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Protection Devices

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ABSTRACT
The protection devices are one of the most important part of any electrical network, whether it is small network or large. we will discuss about only three main and famous types in which they are commonly used in all electrical networks. It is also concentrate on the principle of their operation and it will not exposed to the selection methods of them.
Keywords – Protection device, fuses, circuit breaker, overcurrent device, relays

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I. INTRODUCTION

Protection devices used to protect two main things, the human from any electric shock and Any electrical element or device from any damage caused by the heavy load or short circuit. The fundamental principles of protection are to disconnect and isolate the faulty part of the system so that the fault is not sustained and aggravated by a continuing flow of power into it and the rest of the system is not damaged and can revert to its normal state. The protection devices, differs according to the type of the load or the electrical equipment's or the cables which intended to be protected, for examples, Motor – Generator – Cable …. Etc., We are going to discuss in this written subject only the protection devices which are used for a common electrical equipment (more than one electrical equipment). But before that we will mention the list for the protective devices used generally in the electrical systems and network.

1.1 main protection devices used in electric networks.

1- Fuses, power or control
2- Circuit Breakers
3- over load device
4- over current devices
5- under current devices
6- over voltage device
7- under voltage device
8- Earth fault device
9- differential protection
10- over temperature protection
11- reverse power protection (RP)
12- over pressures protection
13- Negative phase sequence protection (NPS)
14- over frequency
15- under frequency
16- field failure
17- diode failure
18- over speed.
19- and there are some protection devices related to other electrical equipment's.

1.2 main electrical elements or equipment's available in the electrical networks.

1- Generators.
2- Cables and transmission lines.
3- Transformers.
4- Motors
5- Heaters
6- Lights.

II. FUSES, CIRCUIT BREAKERS AND OVERCURRENT DEVICES

We discuss in detail the main protection devices, fuses, circuit breakers and overcurrent device.

2.1 FUSES

A fuse consists essentially of a length of metallic wire or strip carrying the circuit current which, if that current exceeds a certain stated value of a certain minimum time will melt and break the path of the current in that circuit. It has both a normal current rating corresponding its service current and a breaking current rating corresponding to the maximum fault current of that part of the system in which it will be used. There is often confusion between the normal breaking current ratings of a fuse. The normal rating is matched to the load and is the maximum value of current which the fuse can carry continuously without melting or deteriorating. The breaking rating is the maximum protective current which the fuse can safely interrupt at its rated voltage. It is usually quoted in kilo amperes (KA) rms symmetrical and is related to the system fault level.

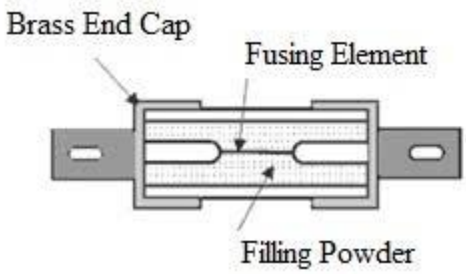

Fig 1.1

2.2 Circuit Breakers

Circuit breakers or switch gear is used on both high voltage and low voltage systems. It is required to enable generators, feeders, transformers and motors to be connected to and disconnected from the high voltage or low voltage system. This switching is necessary both for normal operational purposes and for the rapid disconnection of any circuit, that becomes faulty. The switch gear also allows any circuit to be isolated from the live system and for that circuit to be made safe so that work may be carried out on equipment connected to it.

First, the circuit Breaker for high voltage system used to control generators, transformers, bus sections, bus couplers, inter connecting cable between switch boards and the starting and running of very large motors. They are designed to make and break full fault current. They are three types, Oil circuit breaker, Vacuum circuit breaker and Air circuit breaker. A circuit breaker has five rating (voltage, normal current, breaking capacity, making current and short-time rating).

Voltage: This is the nominal system voltage at which the switch will operate without break down.

Normal current: This is the current will carry continuously without overheating.

Breaking Capacity: - This is the maximum fault current (expressed in KA rms) or MVA) which the switch will interrupt on all three phases.

Making current: - This is the maximum peak a symmetrical current (expressed in KA)
that the switch can carry in any pole during a making operation.

Short – time Rating: - This is the maximum time (usually specified as 3 sec or 1 sec) for which the switch will carry, without damage, the full fault current before that current is broken.

