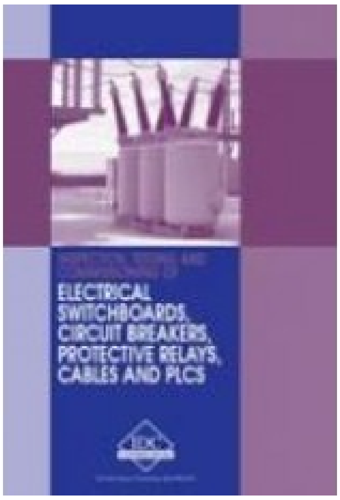
EK-E - Inspection, Testing and Commissioning of Electrical Switchboards, Circuit Breakers, Protective Relays, Cables and PLCs



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Short Description

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Protection relays are then discussed. These are used in power systems to maximise continuity of supply and are found in both small and large power systems from generation, through transmission, distribution and utilisation of power in plant, industrial and commercial equipment.

It also covers commissioning and periodic inspection of cables and their various failure modes and how to detect these faults. The often neglected topic of switchboards is also detailed, followed by the interesting topic of interfacing to the control system (either PLC's or other control devices).

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Fundamentals of Switchgear

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Fundamentals of Switchgear

In this chapter, we will learn about one of the basic, but most important components of any electrical system, namely the Switchgear. As a preparatory step towards the understanding of switchgears, we will review the use of electrical single line diagrams and the types of components that make up electrical systems. We will also study the various applications of switchgear in the later part of this chapter.

Learning objectives

You will learn about:

- Single line diagrams
- Typical construction – LV/MV and HV
- Active and passive network components
- Circuit breaker utilization
- Fuse switches
- HV fuses in combination with and as alternatives to circuit breakers
- Auto-reclosers and auto-reclose operations

1.1 Single line diagram

Electrical systems are mostly made up in the form of three phase configuration. However trying to represent three phase systems in drawings as actual three phase connections may not only be laborious but also make the drawing quite difficult to understand. This is where the concept of single line diagram comes into being. The term 'Single line diagram' simply means that the three phase nature of the circuits and components is ignored. Figure 1.1 shows a typical example of a high voltage distribution network, represented as a single line diagram, complete with transformer infeeds, cable and overhead circuits, distribution substations, circuit breakers and other network switchgear.

Figure 1.1

Typical network as a single line diagram

1.2 Typical construction – LV/MV and HV

Circuit breakers come in a variety of types. The prominent types being:

- Bulk oil circuit breaker
- Minimum oil circuit breaker
- Air blast circuit breaker
- Vacuum circuit breaker
- SF6 circuit breaker

Figure 1.2 shows the construction of a typical bulk oil type circuit breaker. Such breakers used oil as the insulation medium and were very heavy and bulky. They also posed serious fire hazards and oil pollution problems. With the advancements in technology such breakers have over a period of time been gradually replaced with more compact and versatile vacuum and SF6 breakers.

Figure 1.2

Bull oil circuit breaker

Figure 1.3 shows the typical construction of a minimum oil circuit breaker. Similar to bulk oil breaker, oil is used as the insulation medium in this breaker. However, as the name implies, much lesser quantity of oil is used in this type of breaker. Porcelain is used for the construction of the body and minimum oil circuit breakers have much smaller foot prints than the bulk oil breakers.

Figure 1.3

Small oil volume circuit breaker (one phase shown)

Figure 1.4 shows the typical construction of an air blast circuit breaker. High pressure air is used as insulation and arc extinguishing medium. Disadvantages of this type of breaker are the need for a compressed air plant and associated pipe lines.

Figure 1.4

Basic air blast circuit breaker

Figure 1.5 shows the construction details of a vacuum interrupter. Vacuum is used for interrupting and extinguishing the arc at the time of the breaker operation. The ceramic cartridge contains the fixed and moving electrodes maintained under high vacuum conditions. Owing to the sealed nature of the interrupter, the vacuum breaker is impervious to external dust and pollution conditions.

Figure 1.5

Vacuum interrupter

Figure 1.6 depicts the construction details of a typical SF6 gas insulated breaker with a vacuum interrupter. SF6 gas under pressure is used as the insulation medium and this enables the breaker to be constructed quite small and compact. The pressure of the gas needs monitoring on a continuous basis and the purity of the gas has to be checked periodically to maintain the effectiveness of the breaker.

Figure 1.6

Vacuum interrupter in SF6 enclosure switchgear, with rated three position *disconnector (isolator)*

1.3 Active and passive network components

Network components may be divided into two broad categories, those that are continuously in use whenever electricity is being supplied, called the ACTIVE components and those called upon to function only when required to do so, the PASSIVE components.

ACTIVE components comprise transformers, cables, overhead lines and metering equipment and may be considered the main revenue earning elements. **PASSIVE** components compose mainly switchgear in its various forms, together with switchgear's ancillaries, current and voltage transformers and protection relays. These components perform no revenue earning function and may be considered as an added cost, and to be minimized wherever possible.

1.4 Circuit breaker utilisation

In an ideal network having perfect reliability and no maintenance or repair requirement, there is no need to break the electric circuits; however, this is impossible; therefore switchgear has to be installed. However, we should be careful not to install more switchgear than is absolutely required and the switchgear that is installed should have no more functionality than is necessary.

The two most common forms of medium voltage switchgear are automatic circuit breakers and non-automatic, load breaking, fault making switches. The main function of a circuit breaker is to automatically interrupt fault current, although an important secondary function is to close onto a fault and thereby make fault current. This function may be required during for example, fault location. The automatic disconnection of faults by circuit breakers allows the remainder of the network to continue in operation, after the faulty branch has been disconnected. Without this feature, network operation would be 'all or nothing'.

