacks or looping of the cable inside it. The wires inside the race way should not more than the half fill.

Bunching and tying

Run the wires in horizontal and vertical lines avoid diagonal runs as possible. Do not run the wire over the other devices or race ways. Uses of spring cage terminals instead of standard screw terminals can reduce the termination error, the wiring and maintenance time which in turn reduce the cost and labour.

To connect the accessories, cut the individual control wires to the proper lengths, strips the insulation, mark wire identification, insert ferrules at the ends of wires, use suitable lugs or thimbles.

The wires should be neatly bundled, run in the race ways and routed with smooth radius bends.

All the terminals, wires and components should have identification marks and labels. A good labelling and identification will reduce the errors in termination, testing, maintenance and repairs. A legible and durable label in an efficient and cost effective manner may be chosen.

To the possible extent the power and control wiring should be run in separate race way or cable management which will reduce the radio interference, trouble shooting time and make the future alteration if any is easier.

By taking some extra cares like pest control, dust control, adequate terminal pressure, selection of proper wires and accessories, it can be ensured that the control panel has no failure time and with moderate maintenance it will be trouble free panel for entire life.

Where the multiple earths are used it is necessary to use a common earth terminal or connectors as in Fig 5.

Tests

Before energizing the control panel all necessary tests should be carried out like open, short, earth continuity and earth soundness etc. The supply voltage and frequency are also to be checked.

Control elements

Difference between control panel and switch board

A panel board contains a single panel or a group of panel units as single panel that includes bus-bars, protective devices and control switches, instruments and more starters etc.

In a panel board, the interior are designed to place the accessories and wires in a cabinet or cut out box or partition and accessible only from the front.

A switch board consists of a large single panel or frame or assembly of switch gears, with or without instruments, but the term switch board does not apply to a group of local switches in the final circuit. Unlike panel boards, switch boards are generally accessible from the rear as well as from the front and are not intended to be installed in cabinets. However the terms, panel board and switch board, are used normally without much discrimination.

For wiring of control panel board the following control elements / components and accessories are required.

They are

- Isolating switch
- Push button switch
- Indicating lamp
- MCB (Miniature Circuit Breaker)
- Contactors
- Electro mechanical relays
- Thermal over load relays
- Time delay relay (timers)
- Rectifiers
- Limit switches
- Control transformers etc.

Control elements for control panel

1 Isolating switch (Fig 7)

Isolating switch (Isolator) is a manually operated mechanical switch which isolates/disconnects the circuit which are connected with it from the supply system as and when required. It should be normally operated at "OFF" load condition.

It is available in different current, voltage rating and size.

Fig 7

ISOLATING SWITCH

ELN4217517

2 Push button switch (Fig 8)

Fig 8

PUSH BUTTON SWITCHES

ELN4217518

Push button is a simple push switch mechanism for making or breaking the circuit as and when required. It is made out of hard plastic or metal. An indicating lamp is incorporated with the push button switch to indicate start or stop is also available.

3 Indicating lamp (Fig 9)

Fig 9

INDICATING LAMP WITH HOLDER

ELN4217519

It is a low voltage, low wattage filament or neon or LED lamps used to indicate the various indication like availability of supply or motor **ON/OFF,** mains/motors fails or trip etc.

It is available in different size, colour and wattage. It should be generally fitted in the front side of the control panel with suitable holder.

4 MCB (Fig 10)

Fig 10

MINIATURE CIRCUIT BREAKER

ELN421751A

Miniature circuit breaker (MCB) is an electro mechanical protective device which protect an electrical circuit from short circuit and over load . It automatically turns off, when the current flowing through it exceeds the maximum allowable limit.

5 Fuses

It is a protective device which is connected is series with the live wire to protect the circuit from short circuit and earth fault.

6 Contactors (Fig 11)

Fig 11

MINIATURE CIRCUIT BREAKER

ELN421751B

A contactor is an electrically controlled double break switch used for switching ON / switching OFF the electrical circuit, similar to a relay with higher current ratings. It is controlled by a circuit which has a much lower power level than the switched circuit.

7 Electro mechanical relays (Fig 12)

Fig 12

ELECTRO MECHANICAL RELAY

ELN421751C

Electromechanical relays are electrically operated switches used to control a high powered circuit accessories using low power signal. When an electric current passes through its coil it produces a magnetic field that activates the armature to make or break a connection.

current passes through its coil it produces a magnetic field that activates the armature to make or break a connection.

8 Thermal overload relays (Fig 13)

Fig 13

THERMAL OVERLOADED RELAYS

ELN421751D

It is a thermally operated electromechanical device that protects motors from over heating and loading.

9 Time delay relay (timers) (Fig 14)

Fig 14

TIMER

ELN421751E

Time delay relays are simply the control relays in - built with a time delay mechanism to control the circuit based an time delay.

In time delay relays its contact will open or close after the pre-determined time delay either on energising or on de-energising its no volt coil. It can be classified into two types as ON delay timer and OFF delay timer.

10 Rectifiers (Fig 15)

Fig 15

RECTIFIER

ELN421751F

A rectifier is a static device consists of one or more diodes that converts alternating current (AC) to direct current (DC). A diode is like a one -way valve that allows an electrical current to flow in only one direction.

11 Limit switches (Fig 16)

Fig 16

LIMIT SWITCHES

ELN421751G

Limit switch is a switch with an actuator which is operated by the motion of a machine part or an object.

When an object or parts comes into contact with actuator, it operates the contacts of the switch to make or break an electrical connection. They are used to control the distance or angles of movement of any machine parts or axis or objects.

12 Control transformer

It is a transformer which is used to supply the power to the control or auxiliary circuit or equipment which does not intend for direct connection to the main supply.

13 Panel meter (voltmeter and ammeter)

They are the measuring instruments used to measure the various electrical parameter of the circuits such as voltage and current etc.

Wiring accessories for control panel wiring

1 PVC channel / Race ways (Fig 17)

Fig 17

PVC CHANNEL

ELN421751H

It is an inspection type PVC enclosed channel which provides a pathway for electrical wiring inside the control panel. It has the opening slots on both sides to facilitate the good ventilation and visual inspection.

It protects the wires from dust, humidity, corrosion, water intrusion, heat, mechanical damage and physical threats.

2 DIN rail (Fig 18)

Fig 18

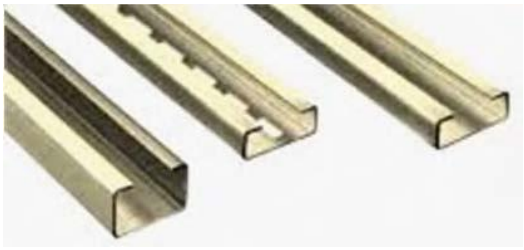
DIN RAILS

ELN421751I

It is a zinc - plated or chromated metal rail which is used for mounting the control accessories like MCB, contactors and OLR etc, with out using screws inside the control panel.

3 G Channel (Fig 19)

Fig 19



'G' CHANNEL

ELN421751J

It is a zinc - coated metal channel which is especially used for mounting the feed through or spring load or double deck terminal connectors without using screw inside the control panel.

4 Terminal connectors (Fig 20)

Fig 20

TERMINAL CONNECTORS

ELN421751K

It is the set of insulated screw terminals at both sides used to connect the accessories of the control panel with external control switches, limit switches, input supply and motor terminals etc.

Terminal connectors with barrier strips and clamping plates provide a tight and electrically sound termination. It is available in various size, current and voltage ratings.

5 Wire ferrules (Fig 21)

Fig 21

WIRE FERRULES

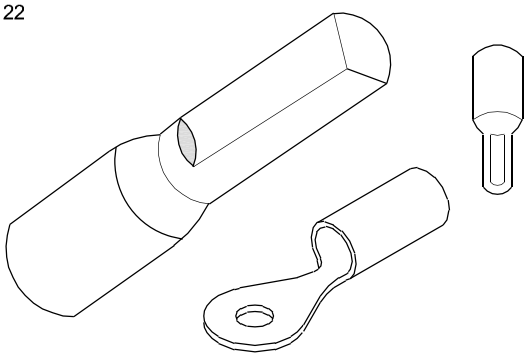
ELN421751L

It is a small circular ring made up of polymer plastics or rubber or fibre, used to easily identify the ends of wires which are to be connected into a particular terminals or accessories. It should be inserted on the both ends of a wire as collar or bracelet.

It is available is different size like 1 sq.mm, 1.5 sq.mm and 2.5 sq.mm etc generally in yellow colour printed with either numerical or alphabet letters on it.

6 Lugs and thimbles (Fig 22)

Fig 22



LUGS AND THIMBLES

ELN421751M

It is a cylindrical barrel along with circular rings or cylindrical rod or U shape or flat surface made up of aluminum or copper or brass, used to ensure the sound electric connection of the cable / wire on to the terminals. It prevent flare out of stripped and stranded cable, increase the conductivity of the connection, support the cable / wire and avoid the loose connection and sparking. Suitable crimping tool has to be used to connects them with cables / wires. It is available in different size like 1 sq.mm, 4 sq.mm, 25 sq.mm, 70 sq.mm, 125 sq.mm and so on.

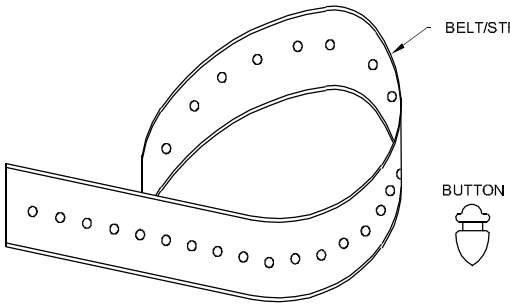
- Thimbles may also be referred as sockets.

7 Cable binding straps and button (Fig 23)

It is made up of PVC or polymer belt with a small holes at regular intervals, used to tie up, bunching, binding and dressing the cable / wires with help of buttons.

It is reusable and good insulator to the heat and electricity. It is generally available 8mm, 10 mm and 12 mm width.

