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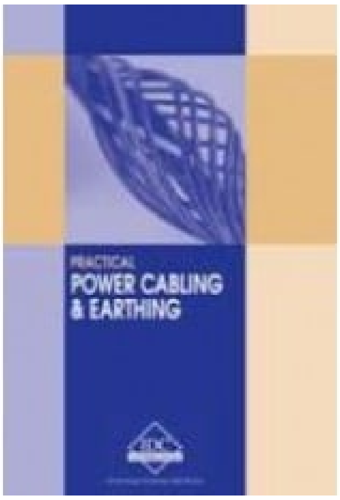
OW-E - Practical Power Cabling and Earthing



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Short Description

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First Chapter

Practical Power Cabling and Earthing - Introduction

1 **Introduction**

In this chapter, we will discuss the role of power cables in electrical power systems and issues in ensuring trouble free operation of cabling. We will discuss the importance and functions of earthing in electrical installations.

Learning objectives

- Power cables in electrical systems
- Main issues in ensuring trouble free operation of cabling
- Principles of earthing and its importance
- Various functions of earthing in electrical installations
- System earthing and protective earthing

1.1 Role of power cables in electrical power systems

Cable is a general term used to denote a bundle of wires, such as wire ropes. An electrical cable is a bundle of electrical conductors used for carrying electricity. An insulated cable has a covering of an insulating material over the conductor in order to protect persons from direct contact with the electrical conductor, thus risking an electric shock. Though the term cable does not automatically imply insulation or even an electrical conductor, in current electro-technical terminology, a cable is taken to mean an insulated current carrying conductor. In this text, the term cable will be solely used to represent such a conductor. There are several types of electrical cables which are classified based on their application. Power cables transfer power, control cables transfer control variables or impulses, instrumentation cables transmit measured values and communication cables and data cables transfer analog or digital data in telecommunication networks. The type of cable we will be covering in this course is the Power Cable.

Utility companies produce power from electrical generators also sometimes called as alternators driven by prime movers. The prime movers that drive the generators are steam turbines in the case of thermal and nuclear power plants, water wheels and water turbines in the case of hydro power stations and wind turbines in the case of windmill generating stations. The power thus produced needs to be evacuated or sent to the users' factories or houses for their use / consumption. This is made possible by the use of overhead transmission lines or by the use of electric cables, which connect the utility station and the users' loads. Overhead transmission lines comprise an open system of conductors made of steel and aluminum or copper wires strung over porcelain or ceramic insulators. Figure 1.1 shows a typical high voltage overhead transmission line system terminating at a substation.

Figure 1.1

Typical view of an overhead transmission line terminating at a substation

Electric cables used for transfer of electrical energy comprise copper or aluminum wires with layers of insulating materials over the conductors. Figure 1.2 shows a typical view of a high voltage cable for 33kV applicati

Figure 1.2

Typical view of a 33kV, cross-linked polyethylene cable

Overhead transmission lines cannot be installed at all applications due to reasons attributable to environment, space requirement, safe clearances etc. and likewise, cables cannot be used in all applications for reasons attributable to economic voltage level, distance, leakage current through the insulation etc.

Thus, it has become the practice to use cables for low voltage and medium voltage for power distribution in cities and other crowded habitats, whereas overhead lines are used in rural areas for power distribution both in low and medium voltages. Power distribution in large industrial plants invariably uses cables for all voltages (the voltage rarely goes beyond 33 kV) since the use of overhead lines will be difficult and cumbersome. Cables are invariably laid underground either buried directly in the soil or run through underground cable tunnels, trenches or cable ducts.

