

Distribution Line Design - Volume 2: Conductors

An Online Continuing Education Course for Engineers

Course Number: E-3068

Credit: 3 Hours / 3 PDH / 3 CPD

Distribution Line Design – Volume 2: Conductors

Lee Layton, P.E.

Introduction

This course is the second in a series of three courses on the design of electric distribution pole lines. This volume presents the methodology and equations required to calculate distribution line ruling spans and conductor sags and tensions. It explains the guidelines used for preparing or selecting sag-tension tables. The course also explains conductor characteristics, behavior, installation and aeolian vibration.

The first volume in this series provided information to determine: The loads applied to un-guyed wood distribution poles 55 ft or less in total length, a pole's strength requirements to sustain applied loads, maximum horizontal spans based on pole strengths, crossarm vertical loads, and crossarm horizontal loads. The third volume in the series explains the proper guying methods for distribution pole lines.

In addition, clearances are reviewed in this volume. The conductor clearance requirements of Rule 235 of the National Electrical Safety Code (NESC) may limit overhead distribution span lengths. This course presents information and the equations needed to determine the maximum span lengths that will meet NESC mid-span and supporting structure clearance requirements between conductors. Only bare electric supply conductors supported by standard distribution primary, pole-top assemblies are analyzed. However, the equations presented can be applied to other types of conductors and support assemblies. Diagrams and example solved problems are included to clarify the presentation.



The course references rules and presents selected data contained in the 2002 Edition of the National Electrical Safety Code (NESC). At the time this course was written, the 2002 Edition was the latest edition of the NESC. All of the references to the NESC are references to the 2002 Edition of the NESC. Periodically the NESC is updated and revised. Users should use the rules and data, as may be revised and renumbered, from the most recent edition of the NESC. Copies of the NESC may be obtained from the Institute of Electrical and Electronic Engineers, Inc., (IEEE).

Chapter 1: Sag and Tension Calculations

The behavior and movement of a suspended conductor is the most unpredictable variable in distribution line design. Since complex equations are used to calculate the conductor sag curve, some simplifications and approximations are used. The approximations cause small errors. The accuracy of the final calculated results decreases as the curve equation is simplified.

The curved shape of a completely flexible cable suspended between two rigid supports is defined as a *catenary*. A conductor, although not completely flexible, very nearly has this same shape. The equation for the sag of a catenary is expressed in the following hyperbolic equation:

$$D = \frac{T_h}{W} * \cosh\left(\frac{W * S}{2 * T_h} - 1\right)$$

Where:

D = Vertical conductor sag length at midspan

T_h = Horizontal component of conductor tension

S = Horizontal length of the conductor span (between supports)

W = Unit vertical weight of the conductor (including ice or wind loads)

cosh = Hyperbolic cosine

The catenary equation can be approximated to the degree of accuracy desired by using Maclaurin's infinite series for hyperbolic functions. In this form, each added term in the series increases the accuracy. The first three terms of the series are:

$$D = \left(\frac{W * S^2}{8T_h}\right) + \left(\frac{W}{6T_h}\right) \left(\frac{W * S^2}{8 * T_h}\right)^2 + \left(\frac{4}{10}\right) \left(\frac{W}{6T_h}\right)^2 \left(\frac{W * S^2}{8 * T_h}\right)^3$$

Three terms of this equation are usually sufficient for exacting sag calculations. Two terms generally provide the necessary accuracy for long-span transmission lines. A single term satisfies the accuracy requirements for the majority of distribution, sub-transmission, and transmission line sag calculations when spans are no more than 1,000 feet. The first term of the equation is identical to the equation for a parabolic curve. Therefore, for distribution lines and most transmission lines, the midspan span conductor sag is approximated by the first term of the above equation.

The weight of a conductor in a catenary span equation is assumed to be evenly distributed along the conductor sag curve. In a parabolic equation the conductor weight is assumed to be evenly distributed along a straight line between the conductor supports. For relatively short spans with small sags, the difference in weight distribution is generally negligible.

The parabolic equation is used for the great majority of the manual sag and tension calculations for distribution lines. Catenary equations of several terms are used in computer programs where greater accuracy is desired. A distribution design engineer might use the two-term catenary equation to check the sag error of a parabolic calculation for a long crossing span. The catenary equation has larger sag values than the parabolic equation. Only parabolic equations are used hereafter.