Fig 23

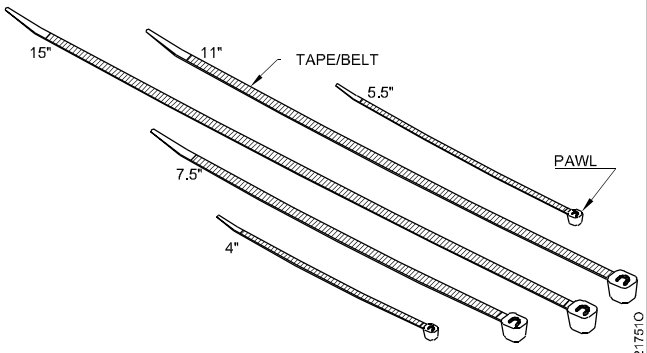


CABLE BINDING STRAPS AND BUTTON

ELN421751N

8 Nylon cable ties (Fig 24)

Fig 24



NYLON CABLE TIES

ELN421751O

- It is a type of fastener used to hold or tie or bunch the wires / cable or group of cables.
- It is made of nylon tape or belt which has teeth that will engage with head of the pawl to form a ratchet and tightens the wires.
- In general the tie can not be loosened, or removed or reused. However some reusable ties are also available.
- it is available in different colour, length and width.
- Because of its low cost and easy to use, it is widely used in general purpose application also.

9 Sleeves (Fig 25)

Fig 25

WIRE SLEEVES

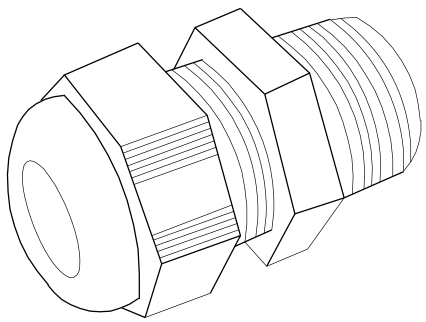
ELN421751P

- It is flexible tubular / cylindrical insulator into which the electric wire or cable or group of cables can be inserted.

- Apart from the electrical insulation and easy identification of wires, it also protect the wires from abrasion, heat, chemical, physical damage and radio interference.
- It is available is different colour, style, materials like carbon fibre, fabrics, Teflon, fibre glass, nylon, poly ethylene (PET) wrap, braided metal and heat shrink sleeves.

10 Grommets (Fig 26)

Fig 26



GROMMETS

ELN421751Q

It is a type of bushing which is used to insulate and hold the cables when they pass through a punched / drilled holes of panels or enclosures. It is generally made of rubber, plastic, plastic coated metal and protect the cable from twist, tug, cut, break, strain, vibration etc and prevent the entry of dirt, dust, water, insects and rats into the panel. It may also called as glands.

11 Wire clips (Fig 27)

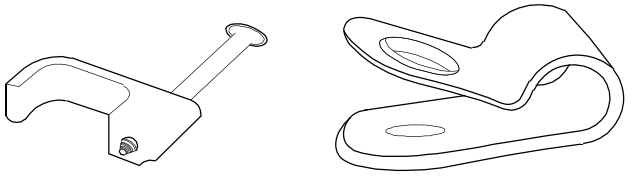
It is a type of fixing or fastening device which is used to fix and hold the cables or punch of cables in a secure manner.

Rotary type switches (Fig 28)

Rotary switches are most commonly used in lathes, milling and drilling machines due to their exact visual position and easiness in operation. These switches are operated by levers or knobs which in turn operate cams inside the switch to contact various terminals in sequence by the internal contact blocks. These cams and blocks are made of hard P.V.C. and are designed to withstand many operations. It is possible to get many circuit combinations by combining various cams and contact blocks. As the contact blocks, terminals and cams are spring-loaded, these switches should not be opened by inexperienced persons for repairs. Fig 28 shows 250V AC 15 Amps 2-pole three position flush mounting coin-slot operator.

Function: This switches can do a number of functions, depending upon the cover and contact block combinations. According they can be used for ON/ OFF switch, manual Forward / Reverse operation, Manual star delta switches, Pole changing switches, Selection switch for meaning instrument etc..

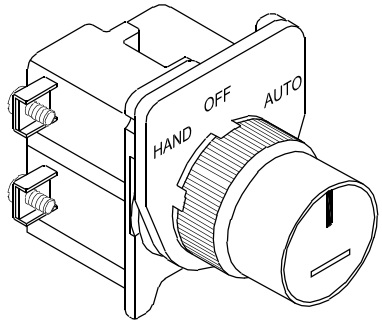
Fig 27



WIRE CLIPS

ELN421751R

Fig 28



ROTARY SWITCH

ELN421751S

Power and control circuits for three phase motors

Objectives: At the end of this lesson you shall be able to

- **state the necessity of starters for a 3-phase induction motor to start and name the types of starters**
- **explain the basic contactor circuit with a single push-button station for start and stop**
- **state the function of DOL starter, semi and fully automatic start - delta strater**
- **explain the function of jogging inching forward and reverse control circuit**
- **explain the remote station control circuit**
- **explain the sequential control of motors.**

Necessity of starter: A squirrel cage induction motor just before starting is similar to a polyphase transformer with a short-circuited secondary. If normal voltage is applied to the stationary motor, then, as in the case of a transformer, a very large initial current, to the tune of 5 to 6 times the normal current, will be drawn by the motor from the mains. This initial excessive current is objectionable, because it will produce large line voltage drop, which in turn will affect the operation of other electrical equipment and lights connected to the same line.

The initial rush of current is controlled by applying a reduced voltage to the stator winding during the starting period, and then the full normal voltage is applied when the

motor has run up to speed. For motors, up to 3 Hp, full normal voltage can be applied for starting. However, to start and stop the motor, and to protect the motor from overload currents and low voltages, a starter is required in the motor circuit. In addition to this, the starter may also reduce the applied voltage to the motor at the time of starting.

Types of starters: Following are the different types of starters used for starting squirrel cage induction motors.

- Direct on-line starter
- Star-delta starter - semi and fully automatic
- Step-down transformer starter
- Auto-transformer starter.

In the above starters, except for the direct on-line starter, reduced voltage is applied to the stator winding of the squirrel cage induction motor at the time of starting, and regular voltage is applied once the motor picks up the rated speed.

Selection of starter: Many factors must be considered when selecting starting equipment. These factors include starting current, the full load current, voltage rating of motor, voltage (line) drop, cycle of operation, type of load, motor protection and safety of the operator.

Contactors: The contactor forms the main part in all the starters. A contactor is defined as a switching device capable of making, carrying and breaking a load circuit at a frequency of 50 cycles per second or more. It may be operated by hand (mechanical), electromagnetic, pneumatic or electro-pneumatic relays.

The contactors shown in Fig 1 consist of main contacts, auxiliary contacts and no-volt coil. As per Fig 1, there are three sets of normally open, main contacts between terminals 1 and 2, 3 and 4, 5 and 6, two sets of normally open auxiliary contacts between terminals 23 and 24, 13 and 14, and one set of normally closed auxiliary contact between terminals 21 and 22.

Auxiliary contacts carry less current than main contacts. Normally contactors will not have the push-button stations and O.L. relay as an integrated part, but will have to be used as separate accessories along with the contactor to form the starter function. The main parts of a magnetic contactor are in Fig 1, and Fig 2 shows the schematic diagram of the contactor when used along with fused switches (ICTP), push-button stations and OL relay for connecting a squirrel cage motor for starting directly from the main supply. In the same way the direct on-line starter consists of a contactor, OL relay and push-button station in an enclosure.

Functional description

Power circuit: As in Fig 2, when the main ICTP switch is closed and the contactor K_1 is operated, all the three windings U V & W of the motor are connected to the supply terminals R Y B via the ICTP switch, contactor and OL relay.

Fig 1

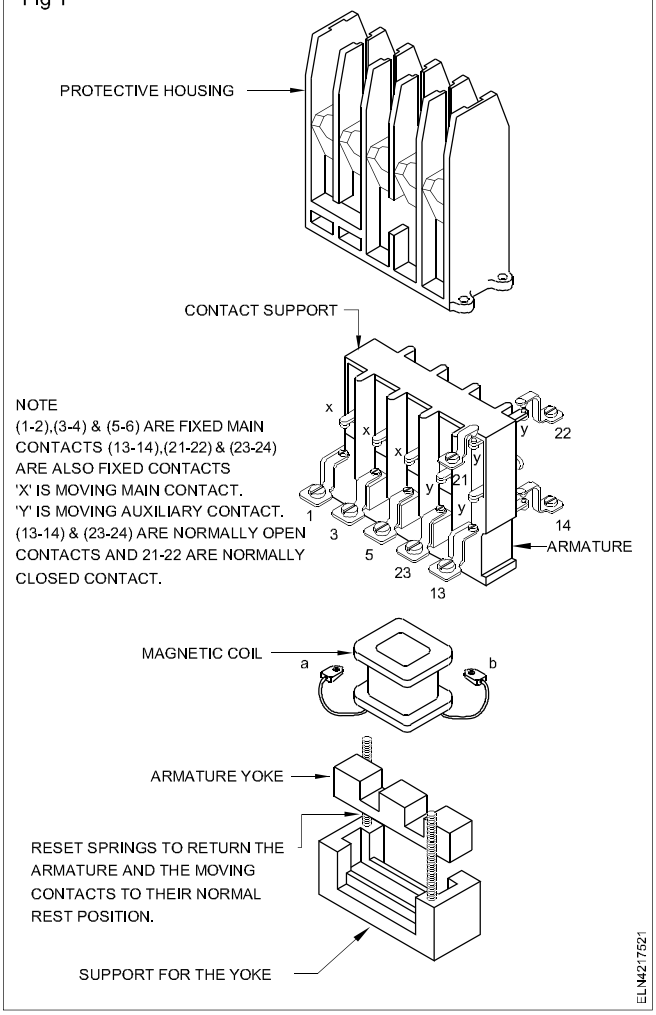
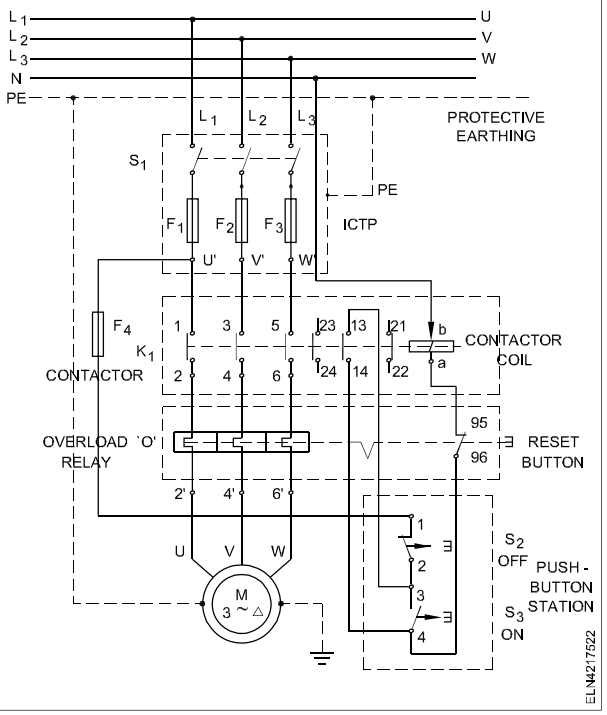