In theory all the switchgear shown in Figure 1.1 could be implemented by circuit breakers, but this choice would be very expensive and result in an excessive maintenance burden. In practice, circuit breakers are normally located only at the beginning of the cable, overhead line or mixed circuit, where they serve to disconnect faults either phase to phase or phase to neutral/earth (or both).

1.5 Fuse switches

Historically, circuit breakers were also utilized at each distribution substation, to control and protect the transformer, although fuse switches may nowadays implement this function. Figure 1.7 shows the cross section of a typical switchfuse unit.

Figure 1.7

Fuse switch in cross section

1.6 HV fuses in combination with and as alternative to circuit breakers

Medium voltage fuses are available up to a current rating equivalent to a three phase rating of approximately 1.5 MVA and offer a cost-effective means of transformer protection. Generally they are combined with a three phase disconnector and a 'trip all phases' device, so that if one fuse fails, the disconnector trips and the supply to the transformer are fully disconnected. If this device were not fitted, the transformer may be subjected to 'single phasing' and a corresponding low LV side voltage.

The use of fuses over circuit breaker has the advantage of lower cost of installation and very fast disconnection (typically less than half a cycle) in the event of a fault. However the disadvantage is the amount of time needed to replace the blown fuse and inability to close or open the circuit from a remote location.

Where fuses are used in conjunction with reclosing type circuit breakers, the satisfactory operation of a circuit breaker in association with fuses depends upon the degree of co-ordination obtained, requiring that the time/current characteristic of the re-closed circuit breaker be graded with those of the fuses to give optimum discrimination. The first trips must be short enough that the fuses are not degraded, whilst the second and third must be long enough to allow the fuses to operate.

1.7 Auto-reclosers and auto-reclose oper+ations

In networks comprising substantial lengths of overhead line, many of the faults that occur are transient in nature. These are caused for example by wind blown debris bridging conductors, insulator flashover, etc. The reliability of the supply may be considerably improved by arranging for the controlling circuit breaker to re-close automatically after a fault occurs. This ensures that for transient faults, the restoration time is measured in seconds, rather than the hours it might take for an engineer to travel to the substation and re-close the circuit breaker manually.

On overhead line networks, most transformers and spur lines are protected by medium voltage expulsion type fuses and it will be necessary for the protection/re-close relay of the circuit breaker controlling the circuit to grade with these fuses. This ensures that where a fault on a connected transformer or spur line is permanent, the circuit breaker will close for long enough to allow the fuse to blow, before the circuit is re-energized. Fitting the circuit breaker with a timing mechanism to provide, for example, two instantaneous trips and two delayed trips fulfils these requirements. The timing sequence adopted varies according to local conditions, but Figure 1.8 shows a typical arrangement.

Figure 1.8

Typical auto re-close sequence

The timing sequence is described as follows. At the instant when the fault occurs, the circuit breaker trips immediately and remains open for 1 second. This period is intended to allow for any ionized gases to clear. The circuit breaker then attempts a first re-closure. If the fault is still present, the circuit breaker trips again and remains open for a further 1 second. The second re-closure then occurs, but this time, if the fault is still present, tripping is delayed. This is because the system assumes that the fault lies beyond a fuse or fuses and it therefore allows sufficient time for the fuse(s) to rupture. If fault current still persists, a third re-closure is attempted, again with delayed tripping.

After this, the system assumes that the fault is permanent and 'locks out'. It must be re-set either manually or over a telecontrol system. If the fault is cleared at any time during the sequence, the system re-sets itself automatically, ready for the next fault and re-closure sequence.

It should be appreciated that whilst re-closing is not a problem for vacuum and SF_6 circuit breakers, oil circuit breakers have a very limited re-closing capability, depending upon the fault level. Normally, the number of re-closures that may be performed by an oil circuit breaker is programmed into the controlling auto re-close relay and when that limit is reached, further auto-reclosing is prevented until the circuit breaker has been maintained. The advice of manufacturers should be obtained when deciding upon the number of re-closures a particular design of oil circuit breaker may perform.

A disadvantage of re-close type circuit breakers is that, where the controlled network comprises both overhead line and cable, the supply to cable supplied customers will be adversely affected by re-closing operations caused by faults on the overhead network. In practice, this means that the customers on the cable network will experience momentary losses of supply, which they would not experience if the network were not re-closed. In addition, in the case of cable and plant faults, the additional fault closures may well cause additional damage. This effect can be reduced by good network design, where the cabled part of the network is controlled by a circuit breaker not fitted with auto-reclose, whilst the overhead line part of the network is controlled by the pole mounted auto recloser. Originally, oil filled pole-mounted reclosers were used for this purpose, but vacuum and SF_6 designs are now available.

The type of recloser shown in Figure 1.9 has great operational advantages in that the maintenance requirements are low and the unit may be regarded as almost maintenance free, at least so far as the user is concerned, being limited to simple replacement of the primary battery at perhaps 5-year intervals. The vacuum interrupters will provide hundreds of reclosers; eventually, replacement will be required but this is a return to factory operation. A further advantage is that the bushings are elastomeric and less readily damaged than porcelain, either during installation or in service.

In these units the control system is normally sited in a lockable metal box close to ground level, remotely from the recloser proper and connected to it by a multicore (umbilical) cable. Because the protection system is microprocessor controlled, any number of possible reclosure strategies may be implemented, exactly as the operator requires and in addition, the unit is easily re-programmed to suit changing operational circumstances.

Figure 1.9

Vacuum interrupter in SF6 auto-recloser