Motor protection depending on size and voltage level

Motor protection depending on size and voltage level (on photo 3-phase asynchronous motor LeroySomer P280 S-8, 55 kW)

Motor protections vary widely depending on the size of the motor and voltage level involved, thus only the more common ones are discussed in this technical article.

Protection Index

1. Motor Instantaneous Over-current Protection

Instantaneous over-current is usually the result of fault conditions (phase to phase, phase to ground), in which current flow will greatly exceed normal values. Damage due to winding overheating and burning damage associated with large fault currents can occur without this type of protection.

These types of faults can be rapidly detected by a differential protection scheme using Core Balance CTs as will be discussed later and cleared before major damage results. In these situations, fast acting electromagnetic relays will be used to trip the affected motor.

2. Motor Timed Over-Current Protection

Continuous operation of an **electric motor** at currents marginally above its rated value can result in ***thermal damage*** to the motor.
The insulation can be degraded, resulting in reduced motor life through eventual internal motor faults. Typically, an electric motor has a service factor rating listed on its nameplate. This number represents the continuous allowable load limit that can be maintained without sustaining damage to the motor. For example, a typical electric motor is designed to withstand a continuous overload of about 15% without sustaining damage and has a service factor = 115%.

Continuous operation at or above this value will result in thermal damage. To protect against motor damage, we mustensure that this condition is not reached, hence we must trip the motor before the overload limit (service factor) is reached.

The relay most commonly used for this purpose is the induction disc relay. In this relay (***Figure 1***), the current in two coils produces opposing magnetic fluxes, which create a torque on a disc. As the motor current increases, so does the torque on the disc.
When the torque overcomes the spring torque, the disc begins to rotate. When the moving contact meets the stationary contact on the disc, the trip will operate.

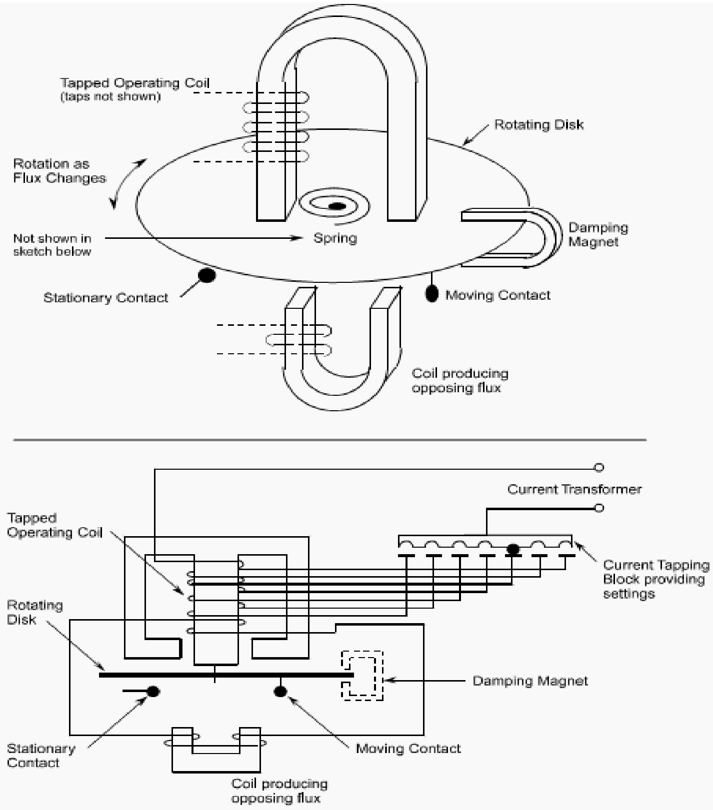

Figure 1 - Induction Disc Relay

Tap settings and time characteristic adjustments can be made to alter the time delay of the relay. The major benefit of the induction disk timed over current relay is that the ***speed of rotation is proportional to the motor current***.

Hence major over-current conditions will trip the supply breaker almost instantaneously, while currents just above rated load will cause operation after several seconds (or minutes).

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3. Thermal OverLoad

Another common type of relay used for timed overload protection is a ***thermal overload relay***. In this type of relay, the motor current or a fraction of the current through a currenttransformer is connected to an in-line heater. ***Figure 2*** shows a simplified thermal overload relay. The heater (***heated by I^2R action***) is used to heat a bimetallic strip, which causes the displacement of a relay contact. A bimetallic strip consists of two different materials bonded together, each having different thermal expansion properties.