Fig 2

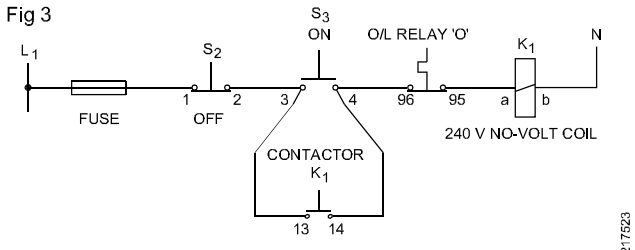


The overload current relay (bimetallic relay) protects the motor from overload (`motor protection'), while the fuses F1/F2/F3 protect the motor circuit in the event of phase-to-phase or phase-to-frame short circuits.

Control circuits

Push-button actuation from one operating location: As shown in the complete circuit Fig 2, and the control circuit Fig 3, when the `ON' push-button S_3 is pressed, the control circuit closes, the contactor coil is energised and the contactor K_1 closes. An auxiliary, a normally open contact 13,14 is also actuated together with the main contacts of K_1. If this normally open contact is connected in parallel with S_3, it is called a self-holding auxiliary contact.

Fig 3



CONTROL CIRCUIT

After S_3 is released, the current flows via this self-holding contact 13,14, and the contactor remains closed. In order to open the contactor, S_2 must be actuated. If S_3 and S_2 are actuated simultaneously, the contactor is unaffected.

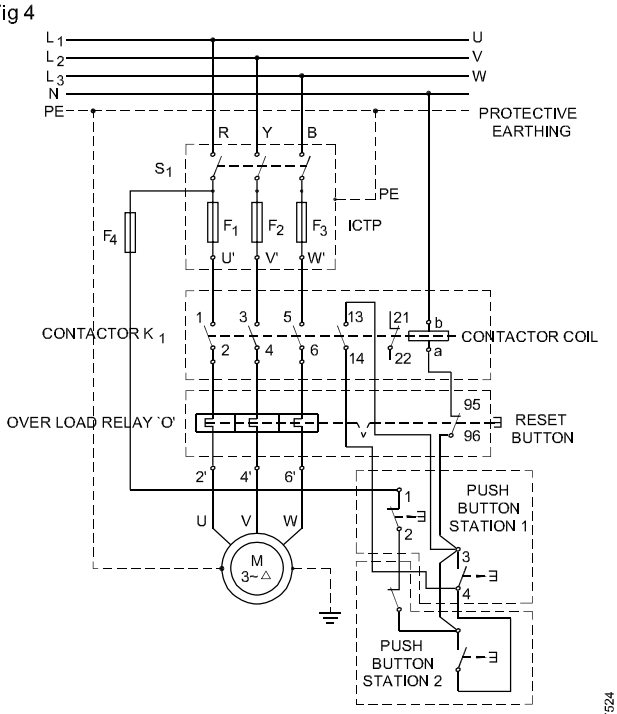
In the event of overloads in the power circuit, the normally closed contact 95 and 96 of overload relay `O' opens, and switches off the control circuit. Thereby $K_1$ switches `OFF' the motor circuit.

Once the contact between 95 and 96, is opened due to the activation of the overload relay `O', the contacts stay open and the motor cannot be started again by pushing the `ON' button S_3. It has to be reset to normally closed position by pushing the reset button. In certain starters, the reset could be done by pushing the `OFF' button which is in line with the overload relay `O'.

Push-button actuation from two operating locations (remote control): If it is desired to switch a contactor OFF and ON from either of the two locations, the corresponding OFF push-buttons should be connected in series, and the ON push-buttons in parallel, as in the complete diagram Fig 4 and the control diagram Fig 5.

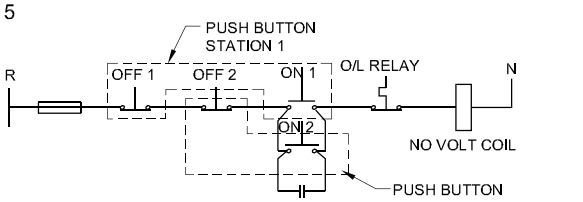
If either of the two ON push-buttons is actuated, K_1 is energised and holds itself closed with the help of normally-open contact 13 & 14 which is closed by contactor K_1. If either of the two OFF push -buttons is actuated, the contactor opens.

Fig 4



COMPLETE CIRCUIT DIAGRAM OF THE CONTACTOR AND THE 3 PHASE SQUIRREL CAGE INDUCTION MOTOR

Fig 5



Tripping of starters: A starter may trip due to the following reasons.

- Low voltage or failure of power supply
- Persistent overload on the motor

No-volt coil: A no-volt coil consists of generally more number of turns of thin gauge of wire.

Coil voltages: Selection of coils depends on the actual supply voltage available. A wide variety of coil voltages like 24V, 40V, 110V, 220 V 230/250 V, 380V 400/440V AC or DC are available as standard for contactors and starters.

Troubleshooting in contactor: Table 1 gives the common symptoms their causes and remedies.

Table 1

Symptoms	Causes	Remedies
Motor does not start when the 'start' button is pressed. However on pressing the armature of the contactor manually, motor starts and runs.	Open in no-volt coil circuit.	Check the main voltage for lower than acceptable value. Rectify the main voltage. Check the control circuit wiring for loose connection. Check the resistance of the no-volt coil winding. If found incorrect replace the coil.
Motor starts when `ON' button is pressed. It however stops immediately when `ON' button is released.	Auxiliary contact in parallel with the start-button is not closing.	Check the parallel connection from `ON' button terminals to the auxiliary contact of the contactor. Rectify the defect.
		Check the auxiliary contact points of the contactor for erosion and pittings. Replace, if found defective.
Motor does start when the start-button is pressed. However, a humming or chattering noise comes from the starter.	Movable armature and fixed limb of electromagnet are not stably attracted.	Dust or dirt or grit between the mating surfaces of the electromagnetic core. Clean them. Low voltage supply. Find the cause and rectify the defect. Break in the shading ring in the case of AC magnet.
Failure of contactor due to too much heating of the `No' volt coil.	Higher incoming supply rating. No-volt coil rating is not high.	Higher supply voltage than normal. Reduce the incoming voltage. Voltage rating of the no-volt coil is less. Replace with standard rating, according to the main supply.
Motor does not restart immediately after tripping of OL relay even though OL relay was reset.	It takes a little time for the thermal bimetal to cool and reset.	Wait for 2 to 4 minutes before re-starting.
Coil does not get energised even though supply voltage is found across the no-volt coil terminals.	Open-circuited NVC. NVC burnt out.	Check the nylon strip on relay. Check the nylon button below the start button Replace, if necessary.
Relay coil has been changed. However motor does not start when the start-button is pressed.	Control circuit of relay open.	Check the control circuit for open. Clean the control station contacts. Overload relay not reset.
Humming or chattering noise.	Low voltage. Magnetic face between yoke and armature is not clean. Shading ring on iron core missing.	Feed the rated voltage. Clean the surfaces of yoke and armature. Provide shading ring in the iron core.

D.O.L. starter

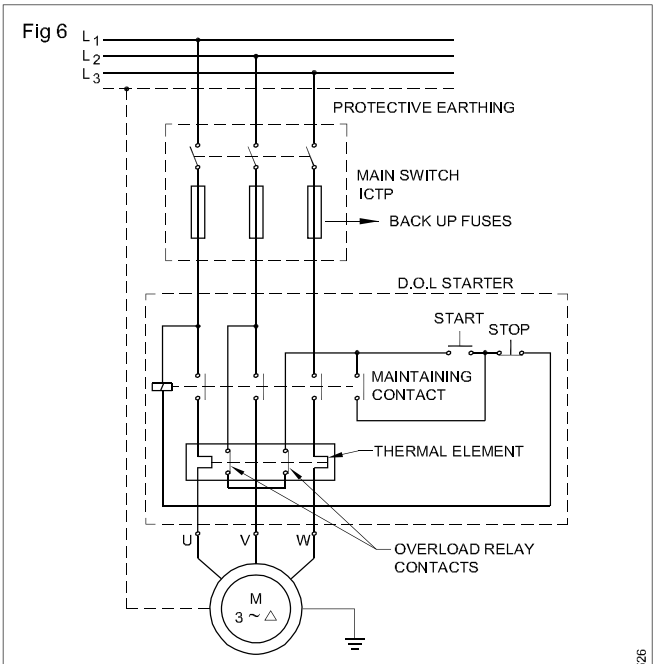
A D.O.L. starter is one in which a contactor with no-volt relay, ON and OFF buttons, and overload relay are incorporated in an enclosure.

