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ELECTRICAL SWITCHGEAR AND CONTROLGEAR

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The functioning of an air-conditioning and refrigeration plant is vitally dependent on a proper electrical installation and its correct design. While this work is normally entrusted to an experienced electrical engineer, the HVACR or ACR engineer should be sufficiently familiar with the basic switchgear and control gear specified and installed. In this article the author, an electrical engineer by profession, explains some important and basic information to the ACR engineer about switchgear and control gear, Subsequent issues will endeavor to further demystify the electrical and electronics that form an important part of an ACR installation today.

Q. What is the basic difference between an Isolator, Switch, Switch Fuse Unit or Fuse Switch Unit and a Circuit Breaker?

All the four are mechanical devices. The Isolator and Switch Fuse unit of Fuse Switch Unit are manually operated devices where as a Circuit Breaker can be either manually or electrically operated.

An Isolator can merely establish the circuit, that too under no load. It can not establish or break any load current, whereas a switch can make or break an electrical circuit under rated load current.

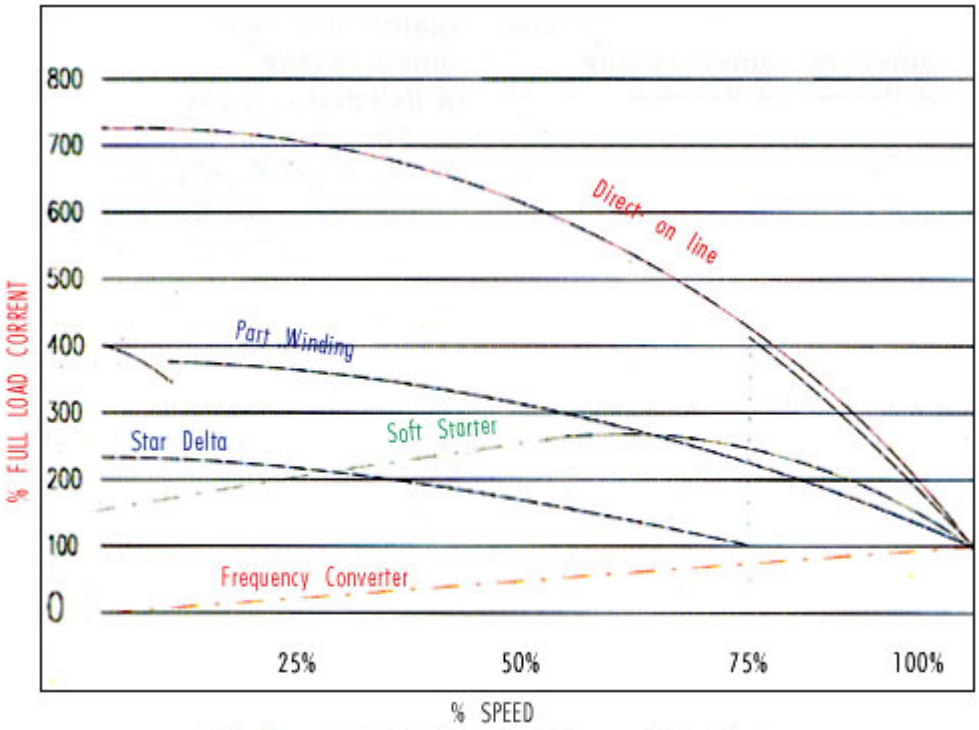
A Switch Fuse Unit or a Fuse Switch Unit also functions like the Switch, but can interrupt the power supply by blowing the fuse in case the connected load draws excess current or when a short circuit occurs.

A Circuit Breaker also interrupts the power supply when excess current flows through the circuit or when a short circuit takes place and it is designed to trip with internal or external sensitive devices.

Since a Circuit Breaker is designed to make as well as break a large amount of power, it is widely used to protect an entire electrical installation, against a massive short circuit current or current drawn in excess of its rated capacity.