Second, The circuit Breakers for low voltage system

Three main types are considered, Air circuit breakers, Molded case circuit breakers and Miniature circuit breakers.

Air circuit breakers, the construction and operation are like those of high voltage Air Circuit breakers. Being designed for low voltage system their insulation levels are of course lower, but by the same token, their normal rated currents and their short circuit current rating are considerably higher.

Molded case circuit breakers (MCCB), It consists of a molded plastic cases containing a switching element which is operated manually by an external handle or 'dolly'. Because the original design was American, the dolly position is down for 'off' and up for 'ON'. MCCB can be used for switching either a.c or d.c circuits. They are usually mounted, when used on distribution panels, behind the panel and only the dolly shows, other arrangements however such as surface mounting, are also found.

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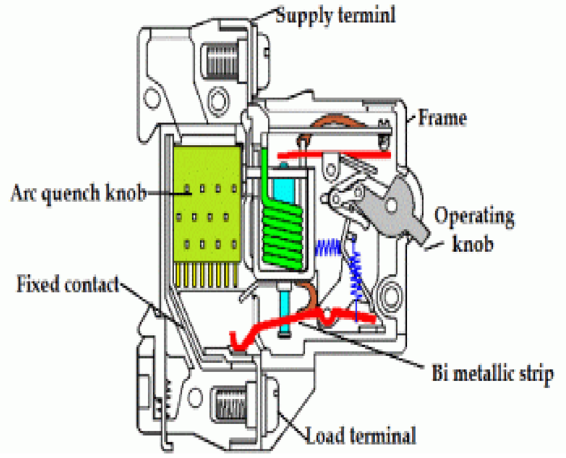

Fig 1.2

Miniature circuit breakers (MCB), In operation it is generally like though physically smaller than the modulated case design. The MCB has a modulated plastic case and is manually operated by an external dolly. It is manufactured as a 1-pole, 2-pole, 3-pole or 4-pole unit, but the commonest types in some installations are the 1-pole and 2-pole models which are used in single-phase and neutral sub-distribution panels. The following figure show miniature circuit breakers(MCB)


Fig 1.3

a comparison between the ratings of modulated case circuit breakers MCCB and the miniature circuit breakers MCB described in the tables.

MCCB

Normal current	Breaking |Capacity to BS \Rule		
	MVA (3-phase, 440V)	Equiv. KA(a.c.) (rms symmetrical)	KA (d.c. 250V)
125 A	7.5 MVA	10kA	18 kA
250 A	15 MVA	20kA	25kA

Table 1: MCCB circuit breaker

MCB 70 A size

Trip Unit	Breaking Circuit (kA)			
	250V a.c		440V a.c	125V d.c
	1-pole	2-pole	3-pole	2-pole
3A	1kA	1kA	1kA rms symm(=0.75MVA)	1kA
6A	1kA	1kA	1kA rms symm(=0.75MVA)	1kA
10A	5kA	8kA	5kArms symm(=3.8MVA)	10kA
16 to 70A	5kA	8kA	3kA rms symm(=2.3MVA)	10kA

Table 2: MCB 70 A size

MCB 32 A size

Trip Unit	Breaking Circuit (kA)			
	250V a.c		440V a.c	125V d.c
	1-pole	2-pole	3-pole	2-pole
	6kA	10kA	3kA rms symm(=2.3MVA)	5kA
1 to 5A	6kA	8kA	3kA rms symm(=2.3MVA)	5kA
10 to 32A				

Table 3: MCB 32 A size

2.3 Over current protection relays, over current protection is related primarily to heating effects in and in some circumstance to electromechanical forces on, electrical conductors and may cover both fault and over load protection. over current devices, though all depend on an excess of current to operate them are of several different forms.