Construction and operation: A push-button type, direct on-line starter, which is in common use, is in Fig 6. It is a simple starter which is inexpensive and easy to install and maintain.

There is no difference between the complete contactor circuit explained in Exercise 4.2.175(i) and the D.O.L.starter, except that the D.O.L. starter is enclosed in a metal or PVC case, and in most cases, the no-volt coil is rated for 415V and is to be connected across two phases as in Fig 6. Further the overload relay can be situated between ICTP switch and contactor,or between the contactor and motor as in Fig 6, depending upon the starter design. Trainees are advised to write the working of the D.O.L. starter on their own by going through the

explanation given in Exercise 4.2.175(i) which is for a complete contactor circuit.

Fig 6



WIRING DIAGRAM OF A DIRECT ON-LINE STARTER WITH PROTECTIVE DEVICES

Forward and reversing of 3 phase induction motors

In many machines like large milling machine, it is essential to run the motor in both directions in forward & reverse. In lift also the forward & reverse operation is essential.

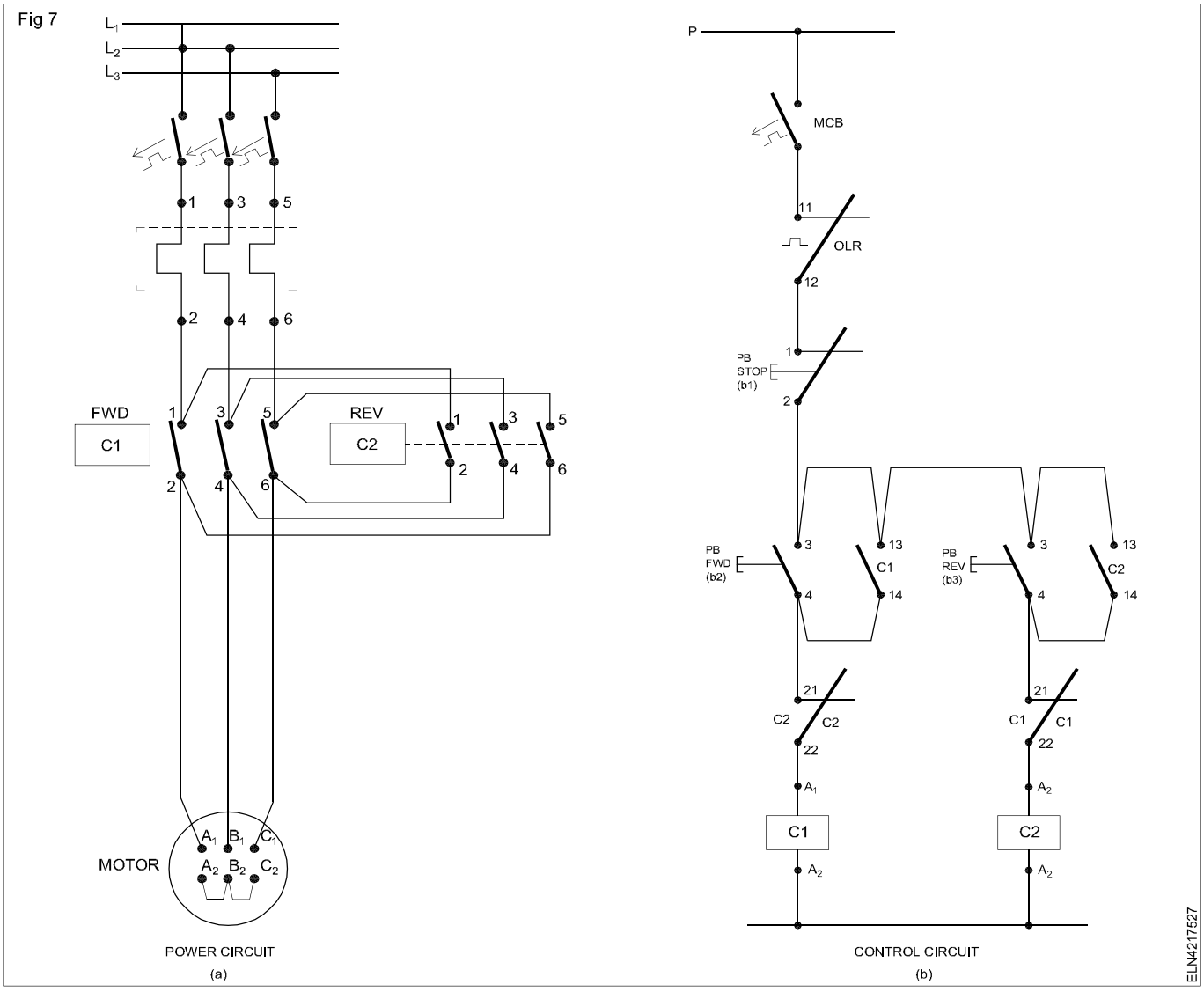
By changing the phase sequence of any two phases the direction of rotation of a 3 phase motor can be changed but it is not practically possible of interchanging any two phases of 3 phase supply when even needed. It consumes time and also damages the equipments.

So it is necessary to have a circuit for forward and reversing of 3 phase induction motors. (Fig 7)

The supply terminal L_1 is connected with motor terminal A_1 in both direction of runing (Fig 7)

Supply terminal L_2 & L_3 are connected with motor terminal B_1 & C_1 in forward direction. While the reverse contact energiser supply terminal L_2 connected with motor terminal C_1 and L_3 terminal connected with B_1 thus the sequence of phase changed the direction of rotation also changed.

Fig 7



The inter locking protection is in corporated by normally closed (NC) contacts of forward and reverse contactors (Fig 7b) By this when forward contactor is working, if reverse push button is wrongly pressed, without any break the motor run in same direction continuously.

The direction only can be changed by switch OFF and press the reverse direction push button.

Table of relay ranges and back-up fuses for motor protection

Sl. No.	Motor ratings 240V 1-phase			Motor ratings 415V 3-phase			Relay range A	Nominal back-up fuse recommended
	hp	kW	Full load current	hp	kW	Full load current	a	c
1				0.05	0.04	0.175	0.15 - 0.5	1A
2	0.05	0.04		0.1	0.075	0.28	0.25 - 0.4	2A
3				0.25	0.19	0.70	0.6 - 1.0	6A
4	0.125	0.11		0.50	0.37	1.2	1.0 - 1.6	6A
5	0.5	0.18	2.0	1.0	0.75	1.8	1.5 - 2.5	6A
6	0.5	0.4	3.6	1.5	1.1	2.6	2.5 - 4.0	10A
7				2.0	1.5	3.5	2.5 - 4.0	15A
8	0.75	0.55		2.5	1.8	4.8	4.0 - 6.5	15A
9				3.0	2.2	5.0	4.0 - 6.5	15A
10	1.0	0.75	7.5	5.0	3.7	7.5	6.0 - 10	20A
11	2.0	1.5	9.5	7.5	5.5	11.0	9.0 - 14.0	25A
12	3.0	2.25	14	10.0	7.5	14	10.0 - 16.0	35A.

Semi-automatic star-delta starter

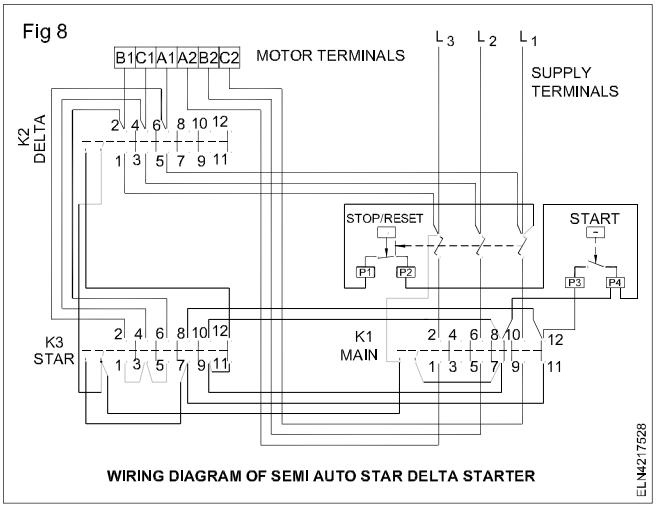
The standard squirrel cage induction motors with both ends of each of the three windings brought out (six terminals) are known as star-delta motors. If the starter used has the required number of properly wired contactors, the motor can be started in star and run in delta.

The proper use of manual star-delta starter demands a special skill in handling the starter. The sluggish operation of the manual lever often causes damage to the moving and fixed contacts in a manual star-delta starter.

The contactors are employed for making and breaking the main line connections. Figure 8 shows the wiring diagram and Fig 9 shows the line diagram of power circuit and the control circuit.

Operation: Refer to the control circuit and power circuit diagrams shown in Fig 9a,9b. When the start button S_2 is pressed the contactor coil K_3 energises through P_4, P_3 and K_1 normally closed contact 12 and 11. When K_3 closes, it opens the normally closed contact K_3 between 11 and 12 and makes contact between 10 and 9 of K_3. The mains contactor K_1 energies through P_4, 10 and 9 of K_3. Once K_1 energises the NO contact of K_1 point 8 and 7 establishes a parallel path to K_3 terminals 10 and 9.

