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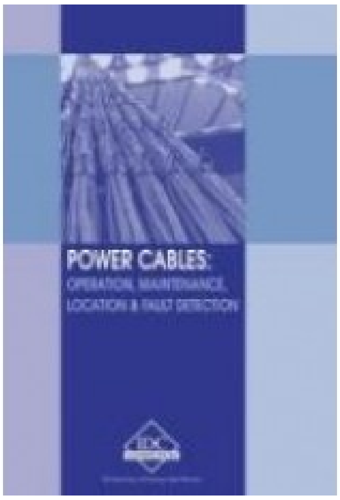
PO-E - Power Cables Operation, Maintenance, Location and Fault Detection



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Short Description

Locating power cable faults with minimal excavation time requires efficient, experienced and accurate technical staff to attain service reliability. This manual is designed to ensure that those responsible for the selection, laying, operation, maintenance and monitoring of power cables understand the technical issues involved and comply with relevant specification and requirements.

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Power Cables: Operation, Maintenance, Location and Fault Detection - An Introduction

1 Cables and Accessories - An Introduction

In this introductory chapter, we will discuss the need for power transmission and distribution through HV cables as well as their advantages and disadvantages compared to overhead power line. We will discuss the different types of high voltage cables, the need for jointing/termination, as well as the various types of jointing/termination kits that are available in the market.

Learning objectives

- Need for high voltage cables
- Advantages of using cables over overhead transmission lines
- Disadvantages of cables
- Various types of high voltage cables
- Need for cable jointing
- Need for termination
- Various types of jointing kits and termination kits

1.1 Introduction

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 reducing the risk of 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.

Utility companies produce power from electrical generators, also sometimes called 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 of an open system of conductors made from 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 comprise of 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 application:

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.; likewise, cables cannot be used in all applications for reasons attributable to economic voltage level, distance etc.

Therefore, it has become the practice to use cables for low voltage and medium voltage for power distribution in cities and other crowded habitats; however, overhead lines are used in rural areas for power distribution both in low and medium voltages. Power distribution in large industrial plants invariably use cables for all voltages (the voltage rarely goes beyond 33 kV) since the use of overhead lines would be difficult and cumbersome. Power transmission which is the responsibility of utilities, is invariably done using overhead transmission lines and is usually at high and extra-high voltage. In large cities, cables of high and extra high voltages (up to 220 kV) are also used for the sub-transmission system due to difficulties in installing overhead conductors, as the lines require considerable space for ensuring safe clearances with nearby structures. Over a period, overhead lines would be eliminated in our cities for various reasons (some explained above) and high voltage cables will replace them. Due to restrictions of location, all outdoor substations inside cities will be converted into compact gas insulated indoor substations and most new substations will in future be the indoor type. High voltage cables will play a crucial role in such cases i.e., for interconnections to and from indoor substations.

1.2 Low and high voltage cables

As we saw in the previous section, cables need to be manufactured for a wide range of voltages. Low voltage cables (often rated as 1100 volts, grade as well as higher voltages such as 3.3 kV, 6.6 kV, 11 kV, 22 kV and 33 kV). While the lower voltage cables are used for consumer loads such as lighting and motive power, higher voltages often become necessary for economy of distribution and for direct feed to larger rating of loads.

Normally power produced by the generators at the utility stations varies from 6600V to about 15000V depending on the output rating. Thus, power produced at the above voltage can be used at the same voltage level for consumers living in the same or nearby locality by the use of a properly designed distribution system. For consumers living in far off places or for consumers situated in a huge, well spread out factory such as an integrated iron and steel works, it is not economically possible to make the above connections (called transmission of power) at the generated voltage, due to increase in energy losses.

Transmissions at higher voltage say 33kV, 66kV, 110kV, 132kV, 220kV etc. mitigate the above drawback and bring down the energy loss levels significantly. In order to achieve a higher transmission voltage level, the voltage level of the generated power needs to be stepped up or increased using step-up transformers. At the consumer end, step-down transformers are used to bring back or change the voltage to a lower value suitable for the consumer.

In addition, loads such as electric motors operate at higher voltages at higher output ratings. In general, the following table gives the relation between motor ratings in kW and their voltage level of operation:

Table 1.1

Motor output and commonly used voltage rating

From the above table it can be seen that large motors need power supply at higher voltages and therefore require the use of high voltage cables. There are other examples of loads which would need operation at high voltage such as furnace transformers, electrostatic precipitators in dust control systems etc.

Thus, we see that for the basic needs of power distribution inside a factory or for transmitting to far off consumers, high voltage cables are needed.