Power transmission which is the responsibility of utilities is invariably done using overhead transmission lines, and is usually done at high (above 1 kV) or extra-high voltage (220kV+). There are however some exceptions. Transmission of power from a mainland to an island is often done using undersea (also called as submarine) cables, usually using high voltage dc (HVDC) as the transmission voltage. In large cities, cables of high and extra high voltages are also used for the sub-transmission system due to difficulties in installing overhead conductors as the lines involve considerable space for ensuring safe clearances with nearby structures. Over a period, overhead lines would be eliminated in our cities for various reasons explained above and high voltage cables would replace them. Due to restrictions of location, all outdoor substations inside cities would be converted into compact gas insulated indoor substations and most new substations would be indoor type in future. High voltage cables would play a crucial role in such cases i.e., for interconnections to and from indoor substations.

Apart from underground cables, there is another application where insulated cables are installed overhead (instead of bare conductors). Systems where such cables are used are called Aerial Bundled Cable (ABC) systems. Such systems combine the advantages of overhead line with those of cables and often find application in semi urban and rural areas. They are much more immune to lightning effects and failures caused by vegetation and animal life which are common with bare overhead conductor systems, thus improving system availability. The requirement of electrical clearances is much less and thus the right of way requirements are reduced considerably.

1.2 Trouble-free operation of cables

The manufacturing process of cables has been perfected over several decades and failure mechanisms are well understood. Moisture ingress is largely avoided by the cable construction and cable sheaths of PVC can withstand chemical activity from outside environment/soil. The quality of materials used and control of manufacturing process have been improved to such an extent that it is usual for a cable to last for periods longer than 30 years and often up to 50 years. The main problems arise from:

- Mechanical activities in the vicinity which can cause physical damage to the cable (in the absence of proper protection).
- Accessories such as cable splicing and termination kits: Inadequate design and faulty preparation.
- Improper selection of the cable (especially the current rating) for the environment of use.
- Over voltages arising from system operation or due to external factors such as lightning induced surges.
- Installation problems causing excessive stresses (pull tension being high or sharp bending).

1.3 Earthing and its importance

Earthing can be defined as an intentional connection of an electrical system component and a common reference point called ‘earth’ or ‘ground’. Usually the reference point is the soil mass. This connection is achieved by placing a metal rod or a section (a plate, a strip etc.) in contact with soil containing a reasonable amount of moisture.

Figure 1.3 shows an earthing rod usually referred to as an ‘earth electrode’.

Figure 1.3

A typical earth electrode used in electrical installations

There are situations where an electrical system cannot be connected to the soil mass, examples being on a ship or an aircraft. In such cases the metallic structure/chassis is considered as the reference point and connections are established to these reference points. Figure 1.4 illustrates the metal chasis.

Figure 1.4

A metal chassis being used as earth reference

Earthing serves the following principal purposes:

- It provides an electrical supply system with an electrical reference to the earth mass. By connecting a particular point of the supply source to the earth (such as the neutral of a three phase source), it is ensured that any other point of the system stays at a certain potential with reference to the earth.
- A metallic surface of the enclosure of an electrical system is earthed to ensure that it stays at earth potential always and thus remains safe to persons who may come into contact with it.

Electrical systems were not always earthed. The first systems were unearthed ones with no earth reference at all. Even though such systems still exist in specific areas, they are the exceptions rather than the rule and by and large, some form of earthing is adopted for all power systems. We all know that the insulating layer around the current carrying conductors in electrical systems is prone to deterioration. When a failure of insulation takes place due to aging, external factors or due to electrical or thermal stress, it is necessary to detect the point of failure so that repairs can be undertaken. In a system that has no earth reference at all, it is not easy to correctly pinpoint the faulted location. Refer to Figure 1.5(a), which shows such a system. It can be seen that due to the absence of a conducting path through earth, the fault remains undetected. If, however, a second fault occurs in the unaffected line at some other point in the system, it can cause a shorting path and results in the flow of high magnitude fault currents that can be detected by protective devices.

To detect the first fault point as soon as it happens without waiting for a second fault to develop, we earth one of the two poles of the source S (refer to Figure 1.5b). The pole that is earthed is generally called the neutral and the other, 'Line'. It would be of interest to note that the connection between neutral and earth is only at the source. The return current from the load flows only through the neutral conductor back to the source. For this reason, the neutral is always insulated from earth and usually to the same degree as the line conductor. When there is an insulation failure in the line conductor, high current flows through the electrical circuits and through the earth path back to the source and depending on the resistance of the earth path, the current flow in this path can be detected by appropriate protective equipment.