For proper selection and application of an Isolator or a Switch, standards like IEC and IS specify the following five categories:

- AC 20: Switch capable of connecting and disconnecting under no load condition. Example: An isolator installed near a motor merely to disconnect motor is under maintenance.
- AC 21: Switch capable of making and breaking resistive (s) at rated current or slightly higher current, say 1.5 times the rated current. Example: A switch used in a heater bank.
- AC 22: Switch capable of energizing a motor, having a capacity to make and break three times the rated current. Example: A switch used in a motor circuit for a compressor, pump or fan.
- AC 23: Same as AC 22, but can energies a heavy inductive load or a capacitor bank and can also make and break a heavy current to the extent of 10 and 8 times its rated current respectively. This category of switch can directly switch on and switch off individually connected motors on the event the contactor on the starter fails to operate. Example: A switch used in a motor circuit or capacitor bank.
- A switch or fuse switch unit or isolator suffixed with 'A' or 'B' represents frequently or infrequently operate type respectively. Example: AC 23A or AC 23B.



Starting current of various types of starters

Q. Why is a fuse required and what type of fuse should one use in an electrical circuit?

A fuse is a device which by melting opens the circuit in which it is inserted when current through it exceeds a given value. A fuse is used for protecting the switchgear equipment and cables. Bear in mind that a fuse cannot protect motor winding from a short circuit.

When a fuse element blows, the circuit breaks and as a consequence an arc is established between the breaking points, thereby generating a large amount of heat which can damage adjacent equipment and set fire to wires and cables.

In order to prevent this, fuse elements are housed in a strong and non inflammable body (generally ceramic) filled with quartz and so that when the fuse element blows, the sand automatically falls down and covers the live contact, thereby quenching they are. This type of fuse can quench known as a High Rupturing Capacity fuse (HRC fuse).

The High Rupturing Capacity type fuse has a great advantage in that it starts blowing much before the entire short circuit current passes through the fuse element. Thus, an HRC fuse is the fastest acting device to give protection to equipment under short circuit condition.

There are many HRC fuse manufacturers in India. Although every manufacturer follows relevant IS & IEC Standards, the characteristics of fuses manufactured by different manufacturers vary for the same rating of fuses. Therefore each manufacturer recommends the rating of their fused to be used for a given motor rating. Hence while replacing one make, of fuse with that of an other make, care should be taken to check that the fuse selected gives adequate protection from excess over current or short circuit to the starter, associated switchgear and cables.

Q. What is a contactor and how does it differ from a starter? What utilization category of contactors should be selected to switch on i) a squirrel cage induction motor ii) a capacitor bank iii) hermetic refrigerant compressor motor?

A contactor is an electrically operated switch that can be made to switch on or switch off a motor, a heater bank, capacitor bank etc. directly or by a remote controller such as thermostat, humidistat, timer, pilot devices or any protective devices. It consists of 2 or 3 or 4 power contacts and some auxiliary contacts.

Although a switch, circuit breaker and contactor are designed to interrupt electric currents, contactor is the only one device which can do the task of making and breaking the current repeatedly and frequently, due to the simplicity of its mechanism and contact design.

When a contactor breaks the current, an arc is established across the contacts where the circuit is broken and a good amount of heat energy is generated. This increases when the frequency of breaking the current increases resulting into welding of contacts or fusing and contactor failure.

A motor starter is defined as a combination of all switching means necessary to start, to accelerate and to stop the motor in combination with suitable protective, start and stop devices.

It consists of a contractor plus additional overload protective devices in order to protect the motor from drawing excess current under sustained overload conditions. It may also include step resistors, disconnects, reactors, auto-transformers or other hardware to make a more sophisticated starter for large motors.

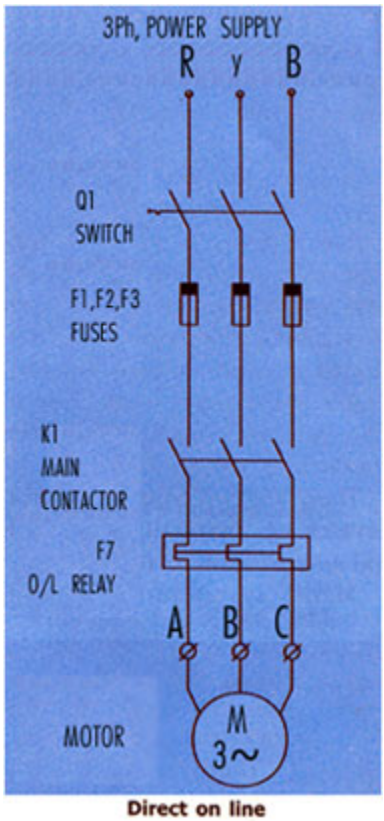
A motor starter is designed to provide one or more of the following functions.

