Mechanical Design of Overhead Lines

An Online Continuing Education Course for Engineers

Course Number: E-4060

Credit: 4 Hours / 4 PDH / 4 CPD

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Mechanical Design of Overhead Lines

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Electric power can be transferred either by underground cables or overhead lines. Underground cables are not commonly used for power transmission over long distances for economic reasons.

Overhead lines are subjected to various weather conditions and other external interferences. This requires 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 that it can withstand the worst probable conditions. This course focuses on the different aspects of the mechanical design of overhead lines.

This course is intended for engineers with a desire to understand the basic elements of overhead lines, design principles, calculation methods and factors that affect the overall current carrying capacity.

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.

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- 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 the above elements. Hence, it is beneficial to have a 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, aluminum, steel-cored aluminum, galvanized steel, and cadmium copper. The selection of a particular material is dependent 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

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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 spiraled 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 aluminum instead of copper.

- Aluminum. Aluminum 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 aluminum conductivity is 60% that of copper. The lower aluminum conductivity means that for any specific transmission efficiency, the conductor cross-sectional area must be bigger in aluminum than in copper. For the same resistance, the aluminum conductor diameter is around 1.26 times the copper conductor diameter. The increased aluminum 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 the consequence of bigger sag.

  - The aluminum specific gravity (2.71 gm/cc) is lower than that of copper (8.9 gm/cc).

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Hence, an aluminum conductor has almost one-half the weight of an equivalent copper conductor. Due to this, the supporting structures for aluminum need not be made so strong as that of copper conductor.

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

- Due to lower tensile strength and bigger coefficient of linear expansion of aluminum, the sag is bigger in aluminum conductors.

Considering the overall characteristics that include cost, conductivity, tensile strength, weight, etc., aluminum has the edge over copper. Hence, it is predominantly used as a conductor material. It is especially profitable to use aluminum 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 aluminum. Due to low tensile strength, aluminum 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 aluminum conductor is strengthened with a core of galvanized steel wires. The obtained composite conductor is known as steel-cored aluminum or ACSR (aluminum conductor steel reinforced). Steel-cored aluminum conductor has a galvanized steel central core surrounded by a number of aluminum strands. Typically, the diameter of both steel and aluminum 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 aluminum conductor having one steel wire surrounded by six aluminum wires. The result of this composite conductor is that steel core takes a bigger percentage of mechanical strength while aluminum strands transfer the bulk of current.

The steel-cored aluminum conductors have the following benefits:

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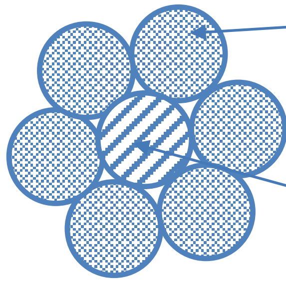

Figure 1. Steel-cored aluminum conductor having one steel wire surrounded by six aluminum wires

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

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

- Galvanized steel. Steel has considerable tensile strength. Hence, galvanized steel conductors can be applied for long spans or for short line sections exposed to significantly high stresses due to climatic conditions. They are considered as very suitable in rural locations where cheapness is the main issue. Due to steel's poor conductivity and high resistance, such conductors are not appropriate for transferring large power over a long distance. Nevertheless, they can be used to advantage for transferring a small power over a small distance where the size of the copper conductor desirable from economic considerations would be too small and therefore inappropriate for use because of poor mechanical strength.

- Cadmium copper. The conductor material now being used in specific installations is copper alloyed with cadmium. An addition of 1% or 2% cadmium to copper improves the tensile strength by roughly 50% and the conductivity is only decreased by 15% below that of pure copper. Hence, cadmium copper conductor can be useful for extremely long spans. Nevertheless, due to high cadmium cost, such conductors will be economical only for lines of small cross-section, i.e., where the cost of conductor material is relatively small in comparison with the support cost.

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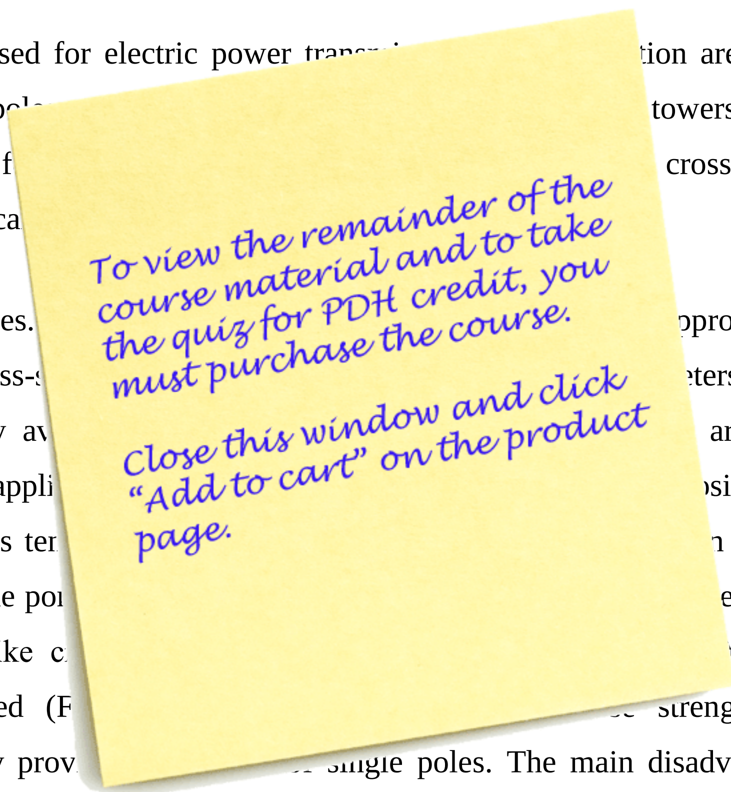
Line Supports

The supporting structures for overhead line conductors are different pole and tower types called line supports. Typically, the line supports should have the following characteristics:

- Light in weight without the loss of mechanical strength
- Big mechanical strength to sustain the conductor weight and wind loads etc.
- Longer life span
- Easy conductor accessibility for maintenance
- Cheap in cost and economical to service

The line supports used for electric power trans... ...tion are of different types including wooden po... ...towers. The selection of supporting structure f... ...cross-sectional area, line voltage, cost, and loca...



- Wooden Poles. ...ppropriate for lines of moderate cross-... ...eters. Such supports are cheap, easily av... ...are widely used for distribution appli... ...osition. Typically, the wooden poles ter... ...n failure. In order to avoid this, the po... ...ed with preservative substances like c... ...' or 'H' type are typically used (F... ...strength than could be economically prov... ...single poles. The main disadvantages of wooden supports are :
  - Tendency to rot below the earth level

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