As the materials are heated, one side will lengthen more than the other, causing bending.

Normal operating currents or short duration overload conditions, will not cause the bimetallic element tobend enough to change the relay contact positions.

Excessive currents will cause increased heating of the bimetallic strip, which will cause relay contacts to open and/or close, tripping the motor.

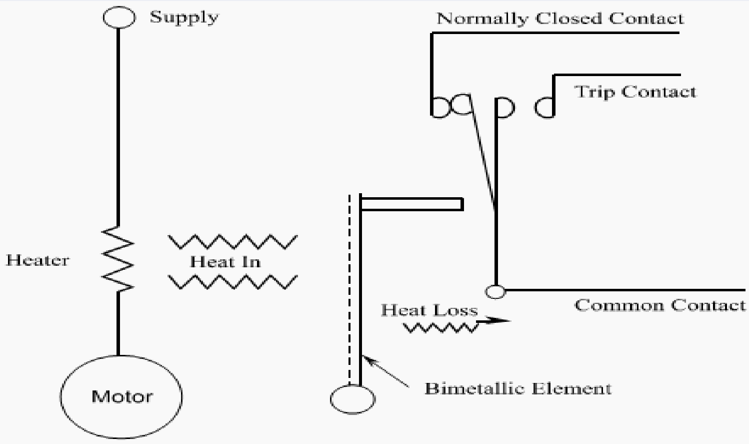

Figure 2 - Thermal Overload Relay

The thermal overload relay has an inherent reaction time, since the heater and bimetallic element take time to heat. Care must be taken to match the current heating characteristics of the motor or else the motor could be damaged during the **locked rotor starting conditions**.

This type of relay can be used for ***direct protection against excessive motor current*** caused by **electrical faults** and motor overloads. Also, it is often used in combination with the timed over-current protection.
Thermal overload relays using in-line heaters and bimetallic strips, provide an alarm in the case of continuous overload. This provides an opportunity for the operator to correct the problem before it reaches trip level magnitude.

As we have stated, thermal over-load trips can occur during **repetitive starts on a motor** or during motor over-loading. Thermal overload trips will seal-in to prevent the motor contactor from closing. This lock-out will require manual reset before the motor can be re-started. The operator or attendant will have to physically confirm that the motor has had sufficient time to cool down and that the cause for the overload has been removed. If the operator is confident that there is not a permanent fault on the motor the relay can be reset.

Note however, that if an instantaneous over-current trip has occurred, no attempt at closing the motor contactor should be made. An instantaneous trip will only occur if there is a fault in the motor or supply cable and this must be corrected before any attempt to reset the relay.

4. Motor Ground Fault Protection

In the detection of ***ground faults***, as with the detection of instantaneous over-currents, it is extremely important that the fault be detected and cleared quickly to prevent equipment damage. Insulation damaged by heat (from extended overload operation), brittleness of insulation (due to aging), wet insulation or mechanically damaged insulation can cause ground faults.
Ground fault protection schemes use differential protection to detect and clear the faulted equipment. For motors, the common method is to use a Core-Balance CT as illustrated in***Figure 3***. The output of the core-balance CT will be the difference or imbalance of current between the three phases.
If no ground fault is present, no current imbalance is present; hence no current will flow in the protection circuit.

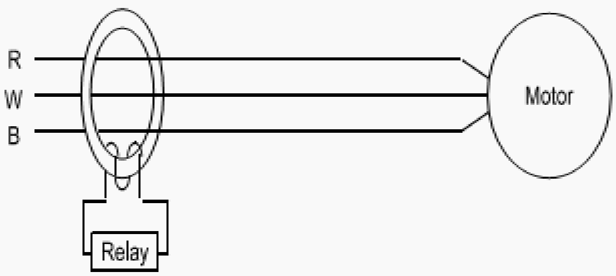

Figure 3 - Three Phase Ground Fault Protection

If a ground fault develops, a current imbalance will be present and a current will flow in the protection circuit, causing it to operate to trip the supply breaker.

Figure 4 shows a similar protection scheme, with each of the windings of the motor protected individually (*this scheme is not normally installed in small motors, but may appear in the protection of very large motors*).