2.3.1 Instantaneous Over current (OC).

An instantaneous overcurrent relay is shown in Figure below

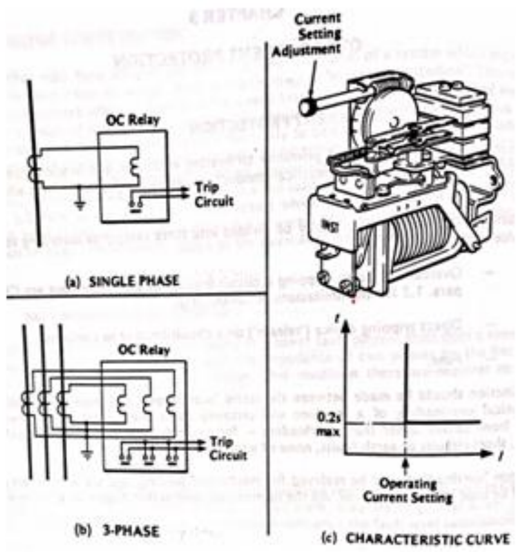

Fig 1.4

it consists of a simple iron armature attracted by a coil carrying the current from a line current transformer and restored to its rest position either by gravity or by a control spring When the current in the coil just exceeds a certain preset value, the pull on the armature overcomes the spring or gravity and causes it to close. In so doing it operates auxiliary contact which initiate a tripping circuit or other desired function. Though termed 'instantaneous 'this type of relay nevertheless requires a small but finite time to operate; this is usually taken to be a maximum of 0.2 seconds, but it is often munch less. The current/time characteristic is thus a 'square' one as indicated in Figure 1.4 (c). The value of the current required to operate the relay is set by the screw adjustment at the top in a single-phase system a current transformer in one line is connected to the relay coil (see Figure 1.4 (a)). In a 3-phase system a current transformer in each phase is connected to one of three relay coils (see Figure 1.4 (b)). The three relay elements may be enclosed in one case or in separate cases. However, in a 3 phase, 3 wires, system any over current in one line.
Most be accompanied by an over current in one or both return lines. Therefore, to achieve complete over current protection in a 3-wire system, it is only necessary to provide overcurrent relay elements in two of the three phases.

2.3.2 Inverse Time Over current (OCIT)

An inverse-time overcurrent relay is shown in the Figure below.

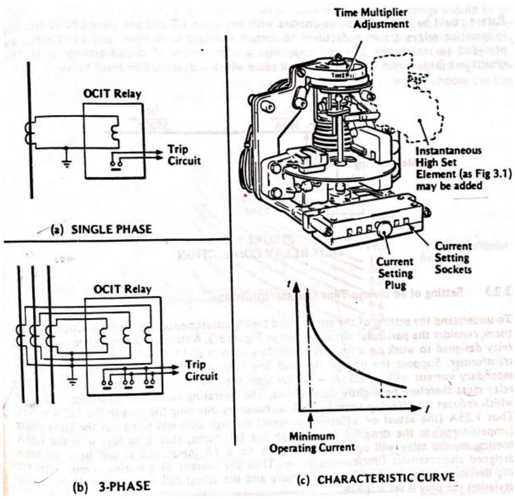

Fig 1.5

It has an induction – type movement like that of a household meter. It consists of a rotating aluminum disc driven by a shaded-pole magnet element which receive the driving current from the CT in the circuit to be monitored. As in a household meter, the disc also revolves between the poles of an eddy-current brake magnet; it is restrained by a light pre-tensioned control hairspring. The relay is used with current transformers in single phase or 3 phase systems as described for simple overcurrent type and as shown in 'Figure 1.5 (a) and (b).

When normal current flows from the CT a driving torque is applied to the disc, but it is prevented from rotating by the pre-tensioned spring. If the current exceeds a certain preset value the disc begins to move and is driven, against the drag of the brake, right round until a contact on the spindle touches a fixed contact. The greater the excess of current above this Value, the greater the drive torque and the faster the disc tries to rotate. But the drag of the eddy-current brake also increases with the speed of rotation, and its slowing effect is greatest at the highest currents. The combined effect of this is to produce a time/current characteristic as shown in Figure1.5 (c). for currents less than a certain minimum the disc does not move at all. For current more than the 'just move' minimum the disc moves, and the operating time becomes shorter with increasing current-that is, it has an 'inverse-time' characteristic.

Two setting adjustment are possible with this relay current and time. Current adjustments are made by fixed taps on the driving coil. They are usually set by moving peg between several holes on the front of the relay face. Typically, the range is from 50% to 200% of the normal operating current (1A or 5A depending on the CT used). The time adjustment is made by moving the 'fixed' contact to increase or decrease the travel of the disc before the contacts touch. The relay is fitted either with a time-scale marked in seconds, or more usually with a 'time multiplier' adjustment which is used in conjunction with curves supplied with the relay.