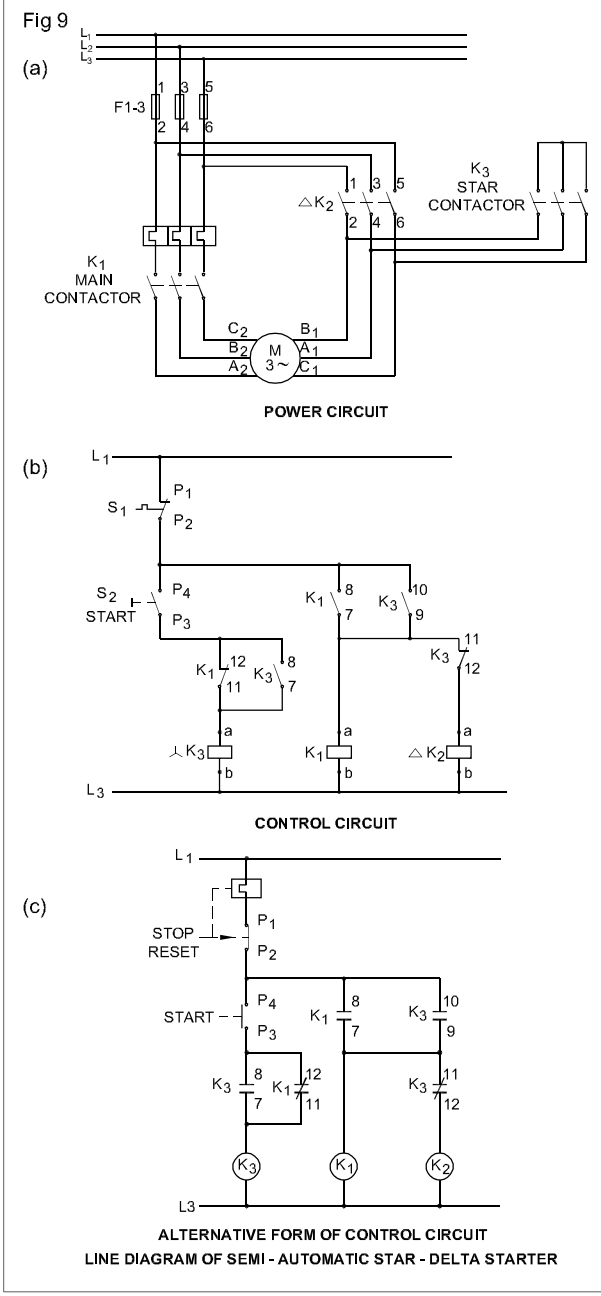
Fig 8



WIRING DIAGRAM OF SEMI AUTO STAR DELTA STARTER

The star contactor K_3 remains energised so long as the start button is kept pressed. Once the start button is released, the K_3 coil gets de-energised. The K_3 contact cannot be operated because of the electrical interlock of K_1 and normally closed contacts between terminals 12 and 11.

Fig 9



When the K_3 contactor get de-energised the normally closed contact of K_3 between terminals 11 and 12 establishes contact in the contactor K_2 - coil circuit. The delta contactor K_2 closes.

The operator has to observe the motor starting and reaching 70% of the synchronous speed for satisfactory starting and running of the induction motor.

Figure 9c shows the alternative form of drawing control circuit.

Automatic star-delta starter

Applications : The primary application of star-delta motors is for driving centrifugal chillers of large central air-conditioning units for loads such as fans, blowers, pumps or centrifuges, and for situations where a reduced starting torque is necessary. A star-delta motor is also used where a reduced starting current is required.

In star-delta motors all the winding are used and there are no limiting devices such as resistors or auto-transformers. Star-delta motors are widely used on loads having high inertia and a long acceleration period.

Overload relay settings : Three overload relays are provided on star-delta starters. These relays are used so that they carry the motor winding current. This means that the relay units must be selected on the basis of the winding current, and not the delta connected full load current. The motor name-plate indicates only the delta connected full load current, divide this value by 1.73 to obtain the winding current. Use this winding current as the basis for selecting and setting the motor winding protection relay.

Operation : Fig 10a, 10b & 10c shows the line diagram of the power circuit and the control circuit and alternative form of control circuit of the automatic star-delta starter. Pressing the start button S-energises the star contactor K_3. (Current flows through K_4 T NC terminals 15 & 16 and K_2 NC terminals 11 & 12). Once K_3 energises the K_3 NO contact closes (terminals 23 & 24) and provide path for the current to close the contactor K_1. The closing of contactor K_1 establishes a parallel path to start button via K_1 NO terminals 23 & 24.

Fig 11 shows the current direction and closing of contacts as explained above.

Fig 11

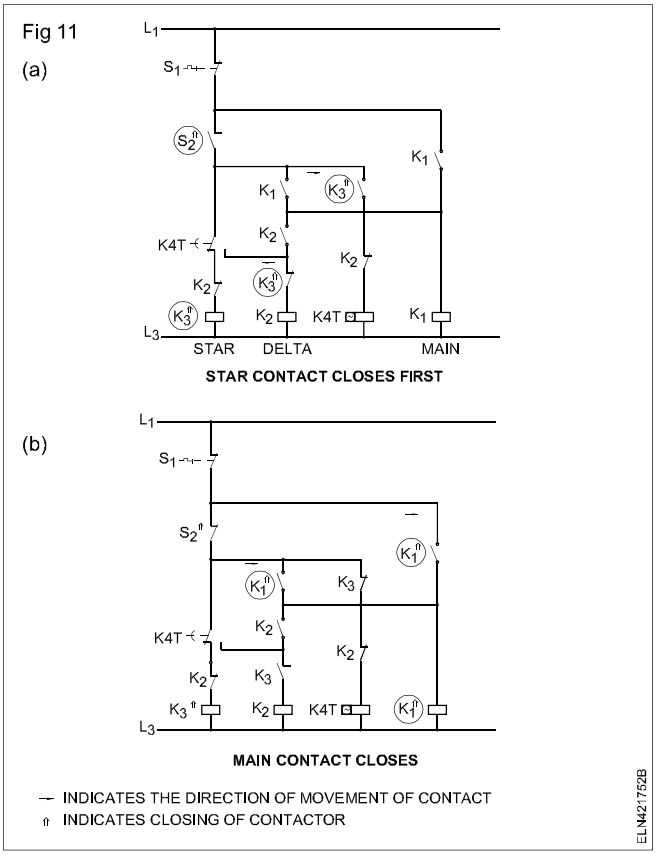
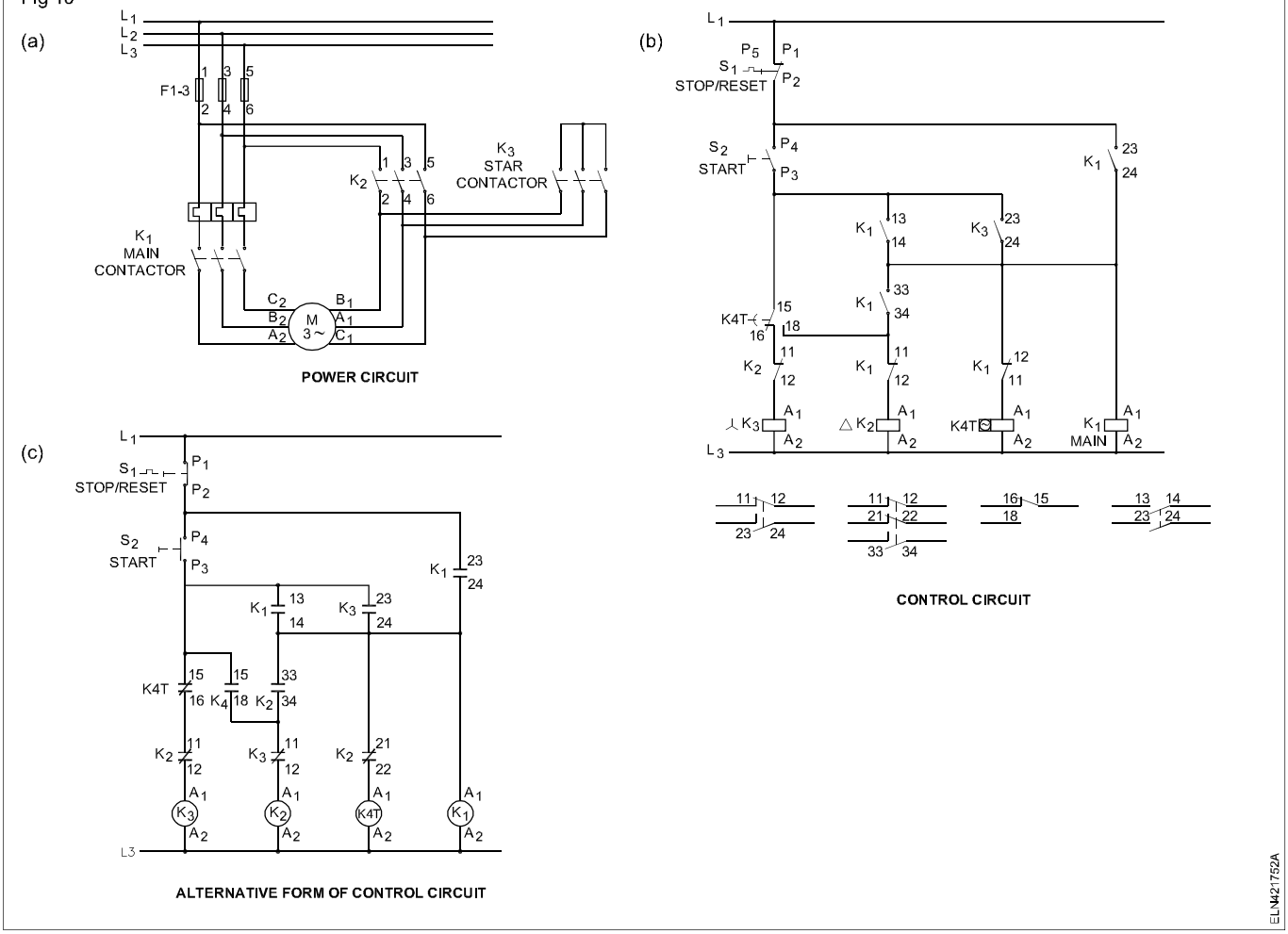


Fig 10



Similarly Fig 12 shows the action taking place after the timer relay operating the contact K_4T.