- Start, accelerate and stop a motor repeatedly, quickly, safely and dependably.
- Protect motor against operational overloads.
- Disconnect supply to motor in case of under-voltage/no voltage, if there is danger to operator or to the machinery die to automatic restarting of motor on restoration of full/balanced voltage.

  The starter can also perform the following functions with suitable additional devices.
- Protect motor against severe unbalance in voltage and current.
- Limit inrush/starting current wherever called for.
- Protect starter components/installation from short circuit fault.
- Provide remote operation facility.

Contactors (used in starters) are, classified based on their duty application or utilization category of which there are 11. In general, only the following categories are used for Air Conditioning and Refrigeration systems.

- AC 3: Squirrel Cage Induction motor - Starting and switching off motors during running.
  Example: Pumps, Fans, Centrifugal Compressors & Heater Banks.
- AC 6b: Switching off Capacitor Bank/s.
  Example: An individual capacitor or a group of capacitor banks.
- AC 8a: Hermetic refrigerant compressor motor control with manual resetting of overload releases.
  Example: Air cooled and water cooled chillers.
- AC 8b: Hermetic refrigerant compressor motor control with automatic resetting of overload releases.
  Example: Air cooled and water cooled chillers.



Direct on line

Q. What is a protective relay and which are the relays commonly used in ACR Systems?

This is an electrical, electronic or thermal switch, designed to initiate disconnection of power supply to a motor or to a part of an electrical installation and/or to give a warning signal in case of abnormal conditions, such as over load, short circuit, high motor winding temperature, earth fault, single phasing preventer.

Some commonly used protective relays in ACR systems are:

Overload/overcurrent relay (thermal and magnetic), single phasing preventing relay, phase reversal relay, short circuit Protection relay, earth fault relay, thermistor relay,

special motor protection relay (for protection of higher HP rated motors).

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Q. What is a Control Device and which are the ones commonly used in ACR Systems?

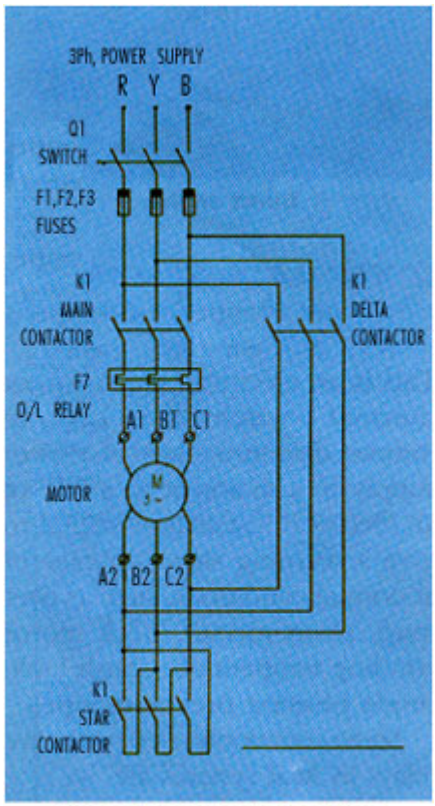
A control device is a mechanical, electrical, electronic or thermal switch which serves the purpose of switching on or switching off a circuit breaker, motor starter, heater & capacitor bank. These also include signaling, electric interlocking etc.

There are two types of control devices i.e., manually operated and automatically controlled.

Manually operated control devices are: push buttons & selector switches. Automatic control devices are: Pressure switches, float switches, flow switches, thermostats, thermistor relays, limit switches, protective relays, timers and auxiliary contactors.

All manually operated devices are actuated manually where as automatic control devices are actuated in response to specified conditions of a requirement.

Bear in mind that control devices can switch on only small current loads like electromagnetic coil of a contactor or small pilot motors in motorised valves and fire dampers or indicating lamps. They cannot be used to interrupt power circuits directly since these carry large currents which can cause immediate failure of the control device.



Star Delta - Open Transition

Q. I know a transformer can step up or step down voltage, but what function does an Auto transformer or a Control transformer serve?