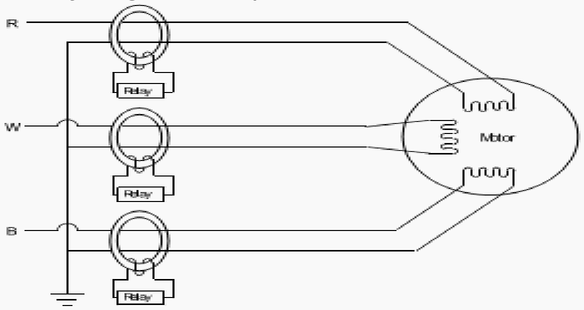

Figure 4 - Single Phase Ground Fault Protection

5. Motor Stall Protection

Stalling or locking the rotor, is a situation in which the circuits of a motor are energized but the***rotor is not turning***. Motors are particularly susceptible to overheating during starts, due to high currents combined with low cooling air flows (due to the low speed of the motor, cooling fans are delivering only small amounts of air).
This is also why some larger motors have a limit on the number of attempted motor starts before a cooling off period is required. However, stall conditions can occur during normal operation. For example, mechanical faults such as a seized bearing, heavy loading or some type of foreign object caught in a pump could be possible causes of motor stalling.

The loss of a single phase while the motor is not rotating or under high load, is another situation in which a ***motor may stall***.
The typical starting time of a motor is less than ten seconds. As long as this start time is not exceeded, no damage to a motor will occur due to overheating from the high currents.During operation, a motor could typically stall for twenty secondsor more without resulting in excessive insulation deterioration.

We use a stalling relay to protect motors during starts, since a standard thermal relay has too much time delay. A stalling relay will allow the motor to draw normal starting currents (which are several times normal load current) for a short time, but will trip the motor for excessive time at high currents.

A stalling relay uses the operating principle of a thermal overload relay, ***but operates faster than a standard thermal relay***.

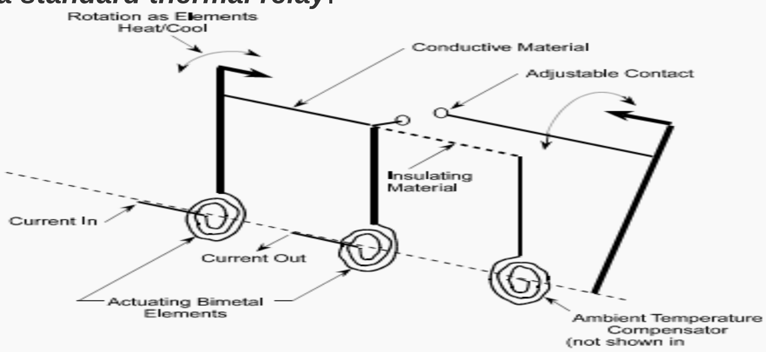

Figure 5 - Stalling Relay

A schematic representation of a stalling relay has be been provided in ***Figure 5*** for reference.
By passing a portion of the motor current directly through the bimetallic elements in this relay, the heating is immediate, just as would be experienced within the windings of the motor.

This type of relay is usually operational only when the motor current is ***above 3 times the normal operating current*** and is switched out when the current is below 2 times the normal operating current. This switching in/out is achieved by the use of an additional relay contact.
When the motor is operating normally, the current in this protection scheme passes through the resistor and bypasses the bimetallic elements.

6. Motor Over-Fluxing Protection

As you can recall from the module on **motor theory**, the current drawn by a motor is roughly proportional to the core flux required to produce rotation. Moreover, the flux in the core is roughly proportional to the square of the slip speed.

$$I \propto f \propto s^2$$

Obviously over-fluxing is most severe during the locked rotor or stall condition when the slip is at the maximum. The stall relay previously discussed ***protects against this***.

However, there is another condition where we can enter into a state of over-fluxing the motor. If one of the three phases of the supply has high resistance or is open circuit (due to a blown fuse, loose connection, etc.), then the magnetic flux becomes unbalanced and the rotor will begin to slip further away from the stator field speed.

The rotor (shaft) speed will decrease while the supply current will increase causing winding over-heating as well as core iron heating. Also intense vibration due to unbalanced magnetic forces can cause damage to the motor windings and bearings.