Fig 12

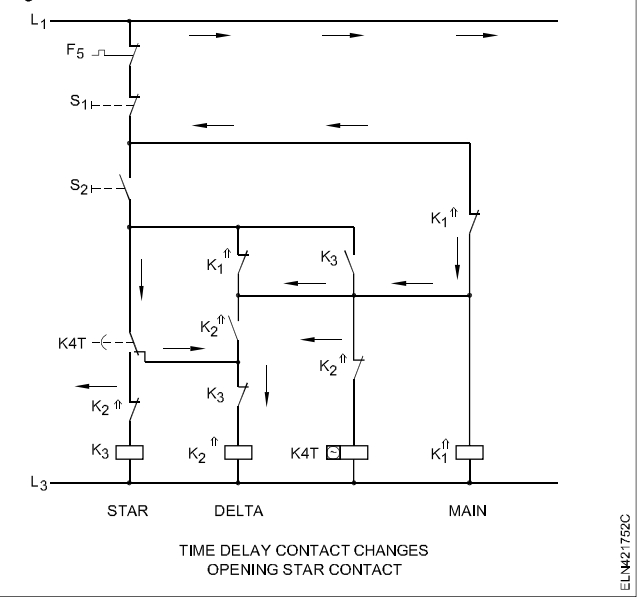
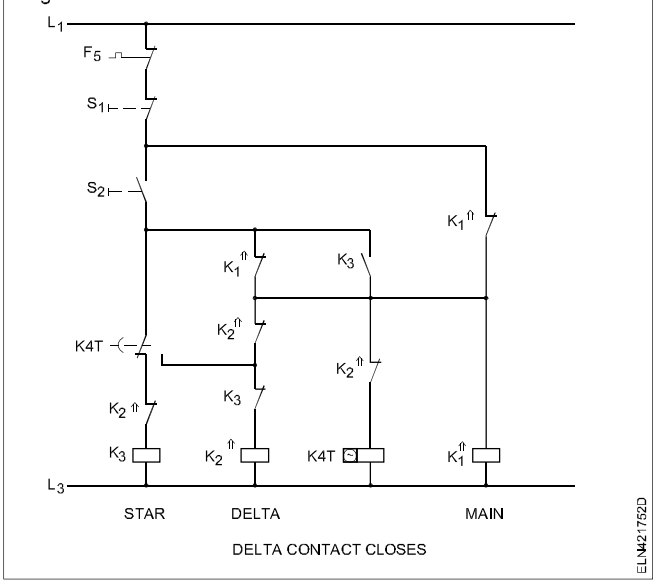


Fig 13 shows the connections established while the motor is running in delta with the contactors K_1 and K_2 closed.

Fig 13



Automatic star - delta starter with forward and reverse control

It is a starter which is used to start the three phase motor in star and after some pre-determined time it automatically runs in delta either in forward or reverse direction depends upon the requirement. Like all other starters it reduces the starting current, protects the motor

from over load and disconnects the motor from supply during power failure.

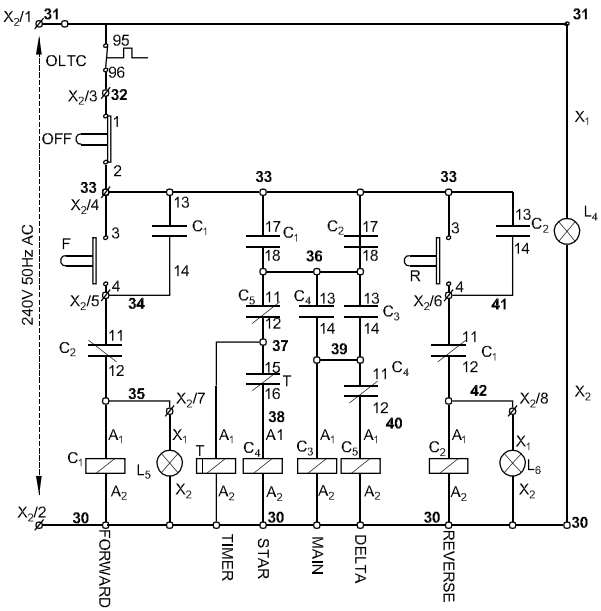
The Fig 14 and 15 shows the power and control circuit of the automatic star-delta starter with forward and reverse operation.

Its main components are, five numbers of power contactors, one ON-delay timer, three numbers of push buttons and one thermal over load relay (OLR). The five power contactors are intended one each for forward direction (C_1), reverse direction (C_2), main contactor (C_3), star contactor (C_4) and delta contactor (C_5).

Six numbers of indicator lamps are also used to indicate the availability of the three supplies, availability control voltage and to indicate whether the motor is running either in forward or reverse direction. These neon indicators lamps are to be mounted in the front door of the control panel along with three push buttons.

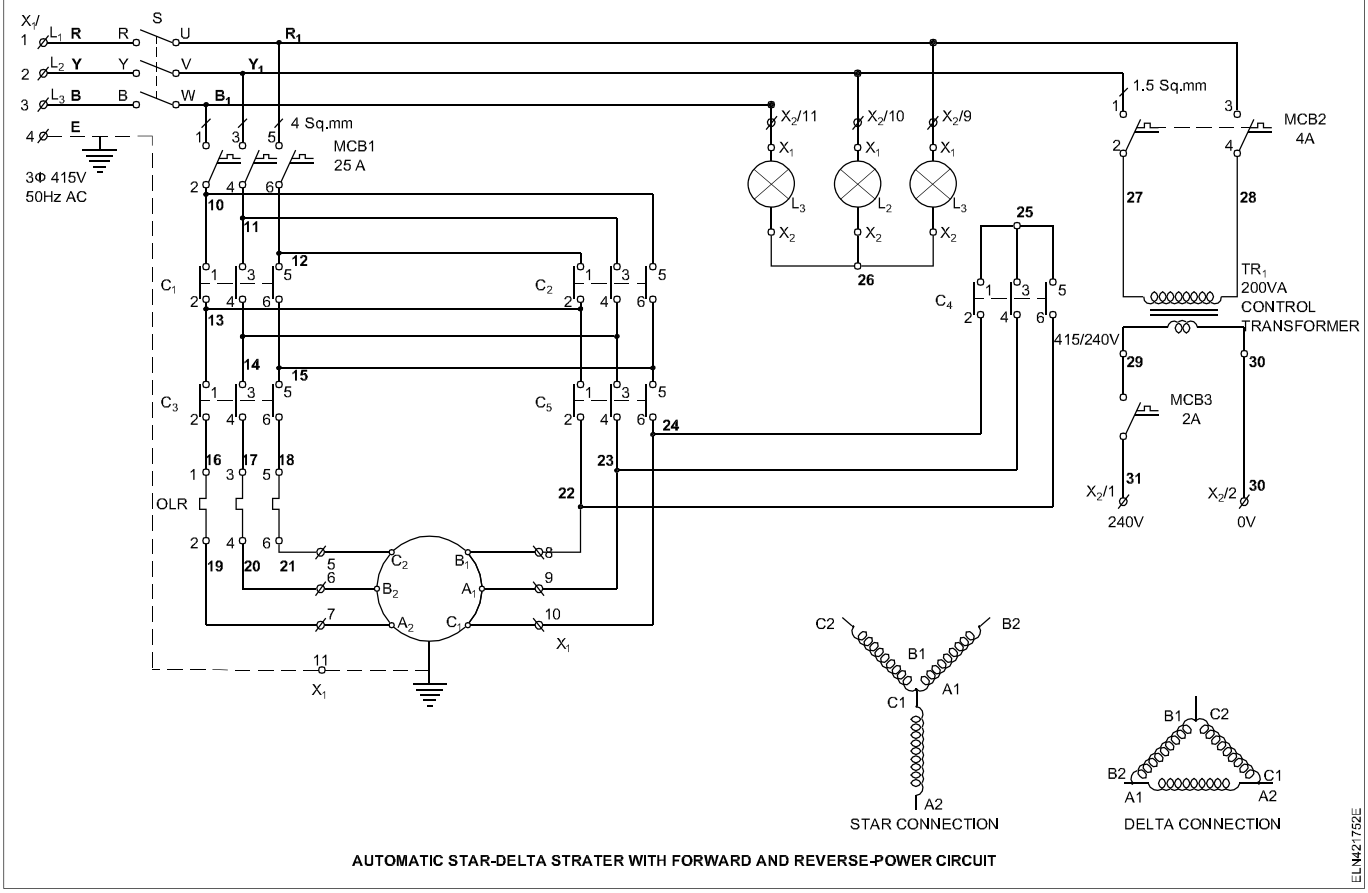
Three push buttons are intended one each for stop push button with one NC (Normally Closed) contact, for forward and for reverse operation with one NO (Normally Opened) contact.

Fig 15



AUTOMATIC STAR-DELTA STARTER WITH FORWARD & REVERSE-CONTROL CIRUIT

Fig 14



AUTOMATIC STAR-DELTA STRATER WITH FORWARD AND REVERSE-POWER CIRCUIT

The choosing of control circuit voltage and power depends on the no volt coil rating of the contactor, whether it needs AC or DC. Here a separate 415/240V, 200 VA control transformer is used for control circuits.

The choice of contactor depends upon the type of supply voltage, load power, load characteristics and duty cycles. The standed duty cycles of the contactors is given below.

For AC loads

AC1 - Resistive load switching example heaters and furnace.

AC2 - Resistive and inductive load starting and stopping example slip ring induction motor.

AC3- High inductive load switching and breaking for continuous running operation.

AC4- High inductive load switching and breaking with frequent and short time operation i.e., intermediate operation like inching and jogging examples cranes, lifts and hoists.

For DC loads

DC1- Resistive loads except motor load

DC2- Starting and stopping of shunt motors.

DC3- Starting and stopping with inching and braking

DC4- Starting and stopping of series motors.

DC5- Starting and stopping of series motor with inching and plugging.

The auxiliary contact can be fitted to the top or to the sides of the contactors depend its design.

Working of starter : When the three phase supply is switched 'ON' by the isolator switch (S) the indicator lamps (L_1, L_2 and L_3) will indicate the availability of supply (Fig 14), the control transformer gets the supply through MCB2 and the indicator lamp (L_4) indicates the availability of control voltage.