Auto-transformers are used as a part of a starter for controlling the inrush current and the torque of a squirrel cage induction motor, where the electric supply company insists on a low starting current or the driven device calls for a low starting torque.

A control transformer is used for reducing the control voltage to a safe working voltage and should be capable of dealing with surge currents or inrush currents of electromagnets that are connected, without allowing the secondary voltage to drop appreciably. Most control circuits in ACR system in India operate on 24, 48 or 110Volts.

Q. Which are the commonly used starters in ACR systems?

Starters are divided into two types:

1. Full voltage or across-the-line or direct on line (DOL) starters where the motor load is directly applied to the line voltage.
2. Reduced voltage or assisted type starter. Where the motors load is initially applied to a reduced voltage and later to the line voltage.

Usually power supply companies determine the type of starter that consumers must apply to their motors. If 415V supply is connected then most companies in India specify that the maximum motor size for DOL start should be 5 HP and sometimes 7.5HP. Above this size, they insist on a reduced voltage starter. If power is supplied at high tension, such as 11/33kV, then this stipulation is relaxed and larger motors are permitted for DOL start. However most starters used in ACR chiller packages are the reduced voltage type.

The following reduced voltage starters are commonly used in ACR Systems:

- Star delta starter
- Auto transformer starter
- Part winding starter
- Soft starter and variable frequency drive. (Not covered in this article)

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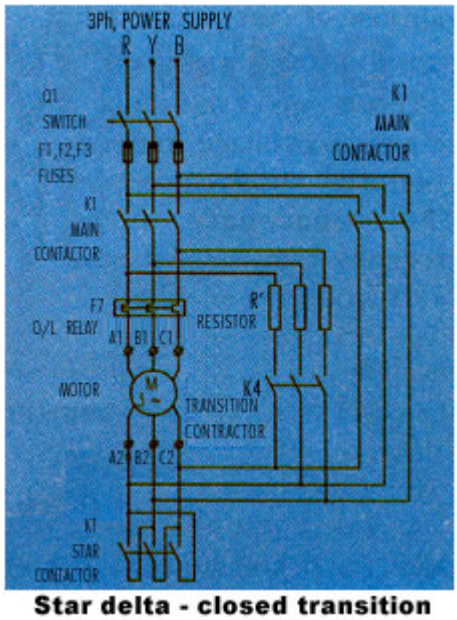
Q What are the pro's and con's of different starters commonly used in ACR Systems?

Direct Online Starter:

DOL starters have the lowest initial cost and since full voltage is applied the motor produces maximum starting torque and the load accelerates fast. However in India, power supplying companies impose restrictions on the use of such starters.

Since the motor draws a high starting current to the extent of 600% to 800% of its full load current, larger hp motors will cause a severe dip in the supply system voltage.

Star Delta Starter:



Star delta - closed transition

In this starter, one end of the motor windings is initially shorted together and supply is fed to the other end of the motor windings. Thus even though full voltage is applied to the motor terminals, the effective voltage applied to the windings becomes only 1/3 i.e., 57.7% of the rated voltage. After a preset time, the shorting done at one end of the winding is removed and motor receives full voltage.

The reduced supply voltage restricts motor starting current to $(0.577)^2$ i.e., $1/3^{rd}$ or 33 per cent of full load starting current. Starting is in two steps, hence jerk is minimised.

As the voltage applied in each phase is reduced by 1/v3 the torque is reduced by $(1/v3)^2$ and hence this starter cannot be used where load requires a high starting torque. The time taken for the motor to accelerate is longer due to reduced voltage input. If timing of changeover from star to delta is not set properly the motor is on full line voltage prematurely and will draw a heavy current thereby defeating the main purpose of restricting the starting current. Closed transition is possible only by adding additional resistor or reactance, timer and power contactor hence this type becomes further expensive. (In a closed transition the current is not broken when the change over from star to delta takes place, where as, in an open transition, not only the current is broken when the change over takes place from star to delta, but also the motor gets a heavy kick/jerk when full voltage is applied).