2.3.3 Combined inverse Time Overcurrent and High Set Instantaneous Relay (OCIT/OC)

An inverse time relay may be equipped with an additional instantaneous element in the same casing but operating at a 'high-set' current value. This gives it the feature of a combined 'inverse-time and high-set instantaneous' relay, the instantaneous feature overriding the time delay only on the most severe faults. An example of this additional feature is shown dotted in Figure 1.5

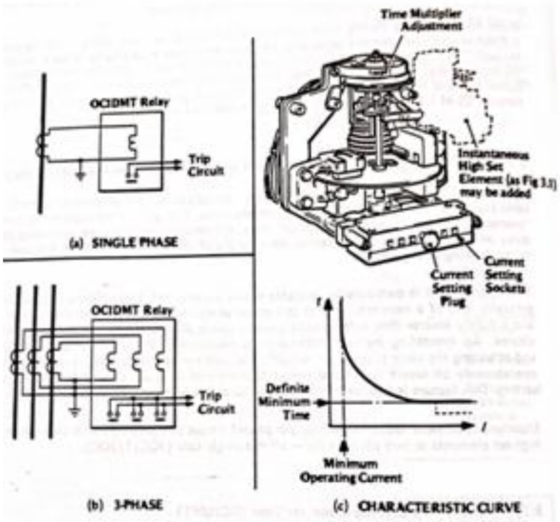

Fig 1.6

This arrangement is particularly desirable where overcurrent protection is installed near the generator end of a network. It is this end that discrimination requires the longest delays, and a purely inverse-time relay would allow a severe short-circuit to persist until eventually cleared. An overdriving high-set instantaneous overcurrent relay, fed through the same CTs and actuating the same trip circuit, would clean such current very quickly. It would however operate only on severe faults and would take no part in fault currents below its own high setting. Usually a 3-element OCIT relay (one per phase) would be combined with two instantaneous high-set elements in two phases only – all in a single case (3OCIT/2OC).

2.3.4 Inverse and Definite Minimum Time (OCIDMT)

An inverse and definite minimum time overcurrent relay is shown pictorially in Figure 1.6 the current transformer arrangements with single-phase or 3-phase systems are like those for the simple overcurrent relay and are shown in Figure 1.6 (a) and (b). This relay is simply a variation of the inverse-time type shown in Figure 1.5, but here the characteristic, instead of tending towards zero time for the highest fault currents, now tends towards a definite and finite small value, as in Figure 1.6 (c). this is built into the relay and cannot be adjusted.

The relay is similar in construction to the normal inverse time type shown in Figure 1.5.

The purpose of this variation is to render the relay settings more accurate. All characteristic curves are subject to tolerance, and the separation of the sloping curves of Figure 1.5. at the high-current end for different relays must be enough to allow for such tolerances. Therefore, tripping delays would need to be longer than would be necessary with more accurate curves. The definite minimum time feature at the highest currents, making the curves horizontal at those currents, enables greater accuracy (that is, smaller tolerance) to be achieved, resulting in less separation of the curves and consequently shorter tripping times.

An ACIDMT relay may be combined with instantaneous high-set overcurrent elements as described for an OCIT relay in para. (c) it is shown in dotted outline in Figure 1.6

III. RELAYS - GENERAL

Most protective relays are fitted with flags which indicate when they have operated. They show the operator, for example, which of the protective systems may have caused a turbo-generator to have tripped out. Such relays are themselves normally self-resetting-that is, they revert to their normal state as soon as the fault has been removed. This may occur either because the circuit-breaker has tripped, so disconnecting the fault, or because the fault itself has disappeared. The flag however remains showing until it has been reset by hand. In some protective systems, particularly for generators and transformers, all the protective relays trip the breaker through an intervening hand rest trip, or 'lock-out', relay (TH). It two has a flag, but this relay, having once, operated, does not reset itself automatically and so prevents the breaker being reclosed until the relay has been deliberately reset by hand. This prevents accidental reclosure onto a fault, and the breaker remains locked out until cleared by the operator resetting the lock-out relay. Whenever an item of plant has tripped because one of the protective systems has operated, it is most important that the operator should not reset the relay flags until he has carefully noted down which flags are showing. If this is not done, all evidence of the cause of the malfunction will be lost. The lock-out relay must on no account be reset until it is safe to operate the plant again.

