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CJ-E - Practical HV Cable Jointing and Terminations for Engineers and Technicians

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Short Description

Cable terminations and joints form the weakest link in any distribution system. Also, a failed joint in an underground distribution system is much more difficult to locate and repair compared to any similar problem in overhead distribution systems. This means that we should do our utmost to achieve a good joint or termination, which can give years of trouble-free service.

Description

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This manual discusses these issues by looking at the fundamental theoretical aspects involved so that the importance of the correct execution of a termination or joint is emphasized.

Table of Contents

Download Chapter List

Table of Contents

First Chapter
Practical HV Cable Joining and Terminations for Engineers and Technicians - Overview

1 Overview

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 with overhead power lines. We will also discuss the different types of high voltage cables, the need for jointing/termination, as well as 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

Utility companies produce power from electrical generators, also 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 etc. Likewise, cables cannot be used in all applications due to reasons such as voltage levels, distances etc.

Cable manufacturers produce cables in standard lengths ranging from 300m to 1000m. The above lengths depend on the type and unit weight (kg/m) of the cable that is being manufactured. Therefore, if our requirement for cable exceeds the standard length, we need to use an additional length of cable to complete our work: hence the need for joints. Cable joints as the name implies, join the tail end of the first cable to the head end of the second cable. Cable companies, or some other manufacturers who specialize in joints, offer “jointing kits”. We use these kits whenever we need a joint.

Cables also need special kits for the purpose of their termination at sending end and at receiving end. These are called “termination kits”, which can be either procured from the cable manufacturers or from the specialized manufacturers of jointing kits. Cables need to be installed with care as per manufacturer’s recommendation and as per installation codes with regard to their voltage class. Cables also need to be jointed and/or terminated by skilled technicians who use standard jointing/termination kits.

1.2 Need for high voltage cables

Normally power produced by the generators at the utility stations varies from 6600V to about 15000V depending on the output rating. Because of this, power produced at the above voltage can be used at the same voltage level for consumers living in the same or nearby localities through the use of a properly designed distribution system. For consumers living in far off places or for consumers situated in a huge factory facility, 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 voltages 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 and 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

Motor rating in kw	***Operating voltages in Volts***
Up to 200kw	415V
Between 200 to 500kw	3300V
Between 500kw to 2500kw	6600V
Above 2500kw	11000V

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

Therefore, we can 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 cities, overhead transmission lines occupy large areas. Apart from looking grotesque, they also pose safety problems. Overhead transmission lines require large areas of land space, as well as further areas of clearances around the conductors calling for 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 the ground preferably routed in the space provided along side the roads called the "berm". Furthermore, the freeing of land space has helped in the reduction 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. The ecological objections include the visual pollution of an area of natural scenic beauty or the invasion of an 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 would suffer frequent breakdown causing power outages. High voltage cables are not affected by atmospheric discharges, as they are safe either buried in 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 possible to transmit power only through underwater high voltage cables as overhead transmission lines are obviously ruled out in such applications

1.4 Disadvantages of cables in power transmission

While we saw that high voltage cables have some notable advantages over overhead transmission lines, they also suffer from a few disadvantages:

- It is more difficult to locate a fault in a high voltage cable system than in 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 when compared with 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 are a constant worry to the maintenance personnel, since they are the weakest links in an 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 the testing of overhead transmission line systems.

Thus, we can conclude that the selection of a transmission system needs to be examined carefully, and the ultimate choice of high voltage cables or overhead system should be made judiciously.

1.5 Various types of high voltage cables

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

- Low pressure oil filled cables
- High pressure oil filled cables
- Paper 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 are 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, use of EHV cables is almost restricted only to utilities and further restricted in distribution circuits.

Power cables are 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 Need for cable jointing (splicing)

Cables are manufactured in standard lengths and delivered to customers wound on drums. The weight of the cable drums is substantial and a typical drum with 500m of 3cx240 sq. mm. XLPE insulated cables can weigh up to 7500 kg**.** This introduces a bottleneck in terms of handling capacity at the cable factory. In addition, large unwieldy drums can pose problems during transportation and installation of the cables at the site. Therefore, joints are needed in order to install large lengths. In the case of cable failure in an existing installation, it would also be prudent to remove the damaged portion and replace this section with a new length, by jointing with the healthy portions of the cables.

Every user would prefer to install their cables without joints, but due to inevitable reasons such as those 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 of the above types. Also, sometimes a distinction is made on the location of the joints, for example, whether they are an indoor type or an outdoor type. We will study the various types of jointing kits in the forthcoming chapters.

Figure 1.3 shows typical cable joints:

Figure 1.3

Various types of cable joints

1.7 Need for termination kits

Every cable, whether it is a low-tension type or a 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 boots, 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 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 do give a systematic procedure for going ahead with the preparation and completion of the termination. Apart from 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, the end sealing kit, is used whenever cable ends are to be left without use for a long time. We will study the various types of termination kits in later chapters.

1.8 Summary

High voltage cables play an important role in power distribution in the modern world. There are continuous improvements occurring in material science, which results in a better quality of materials and accessories which go into the manufacture of cables and the various jointing and termination kits.

Over a period, overhead transmission lines will be eliminated from our cities for various reasons (some 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 the future. High voltage cables would play a crucial role in such cases i.e., for interconnections to and from indoor substations. As with the 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 self-cleaning types with excellent properties in areas of fire resisting capability and UV radiation resisting capability. Testing is an important area once the cables have been installed, jointed and terminated. Testing is crucial, as it reveals the quality of the work performed. We will be investigating the above aspects in detail in the later chapters.