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Mechanical Design of Overhead Lines

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Mechanical Design of Overhead Lines

Electric power can be carried either by underground cables or overhead transmission and distribution lines. The underground cables are not typically used for power transmission due to two reasons.

1. Power is carried over long distances to remote load centres. Obviously, the installation costs for underground transmission will be huge.

2. Electric power has to be transferred at high voltages for economic reasons. It is very difficult to achieve proper insulation to the cables to withstand higher pressures.

Therefore, power transfer over long distances is done by using overhead lines. With the power demand increase and consequent voltage level rise, power transmission by overhead lines has assumed significant importance.

Nevertheless, an overhead line is subjected to various weather conditions and other external interferences. This asks for the use of adequate mechanical safety factors in order to ensure the continuity of line operation. Typically, the strength of the line needs to be such so it can withstand the worst probable weather conditions. This course focuses on the different aspects of mechanical design of overhead lines.

Overhead Line Main Components

An overhead line may be used to transfer or distribute electric power. The proper overhead line operation depends to a big extent upon its mechanical design. While constructing an overhead line, it has to be verified that line mechanical strength is such so as to provide against the most probable weather conditions. Typically, the main elements of an overhead line are:

- Conductors which transfer power from the sending end station to the receiving end station.

- Supports which may be poles or towers. They keep the conductors at an appropriate level above the earth.
- Insulators that are connected to supports and insulate the conductors from the earth.
- Cross arms which give support to the insulators.
- Miscellaneous elements such as phase plates, danger plates, surge arrestors, etc.

The overhead line operation continuity depends upon the judicious selection of above elements. Hence, it is beneficial to have detailed discussion on them.

Overhead Line Conductor Materials

The conductor is one of the crucial items as most of the financial outlay is invested for it. Hence, correct selection of conductor material and size is of significant importance. The conductor material used for transmission and distribution of electric power needs to have the following characteristics:

- High tensile strength in order to sustain mechanical stresses
- High electrical conductivity
- Low specific gravity so that weight per unit volume is small
- Low cost so that it can be used for considerable distances

All above demands cannot be found in a single material. Hence, while choosing a conductor material for a particular application, a compromise is made between the cost and the needed electrical and mechanical characteristics.

Typically used conductor materials

Typically used conductor materials for overhead lines are copper, aluminium, steel-cored aluminium, galvanised steel and cadmium copper. The selection of a particular material is dependant on the cost, the needed electrical and mechanical characteristics and the local conditions. All conductors used for overhead lines are typically stranded in order to increase the flexibility. In stranded conductors, there is typically one central wire and around it, successive layers of wires containing 6, 12, 18, 24 ...... wires. Therefore, if there are n layers, the overall number of individual wires is 3n(n+1)+1. In the production process of stranded conductors, the consecutive layers of wires are twisted or spiralled in different directions so that layers are bound together.

- Copper. Copper is perfect material for overhead lines owing to its great electrical conductivity and increased tensile strength. It is typically used in the hard drawn form as stranded conductor. Even though hard drawing slightly decreases the electrical conductivity, it considerably increases the tensile strength. Copper has great current density. For example, the current carrying capacity of copper per unit of cross-sectional area is significant. This leads to two benefits. Firstly, smaller conductor cross-sectional area is needed and secondly, the area offered by the conductor to wind loads is decreased. Also, this metal is homogeneous, durable and has big scrap value. There is no doubt that copper is perfect material for electric power transmission and distribution. Nevertheless, due to its big cost and non-availability, it is not often used for these purposes. Current trend is to use aluminium instead of copper.

- Aluminium. Aluminium is cheap and light in comparison to copper but it has considerably smaller conductivity and tensile strength. The relative comparison of the two materials is as follows:

- The aluminium conductivity is 60% that of copper. The lower aluminium conductivity means that for any specific transmission efficiency, the conductor cross-sectional area must be bigger in aluminium than in copper. For the same resistance, the aluminium conductor diameter is around 1.26 times the copper conductor diameter. The increased aluminium cross-section exposes a bigger surface to wind pressure and, hence, supporting towers have to be designed for greater transverse strength. Typically, this requires the use of higher towers with consequence of bigger sag.

- The aluminium specific gravity (2.71 gm/cc) is lower than that of copper (8.9 gm/cc). Hence, an aluminium conductor has almost one-half the weight of equivalent copper conductor. Due to this, the supporting structures for aluminium need not be made so strong as that of copper conductor.

- Aluminium conductor being light is liable to bigger swings and therefore bigger cross-arms are needed.

- Due to lower tensile strength and bigger co-efficient of linear expansion of aluminium, the sag is bigger in aluminium conductors.

Considering the overall characteristics that include cost, conductivity, tensile strength, weight etc., aluminium has an edge over copper. Hence, it is being predominantly used as a conductor material. It is especially profitable to use aluminium for heavy-current transmission where the conductor size is big and its cost forms a significant proportion of the total cost of complete installation.

- Steel-cored aluminium. Due to low tensile strength, aluminium conductors have bigger sag. This forbids their application for bigger spans and makes them unsuitable for long distance transmission. In order to improve the tensile strength, the aluminium conductor is strengthened with a core of galvanised steel wires. The obtained composite conductor is known as steel-cored aluminium or ACSR (aluminium conductor steel reinforced).

Steel-cored aluminium conductor has galvanised steel central core surrounded by a number of aluminium strands. Typically, diameter of both steel and aluminium wires is the same. Typically, the cross-section of the two metals are in the ratio of 1:6 but can be modified to 1:4 in order to get more conductor tensile strength. Figure 1. presents steel-cored aluminium conductor having one steel wire surrounded by six aluminium wires. The result of this composite conductor is that steel core takes bigger percentage of mechanical strength while aluminium strands transfer the bulk of current.

The steel-cored aluminium conductors have the following benefits:

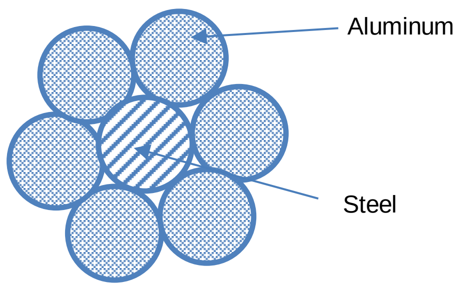

Figure 1. Steel-cored aluminium conductor having one steel wire surrounded by six aluminium wires

- The reinforcement with steel improves the tensile strength but at the same time keeps the composite conductor light. Hence, steel-cored aluminium conductors will create smaller sag and therefore longer spans can be used.

- Due to smaller sag with steel-cored aluminium conductors, towers of smaller heights can be installed.

Purchase this course to see the remainder of the technical materials.