IV. ELECTRONIC RELAYS

Those relays which have so far been described are of the 'electromagnetic' type, where an electromagnet provides the driving force to a mechanical system of moving armature or rotating disc and mechanical contacts. Many of these relays are now being superseded an offshore, and numerous onshore, installations by electronic types which are entirely static except for their final output contacts. Electronic circuits carry out the detection, processing and timing, only the output circuit is passed through normal electromagnetic auxiliary contacts to the external trip circuits. This also isolates the trip circuits proper from the electronics.
Though using different methods, electronic relays reproduce similar characteristics to those of the electromechanical types, and they have similar adjustments such as for current and time setting. To illustrate the principle of operation, a single-phase, electronic inverse –time and instantaneous overcurrent relay (OCIT/OC) is described here and shown in Figure below.

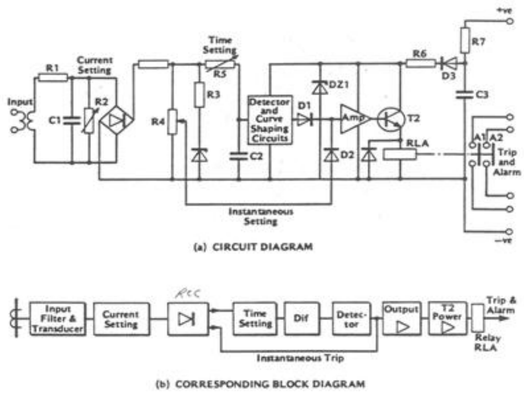

Fig 1.7

The input from the line current transformer is fed through a small adapting transformer to a low-pass filter R1-C1 which suppresses transient voltage surges. A voltage proportional to the input current is developed across the current setting potentiometer R2. this voltage is applied to the bridge rectifier. The d.c. output voltage, which is proportional to the line current, is used to charge the capacitor C2 through the potentiometer R5. The setting of this potentiometer determines the rate at which the voltage across C2 increases and hence the timing of the inverse-time operating characteristic of the relay.

When the voltage across C2 reaches a predetermined value, the detector circuit operates to switch the electromechanical relay, RLA through the output amplifier and power transistor T2. Instantaneous operation is obtained by applying the output voltage of the bridge rectifier directly to the input of the amplifier through R4. thus, for higher values of fault current, the inverse-time delay circuit is bypassed. The power supply for the solid-state circuits is applied through D3 and R6. it is stabilized by Zener diode Dz1, and spike protection is afforded by R7 and C3. the diode D3 protects against reversed polarity of the d.c. power supply. By suitable choice of elements, the electronic relay current/time characteristic can be made to reproduce exactly that of the equivalent electromagnetic type. Having virtually no moving parts, they are, in general, more robust, smaller and lighter. Current and time settings in this case are applied through simple variable resistors.

V. CONCLUSION

Finally, after study the protection devices (fuse, circuit breakers and over current relays).
We find that:

1- protection devices is very essential part of any electrical network or circuit and used to protect both the human and electrical equipment or load.
2- Protection devices which are used in the power system or electrical networks are more than 20 types and we have disused in air subject only three main types.
3- The protection devices which are commonly used in the electrical network are three types (Fuses, Circuit Breakers and over current relays).
4- Circuit breakers are used on both high voltage and low voltage system.
5- The circuit breakers for high voltage system are three types (Oil circuit breakers, Air circuit breakers and Vacuum circuit breakers).
6- The circuit breakers for low voltage systems are three types (Air circuit breakers, Molded case circuit breakers and Miniature circuit breaker)
7- Over current relays consist of four types (Instantaneous over current (OC), Inverse time over current (OCIT), Combined inverse time over current instantaneous relay (OCIT / OC) and Inverse and definite minimum time (OCIDM)).
8- We have learned about the principles of all the previous four types of the over current relays.
9- The principle operation of all types of lover current relay has been described and illustrated.
10- - According to their operation the over current relays are divided into two types (The electromagnetic types which are old in use and the electronic types which are latest in use).

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