Auto Transformer Starter:

It is basically a reduced voltage starter in which an auto transformer is used to supply reduced voltage to the motor windings initially. At start, supply from mains is fed to the motor windings through one of the taps on the auto transformer. This reduced supply voltage caused the motor to draw much lower current as compared to the current

drawn by a DOL starter. Once the motor reaches almost the rated speed, the auto transformer is disconnected from the circuit and full supply voltage is fed directly to the motor. Thus the motor draws full load current and produces full load torque.

An auto transformer is generally provided with 3 tappings of 50% or 57.7% 65% and 80% voltages.

The corresponding starting current and torque at these voltages are:

Taps at	Starting Current	Starting Torque
50%	25%	25%
57.7%	33%	33%
65%	42%	42%
80%	64%	64%

This type has an advantage of reduction in starting current and torque. Being a two step starter, starting jerk is minimised compared to DOL. With a minimum of 3 voltage tappings available in an auto transformer, by selecting appropriate voltage taps, the starter becomes flexible to obtain different starting torque at site to match different load conditions. Closed transition is possible. Having more costly components like auto transformer, contactors, timer etc. It is much more expensive compared to DOL or star delta starter. It is larger in dimensions than DOL or star delta starter. If the timer for changeover from auto transformer to full supply voltage is not set properly, the motor will changeover to full supply much earlier and it will function as a DOL starter and draw much higher starting current thereby defeating the basic purpose of current reduction.

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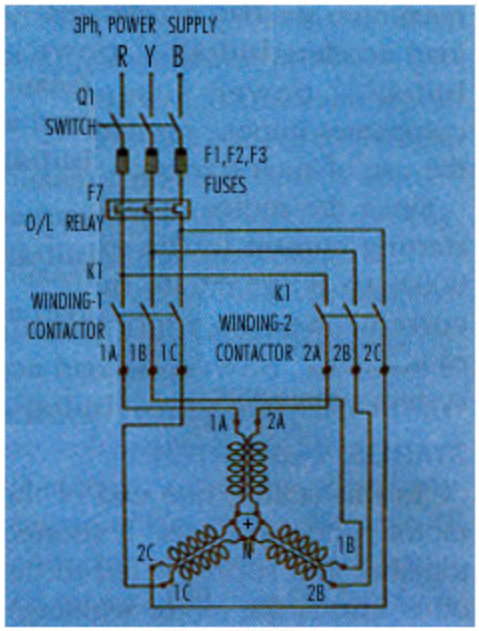
Part Winding Starter:

This is one of the simplest type of reduced voltage starter used to control the inrush current of motor. The poly phase motor has basically two parallel windings, both wound on the same poles. One set of each winding leads are brought out to the terminals and the other set of windings leads are shorted either internally or externally.



Part Winding

As the windings are in two parts, the power supply is initially fed to one of the windings, thus the motor draws a low starting current, The power to the second winding is fed after a set time and the motor then draws full load current.

Motors in either 67% / 33% or 50% / 50% windings can be selected depending upon the starting torque requirement.

It is less expensive than ATS or star delta starters. Closed circuit transition is possible. Starting torque is better than star delta. Small sized fuses are adequate compared to Dol. Inrush current is restricted to a maximum of 65% of starting current depending upon the time the second winding is energised. It can withstand better voltage fluctuations.

Limitation in motor selection and starting torque is restricted to a maximum of 45 percent of rated torque of motor.

Q What are Power and Motor Control Centers (PCC / MCC)

A PCC/MCC is a centralised control unit installed in one location, controlling a group of power feeders /motor feeders. They are modular in design, compartmentalised, fixed or draw-out type suitable for indoor or outdoor installations. The necessary power feeders or starter feeders are housed in each module and this helps start stop, control, inspect and do maintenance of any one or more feeders without disturbing or affecting the control of other power motor feeders.

The enclosure of MCC/PCC is classified according to its capability of withstanding the entry of solid particles such as dust, vermin and liquids such as water, oil etc.

Q What is a busbar and what are the precautions to be taken while mounting them?

Busbars are conductors to which several sources of supply or distribution are connected They form an important function in distribution of power. These are generally located in a separate chamber. The material used for busbars is E91 E grade aluminum or electrolytic grade copper. The precautions that are to be taken while selecting and mounting busbars are:

- Busbars are sized considering system fault current and for specified load current with respect to ambient temperature and final working temperature.
- Busbars should be insulated and properly supported with adequate clearances between phases-neutral-earth.