This open-phase condition is oddly enough called single phasing of the motor, even though two phases are still connected. If the motor continues to operate with an open supply line, the current in the remaining two healthy leads will exceed twice the current normally seen for a given load. This will result in rapid, uneven heating within the motor and damage to insulation, windings, reduced machine life and thermal distortion.

If torque required by the load exceeds the amount of torque produced, the motor will stall. The motor will draw locked rotor current ratings, which are, on average, ***3-6 times full load current***. This will lead to excessive heating of the windings and will cause the insulation to be damaged. If the open circuit is present before the motor start is attempted, it is unlikely that the motor will be able to start rotating.

The phase-unbalance relay used to protect against this scenario is similar in design to the stall relay, but is set for about 20% of the full load current. A rough representation of the operation of the relay is included in ***Figures 6*** and ***7*** for reference only.

If any one of the phases in the motor loses power, the heater will cool down. The bimetallic strip will turn, causing the unbalance contacts to close and the motor to be tripped. This relay will also protect against thermal overload, as the heaters cause the bimetallic strips to close the overload trip contact.

You will also see a compensating bimetal element, which will compensate for ambient temperature changes, thus preventing unnecessary trips.

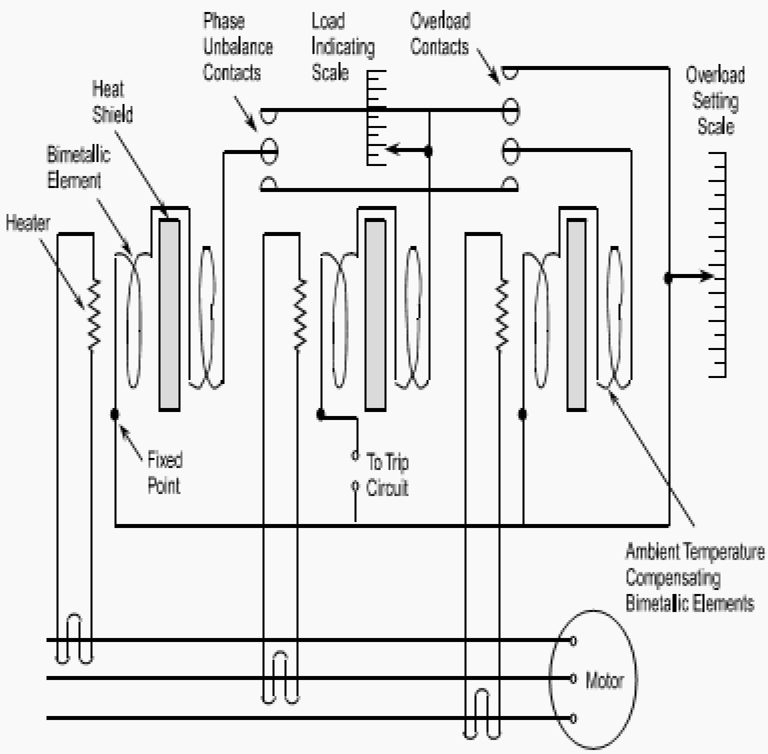

Figure 6 - Phase Unbalance and Overload Protection

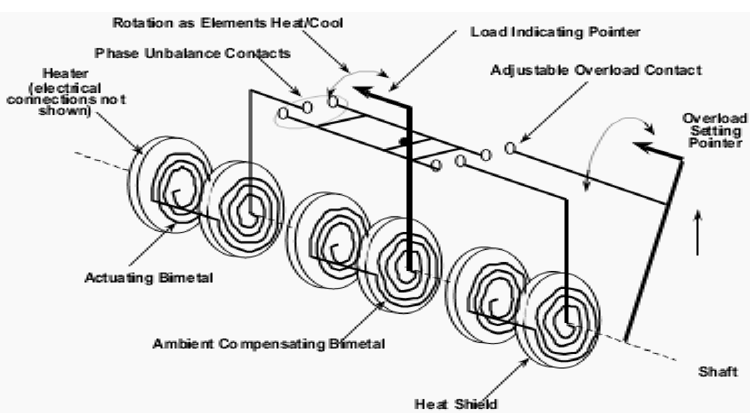

Figure 7 - Phase Unbalance and Overload Protection

Resource: *Science and Reactor Fundamentals – Electrical i CNSC Technical Training Group*

Source:

http://electrical-engineering-portal.com/motor-protection-depending-on-size-and-voltage-level