Sequence of operations for forward direction

1 If forward push button (F) is pressed, the NVC of the forward contactor (C_1) gets control voltage through over load relay trip contact (OLTC), stop push button and NC contact of the C_2. Now the C_1 energized and get self holding through its own NO contact. So even after releasing the 'F' push button the C_1 will continuous in energized condition.

2 The one more NO contact of C_1 is closed, so the NVC of the star contactor (C_4) and timer get the control supply simultaneously through the delta and timer NC contact hence the C_4 and timer (T) getting energized.

3 The NO contact of C_4 closes and the NVC of the main contactor (C_3) getting energized. Now the motor is started in star in forward direction and the main contactor (C_3) is getting self holding through its own NO contact whereas the delta contactor (C_5) will not energize because of the NC contact of C_4 which connected in series with C_5 is already in open condition.

4 After some pre-determined time delay, the timer NC get open causes the C_4 to de-energize and the delta contactor (C_5) is getting energized though the NC contact of C_4. Now the motor is running in delta connection in forward direction.

5 When the motor is running in the forward direction, even by a mistake if the reverse push button (R) is pressed the reverse contactor (C_2) will not get the control voltage because of the interlock NC contact of C_1 is connected in series with C_2.

6 If the stop bush button (OFF) is pressed the C_1, C_3 and C_5 contactors get de-energized simultaneously and the motor stops. In other hand if either the OLTC open due to over load or the supply fails, the motor will stop. Then the motor could be started only by pressing either forward or reverse push button as required after resetting the OLTC and it could not get started automatically even if the OLTC getting reset after cooling down or the power resumes.

Sequence of operations for reverse direction

1 If the reverse push button (R) is pressed, the NVC (No Volt Coil) of the reverse contactor (C_2) get control voltage through over load relay trip contact (OLTC), stop push button and NC contact of the C_1. Now the C_2 energized and get self holding through its own NO contact. So even after releasing the "R" push button the C_2 will continuous in energized condition.

2 The one more NO contact of C_2 is closed, so the NVC of the star contactor (C_4) and timer get the control supply simultaneously through the delta and timer NC contact hence the C_4 and timer (T) getting energized.

3 The NO contact of C_4 closes and the NVC of the main contactor (C_3) getting energized. Now the motor is started in star in reverse direction and the main contactor (C_3) is getting self holding through its own NO contact whereas the delta contactor (C_5) will not energize because of the NC contact of C_4 which connected in series with C_5 is already in open condition.

4 After some pre - determined time delay, the timer NC get open causes the C_4 to de-energize and the delta contactor (C_5) is getting energized through the NC contact of C_4. Now the motor is running in delta connection in reverse direction.

5 When the motor is running in the reverse direction even by a mistake if the forward push button (F) is pressed the forward contactor (C_1) will not get the control voltage because of the interlock NC contact of C_2 in series with C_1.

6 If the stop push button (OFF) is pressed the C_2, C_3 and C_5 contactors get de-energized simultaneously and the motor stops. In other hand if either the OLTC open due to over load or the supply fails, the motor will stop. Then the motor could be started only by pressing either forward or reverse push button as

required after resetting the OLTC and it could not get started automatically even if the OLTC getting reset after cooling down or the power resumes.

Jogging (inching): In some industrial applications, the rotating part of a machine may have to be moved in small increments. This could be done by a control system called jogging (inching). Jogging is defined as the repeated closure of the circuit to start a motor from rest, producing small movements in the driven machine. By pressing the jog push-button the magnetic starter is energised and the motor runs; when the jog push-button is released, the motor stops.

When a jogging circuit is used, the motor can be energised only as long as the jog-button is depressed. This means the operator has instantaneous control of the motor drive.

Purpose of jogging/inching controls: Normally jogging (inching) controls are incorporated in the following machines for operational convenience shown against each.

- Lathe machine controls - for checking the trueness of the job and setting the tool initially.
- Milling machine controls - for checking the concentric running of the cutter at initial setting and also to set the graduated collar for depth of feed of the cutter.
- Grinding machine controls - for checking proper mounting of the wheel.
- Paper cutting machine - for adjusting the cut.

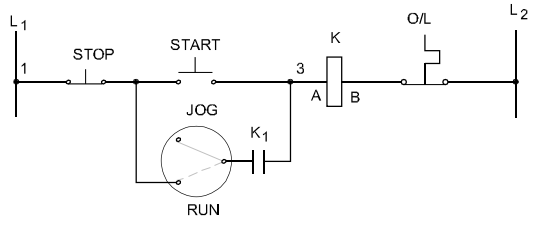
Apart from the above, the inch control is the prime control in cranes, hoists and conveyor belt mechanism so that incremental movements either vertically or horizontally could be achieved in the driven machinery.

Jogging may be accomplished by the following methods.

- Selector switch
- Push-button
- Push-button with a jog relay

Jogging control using a selector switch: By using a selector switch, the existing start button can be used as a jogging push-button in addition to its function as a starting push-button. The holding contacts of the contactor which are in parallel to the start-button are disconnected and the selector switch is placed in the jog position as shown by the circuit in Fig 16 and the panel layout in Fig 17.

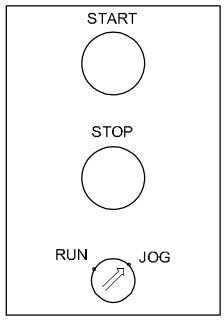
Fig 16



CONTROL CIRCUITS WITH JOG-RUN SELECTOR SWITCH.

ELN4217526

Fig 17



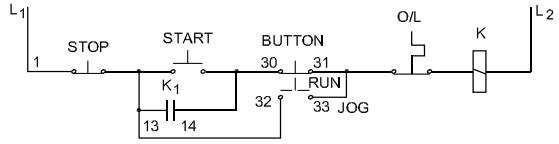
A PANEL OF A STATION IN WHICH THE START BUTTON CAN BE USED FOR INCHING OR JOGGING.

ELN4217524

The motor can be started or stopped by jogging/inching the start button. The motor will operate as long as the start-button is held pressed.

Jogging control using a push-button: Fig 18 shows the control circuit of a D.O.L. starter connected to a start-jog-stop push-button station. When the `ON' push-button is pressed, coil K is energised as the no-volt coil circuit is complete through the normally closed `jog' button contacts 30 & 31, thereby closing the main contactor, and the motor runs. The self-holding auxiliary contact K_1 between terminals 13 and 14 gets closed, and keeps the no-volt coil circuit in function though the `ON' button is released.

Fig 18



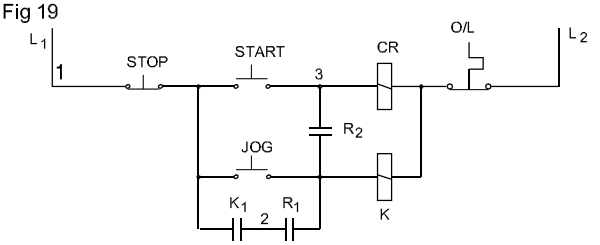
CONTROL CIRCUIT WITH JOG PUSH-BUTTON

ELN4217521

As soon as the jog push-button is pushed, as the circuit of the no-volt coil opens initially, the contactor is de-energised and the motor stops if it is running. Then the jog-button closes the bottom contacts 32 & 33, thereby the no-volt coil circuit closes and the motor runs as long as the jog-button is held pressed. By pushing and releasing the jog-button repeatedly, the motor starts and stops causing the driven machinery to `inch' forward to the desired position. On the other hand, pressing the start-button will make the motor to run normally.

Jogging control using a relay: Fig 19 shows the control circuit of a D.O.L. starter connected to a control relay with the other usual components. When the start button is pressed, the control relay coil CR is energised and closes the contacts R_1 and R_2, thereby momentarily completing the no-volt coil `K' circuit through relay contact R_2. This in turn closes the self-holding auxiliary contact K_1 of the no-volt coil relay K, and the motor runs continuously even though the pressure on the start-button is released.

Fig 19



LINE DIAGRAMS USING CONTROL RELAYS IN TYPICAL INSTALLATIONS

When the motor is not running, if the jog-button is pressed the no-volt coil, K circuit, is completed, and the motor runs only as long as the jog-button is held pressed as the holding circuit through R_1 is not completed for the starter coil as the control relay CR is not energised.

For a 3-phase, D.O.L. starter having the jog control through relay, four normally open contacts (3 for main and 1 for auxiliary) are required and the control relay should have two normally open contacts as in Fig 19.

Sequential control of motors

It is a kind of multiple motor's control in a specified manner by means of timer or limit switches or sensor depend the requirements of industries or application.

In this method generally the operation of two or more individual motors are controlled with respect to the specified time lapse or reaching of the specified level or completion of the specified operation. The operation of first motor will control the operation of the second or other motors and operation of second motor will control the operation of other motors and so on.

This type of the control system reduce the error due to human and man power, increase the accuracy of the operation cycle, minimize the ideal time of the machines and increase the efficiency and production of the industries.

The example of such sequential control system might be found in some of the industrial agitator system which explained in details below.

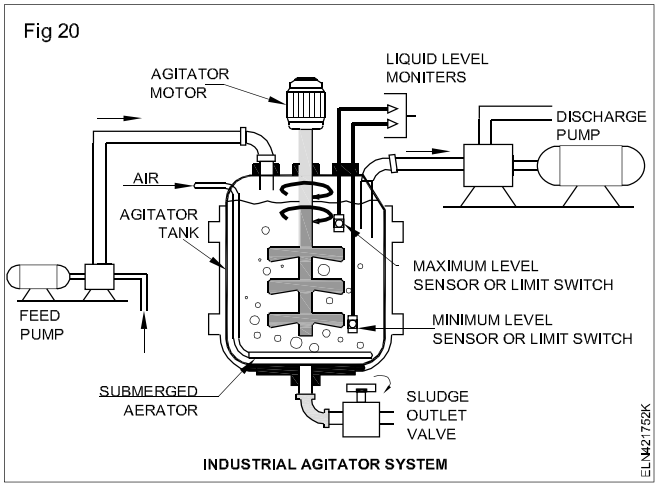
Industrial agitator

It is the machine consists of an electric motor along with impeller in its long shaft and fitted in the agitator tank which used in the chemical, food and pharmaceutical process industries to

- Mix the different type of liquid or chemical homogeneously.
- Improve the chemical properties of the liquid or substance.
- Keep and stir the stored liquid in the specified heat and properties.