Figure 1.5 (a) and (b)

(a) Fault in unearthed system, (b) Effect of earthing the neutral

Thus, one of the primary purposes of earthing is to permit easy detection of faults in electrical systems by providing a path for the flow of currents from the fault point through the earth (and sometimes the earth mass) back to the neutral point of the source.

Now let us take a step further and see as to why it is necessary for this earth reference to be extended to the consumer installation. While Figure 1.5(b) shows that the source is earthed, it does not indicate another point of connection to earth. However, in practical systems, the fact that a failure of insulation takes place does not mean that an earth connection is automatically established. This can only be done if the point of failure is connected to earth through a low impedance earth path. Such a path is created using a reference earth bus at the consumer end and connecting the metallic housing of all electrical equipment to this bus (refer to Figure 1.6).

Figure 1.6

Fault current flow in an earthed system

In fact, it is preferable to have the earth terminal of a low voltage (LV) consumer installation directly connected to the neutral of the source to ensure that the earth fault current has a low impedance path not involving the soil mass. It is difficult to predict accurately the resistance of the earthing system (mainly the earth electrodes) under all conditions and hence except for high voltage systems, the emphasis will be on obtaining direct metallic continuity for fault currents arising from insulation failures. It should be noted that the neutral of the downstream load is isolated from the earth and the connection between neutral and earth is still at the source point only. We will cover the different ways in which the neutral and earth references are distributed by a supply system to its consumers (giving rise to different categories of systems).

We will also see in a subsequent chapters as to how the earthing of metallic enclosures of current carrying equipment fulfills another important function; that of making the systems safe for operation by human beings without fear of electrocution in the event of an insulation failure in the live parts.

1.4 System earthing and protective earthing

It is evident from the foregoing discussions that earthing performs two major functions in electrical systems. The first is to provide a reference for the conductors of an electrical system to earth. This is called system earthing. The other major function of earthing is to reduce electric shock hazards to personnel by clamping the potential of metallic enclosures of electrical equipment to that of earth. This is called protective earthing.

A well designed earthing system will:

- Provide a low impedance return path for earth fault currents back to the power source so that the occurrence of fault can be sensed by the circuit protective devices and faulty circuit can be safely isolated.
- Minimize fire or explosion hazard by providing an earth path of adequate rating, matching the let through energy by circuit protective devices.

(Note: Apart from these, earthing of a building or structure helps to divert the energy of a lightning strike on the building/structure to the earth safely and avoids damage to the equipment or occupants within the building/structure. In the case of a lightning strike on electrical systems with exposed overhead conductors such as transmission lines or outdoor substations, lightning energy is diverted to earth through surge protection devices connected to the electrical system.

Another function of earthing is to dissipate accumulated static charges on machinery parts and electronic assemblies containing sensitive circuits to avoid damage or accidents. Earthing also protects equipment from external electrical noise including Electro Magnetic Interference (EMI). These aspects of earthing are however beyond the scope of this text.)

1.5 Summary

A power cable is an assembly of two or more electrical conductors, usually held together with an overall sheath. The assembly is used for transmission of electrical power. Power cables may be installed as permanent wiring within buildings, buried in the ground, run overhead, or exposed. Flexible power cables are used for portable devices, mobile tools and machinery.

Earthing is as an intentional connection of an electrical system component and a common reference point called ‘earth’ or ‘ground. One of the primary purposes of earthing is to permit easy detection of faults in electrical systems by providing a path for the flow of currents from the fault point through the earth (and sometimes the earth mass) back to the neutral point of the source. We will discuss the details of system earthing and protective earthing in later chapters. We will also discuss the correlation between the way cables or selected or rated and the type of system earthing used and how earth faults within a cable are safely handled by proper design and construction of the cable and cable accessories in following chapters.