1.3 Advantages over overhead transmission lines

In general, we can note that high voltage cables have the following advantages over the overhead transmission lines:

- In crowded metros, overhead transmission lines occupy a large footprint, and apart from looking grotesque, pose a safety problems. Requirement of a large area calls for land space as well as clearances around the conductors (referred to often as ‘a power alley’). This is becoming increasingly difficult to provide in today’s crowded metropolitan cities and their satellite townships. In such cases, high voltages cables offer the advantage of installation in cable trenches or underground cable tunnels thereby freeing valuable land space over ground. The cables can also be buried directly in ground preferably routed in the space provided along side the roads called the “berm”. Freeing of land space has helped in the saving of cumbersome land acquisition procedures and associated litigation issues.
- Ecological restrictions as well as very high real estate costs favor the installation of high voltage cable systems. Sometimes, the objections include visual pollution of an area of natural scenic beauty or a historic site by the incongruous transmission structures. Another problem is the high electromagnetic interference associated with exposed electrical lines.
- In areas prone to atmospheric lighting discharges, the overhead transmission lines suffer frequent breakdown and cause power outages. High voltage cables are not affected by the above atmospheric discharges, as they are either buried in the ground or routed inside a tunnel or trench.
- Due to higher surge impedance, high voltage cables offer increased protection from switching surges to various equipment, mainly transformers in installations such as outdoor switchyards.
- For power supply to small islands, it is only possible to transmit power through underwater high voltage cables, as overhead transmission lines are ruled out in such applications.

1.4 Disadvantages of cables in power transmission

While we saw high voltage cables score over overhead transmission lines in a few situations, they also suffer from a few disadvantages:

- Location of fault in a high voltage cable system is more difficult compared to an overhead transmission line system.
- High voltage cable systems are expensive in voltage levels higher than 33kV when compared to overhead transmission line systems either for the purpose of intra-plant distribution or for interplant transmission of power.
- High voltage cables of the oil filled type call for monitoring and inspection schedules which need to be implemented strictly. In the case of overhead transmission lines, such schedules are less stringent and rectification, if needed, is easier in comparison to the cable systems.
- Cable joints and terminations are expensive and require factory trained and skilled technicians for their installation. In comparison, jointing and termination in overhead transmission line systems are straightforward and simple.
- The joints and terminations in the high voltage cable system pose a cause for worry to the maintenance personnel since they are the weakest links in the otherwise robust electrical system. This calls for constant monitoring of the joints and terminations.
- Testing of high voltage cable systems is a time consuming process compared to testing of overhead transmission line systems.

Therefore, we can conclude that selection of transmission system requires elaborate research and the choice of high voltage cables or overhead systems should be made judiciously.

1.5 Various types of cables

We can classify high voltage cables broadly into different types based on the insulation medium used. These are:

- PVC insulated cables
- VIR insulated cables
- Low pressure oil filled cables
- High pressure oil filled cables
- Paper insulated cables
- Polyethylene (PE) insulated cables
- Cross linked polyethylene (XLPE) cables

Cables can also be classified according to the voltage grades, such as low voltage cables, medium voltage cables, high voltage (HV) cables and extra high voltage (EHV) cables, which in turn is decided by the system voltage where a cable is used. In fact, the type of insulation discussed above is very much dependent on the voltage grade of the cable. The voltage grade based classification can however vary between different countries as no uniform classification is followed internationally. In the forthcoming chapters, we would learn more about the construction and use of these various cables. While MV and HV cables are very common in industrial plant applications, the use of EHV cables is almost restricted to utilities in distribution circuits.

Power cables are also grouped according to the number of cores: single-core, 2-core, 3-core and so on. Multi-core cables are commonly used only up to MV levels. HV and EHV cables are always of the single core type.

1.6 Cable jointing (splicing) accessories

Cable manufacturers produce cables in standard lengths ranging from 300m to 1000m and deliver them to the customers wound on drums. The above lengths depend on the type and unit weight (kg/m) of the cable that is being manufactured. The weight of the cable drums is substantial and a typical drum with 500m of 3cx240 sq. mm of XLPE insulated cable can weigh up to 7500 kg**.** This introduces a bottleneck in terms of the handling capacity at the cable factory. In addition, large unwieldy drums can pose problems during transportation and installation of the cables at site. Thus, cables need to be supplied in pre-agreed lengths. If the feeder length in any system exceeds the standard lengths, it is necessary to use multiple lengths of cable for that feeder; this is when joints are needed. Cable joints as the name implies, joins the tail end of the first cable and the head end of the second cable. Cable companies themselves, or some other manufacturers who specialize only in joints, offer “jointing kits”. We use these kits whenever we need a joint. Also in the case of cable failure in an existing installation, it would be prudent to remove the damaged portion and replace this section with a new length by jointing to the healthy portions of the cables.