Fig 20 show a typical industrial agitator used to remove the sludge and improve the chemical properties of the liquid or chemical before feeding to the process reactor. It has the feeding pump, agitator and discharge pump. The liquid to be treated is fed into the agitator tank through the feed pump which is started manually.

Fig 20



INDUSTRIAL AGITATOR SYSTEM

After some time lapse the agitator motor starts by means of timer and stir the liquid continuously till the level of the liquid reaches the minimum level. When the liquid level in agitator reaches the maximum level, the sensor or limit switch installed in the tank is switched off the feed pump.

After specified time lapse of starting the agitator motor the discharge motor is started by means of one more timer and discharge the liquid to further process. When the liquid level in agitator reaches the minimum level, the sensor or limit switch installed in the tank is switched OFF the discharge pump.

The agitator also have the submerged aerator through which the air is fed, a sludge discharge line with valve to discharge unwanted sludge, minimum and maximum level sensor or limit switches to maintain the liquid level in the tank.

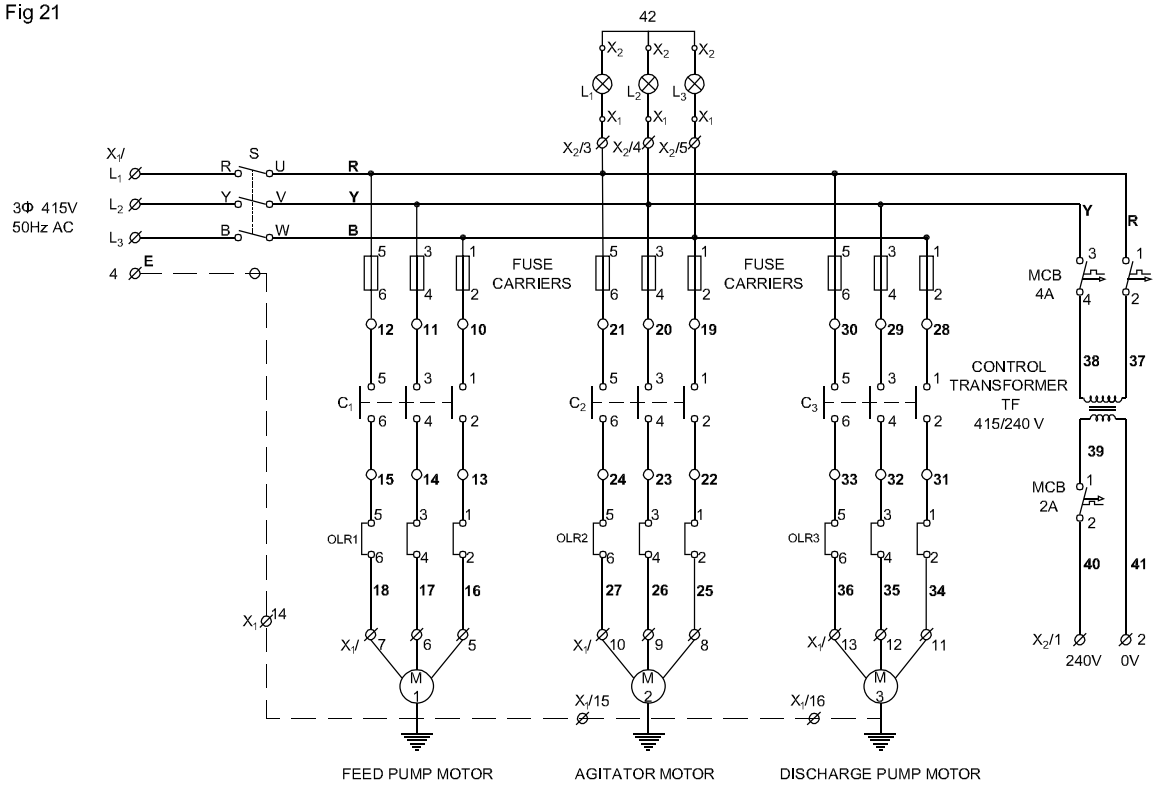
A control panel with necessary wiring and protection are designed and installed to control the sequential control of all the three motors. The Fig 21 and 22 show the power and control circuit of the sequential control of the typical agitator system with three motors.

All the three motors have individual power circuit of DOL starter with over load and short circuit protection. The total control panel has an isolation switch to ON and OFF the supply. It has indicator lamps to indicate the availability of the power supply and control supply and also indicates the running status of feed pump, agitator motor and discharge pump.

Sequence of operations of the sequential control of the agitator system having three motors

When the start push button is pressed the NVC of the feed pump motor contactor (C_1) and timer 1 (T_1) is getting the control voltage through the stop push button, OLTC of OLR1 and NC contact of the maximum level limit switch.

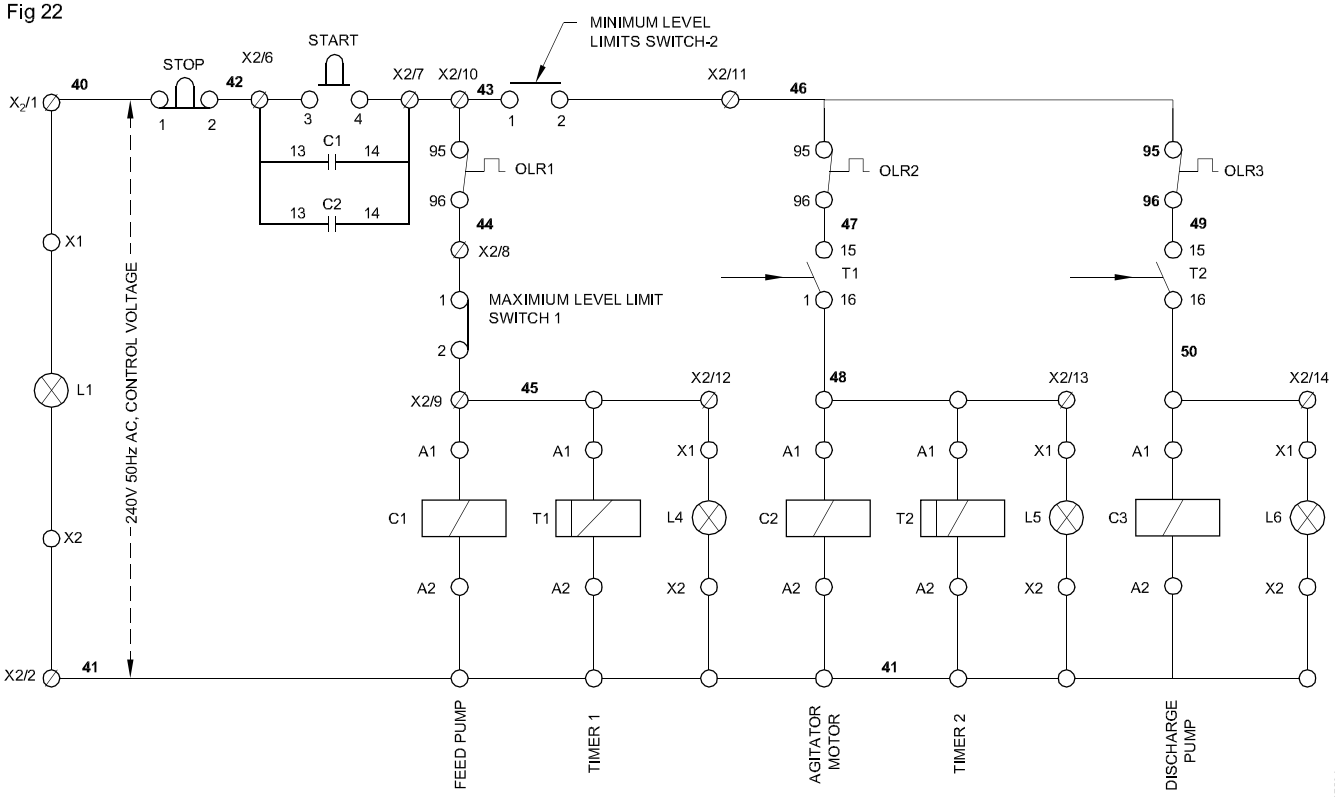
Fig 21



POWER CIRCUIT FOR SEQUENTIAL CONTROL OF THREE MOTORS

ELN421752L

Fig 22



CONTROL CIRCUIT OF SEQUENTIAL CONTROL OF AGITATOR SYSTEM WITH THREE MOTORS

ELN421752M

Now the C_1 and T_1 energized and get self holding through the NO contact C_1. So even after releasing the 'start' push button the C_1 and T_1 will continuously be in energized condition.

After some pre-determined time lapse the NO contact of the timer 1 closes and the NVC of the agitator motor contactor (C_2) and timer 2 (T_2) get control voltage through the minimum level limit switch and OLTC of OLR 2. Now

the C_2 energized and get self holding through its own NO contact. So even if the C_1 if get de-energized due to maximum level limit switch, the C_2 will continuously be in energized condition.

After the some time lapse the NO contact of the timer 2 closes and the NVC of the discharge pump motor contactor (C_3) is getting the control voltage and get energized.

If the liquid level of the agitator reduces to the minimum, the NO contact of the minimum level limit switch open causes C_2 and C_3 get de-energized.

When the all the three motors are working, in case if the OLTC of OLR1 opens the C_1 will only get de-energized and C2 and C3 continuously in energized condition through the self holding contact of C_2.

In case if the OLTC of OLR 2 opens due to over load the C_2 will only get de-energized if the C_1 is in energized condition. In other hand if the C_1 is already of OFF condition due to activation of maximum level limit switch, the C_3 also will get de-energized.

In case if the OLTC of the OLR3 opens due to over load the C_3 alone will get de-energized.