Every user would prefer to install their cables without joints, but due to inevitable reasons (some explained above), cable joints become a necessity. In general, users feel that a cable joint is a weak point in the distribution chain. On the contrary, jointing kit manufacturers vouch that a properly made joint is as good as the original cable. In addition, joints are required when two cables of dissimilar construction are to be jointed. This happens when an expansion takes place in an existing factory. Likewise, “T” joints are required in certain distribution schemes. Another type of joint is the “branch Y” joint which is used in a few applications.

We can group the various types of joints broadly as:

- Straight through
- Branch Y joints
- T joints
- Transition joints

Depending on the type of insulation of the cable under use, there are further variations in the above types. Also, distinction is sometimes decided in terms of the location where the joints are made, namely, indoor types or outdoor types. We will study the various types of jointing kits in the forthcoming chapters.

Figure 1.3 shows typical variants of cable joints:

Figure 1.3

Various types of cable joints

1.7 Need for termination kits

Cables also need special kits for the purpose of their termination at sending end and at receiving end. Every cable, whether it is low-tension type or high-tension type, needs proper termination so that a cable run can be connected to a piece of equipment, usually a circuit breaker, a transformer, or a motor and so on. There are basic requirements such as cable boot, cable lugs and consumables like insulation tapes and cable glands used for low voltage cables etc. In the case of high voltage cables there are other accessories related to sealing, stress control etc. These are called “termination kits”, which can be either procured from the cable manufacturers or from specialized manufacturers of jointing kits as mentioned above, who also make the termination kits. These aspects will be discussed in detail in the forthcoming chapters. In addition, basic types of termination kits vary with respect to their location: indoor or outdoor.

Proper termination kits with proven test results are of great importance in order to provide faultless terminations. An improperly made termination would result in the heating of the joint and eventual flashover and outage in the systems.

The manuals supplied with the kits give a systematic procedure for going ahead with the preparation and completion of the termination. Besides the manual, some amount of hands-on training is also needed to carry out a sound job. Figure 1.4 shows a typical high voltage cable termination arrangement:

Figure 1.4

Typical HV cable termination

We can group the various types of termination kits broadly as:

- Indoor termination kits
- Outdoor termination kits (the arrangement shown in the figure above)
- End sealing kits

The first two types explained above are for active terminations. The third type, namely, the end sealing kit, is used whenever cable ends are to be left without use for a long time. As with cables, there is also a continuous improvement in the field of cable accessories such as jointing and termination kits. There are new composite type insulator designs, which have greatly reduced weights and provide extra creepage distances. These insulators are of the self-cleaning type with excellent properties in areas of fire resisting capability and UV radiation resisting capability.

Cables need to be jointed and/or terminated by skilled technicians who use standard jointing/termination kits. We will study the various types of termination kits in later chapters.

1.8 Installation of cables

Cables must be installed with care as per manufacturer's recommendation and as per installation codes as per their voltage class. This is essential for a long and trouble-free service. Cables by themselves are capable of a number of years of service as they are entirely stationary with no moving components to wear out. However, improper installation may cause gradual damage and will lead to premature failures of the insulation. Faulty installation can also leave the cable vulnerable to external mechanical damage resulting in failures.

The method of installation varies depending on the site requirements. A cable can be:

- Directly buried in soil
- Installed in ducts/conduits
- Installed in air and supported by appropriate structures for support

The selection of the cable (conductor size, insulation, mechanical protection etc.) will depend on the method of installation used for the cable.

Installation thus involves:

- Preparation of installation site
- Arranging cable supports
- Unwinding of cable from the cable drum
- Laying along the supports and clamping to prevent dislocation
- Threading through pipes where a cable duct is used
- Jointing
- Termination
- Testing

Testing is necessary to ascertain the health of the installation before energizing the cables for the first time; testing needs to be repeated at suitable intervals to ensure that the cables are still healthy and to ensure that no appreciable deterioration has resulted which could cause a premature failure in service.

1.9 Summary

Cables play an important role in the power distribution in the modern world. There is continuous improvement in material science, which brings about a better quality of materials and accessories that go into the manufacture of cables and the various jointing kits and termination kits.

Eventually, overhead transmission lines will be eliminated in our cities for various reasons explained above and high voltage cables will replace them. Due to ecological restrictions, all outdoor substations will be converted into compact gas insulated indoor substations. In fact, all new substations will be of the indoor type in future. High voltage cables will play a crucial role in such cases i.e., for interconnections to and from indoor substations. Testing is an important area once the cables are installed, jointed and terminated. Testing is crucial, as it reveals the quality of work done. We will be investigating the above aspects in detail in later chapters.