Dead-End Span Sag and Tension Equations

Most conductor sag and tension calculations are theoretically based on a simple dead-end span of conductor supported at equal elevations. The supports are assumed to be rigid. It is also assumed the conductor length does not change with changes in temperature or stress. These assumptions allow calculations to be made with simple equations of the parabolic curve. See Figure 1 which illustrates the parabolic conductor sag curve and some of the principal variables.

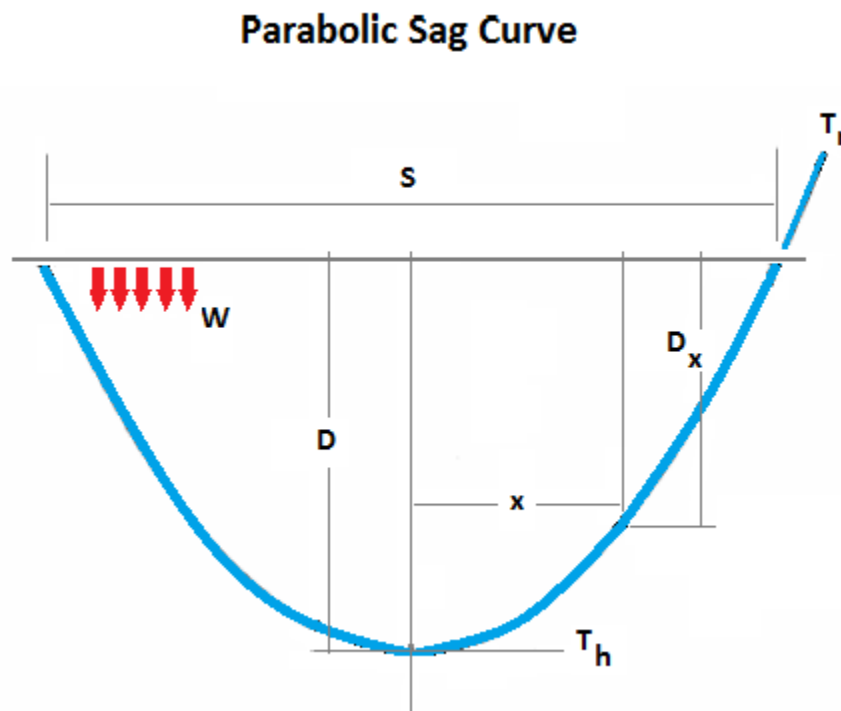


Figure 1

The following symbols define and are used to represent some of the conductor tension variables of the simple parabolic span:

T = Total conductor tension at any specified point in the span

T_h = Horizontal or longitudinal component of tension at any point in the span, assumed to be constant throughout a parabolic span. At the low point of sag, the vertical component of tension is zero, therefore, the horizontal tension is the total tension at that point

T_v = Vertical component of tension at designated point in the span; unless otherwise indicated, assumed to be the vertical component of tension at the support

T_r = Resultant conductor tension; unless otherwise indicated, assumed to be the resultant tension at the supports

T_a = Average tension of the conductor span

Sag Equations

The fundamental sag equation for the parabolic sag curve of a conductor span is:

$$D = \left(\frac{W * S^2}{8T_h} \right)$$

Usually W and S are known quantities. A value is assumed or determined for T_h or D and the equation is solved for the unknown variable. If T_h is decreased, D has to increase, and vice versa. If T_h is held constant and the span length is varied, D will increase or decrease as a function of the square of the span length. This relationship provides the basis for another frequently used sag equation. In a line section that has a ruling span S_r with the sag D_r, and the same values of W and T_h, the sag D of any given span S can be calculated as follows:

$$D = D_r * \left(\frac{S}{S_r} \right)^2$$

Where:

S = Span length of span under consideration

S_r = Ruling span length

D_r = Ruling span sag length

The sag of the conductor at a distance (x) from the midspan or distance (z) from the support can be calculated as follows:

$$D_x = D * \left[1 - \left(\frac{2 * x}{S} \right)^2 \right]$$

$$D_z = D * \left[1 - \left(\frac{2 * z}{S} \right)^2 \right]$$

Where:

x = Distance from mid-span

z = Distance from support

D_x = Sag at point x

D_z = Sag at point z

Tension Equations

The fundamental equati

ductor tension are:

To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

Close this window and click "Add to cart" on the product page.

The formula for the resulta

$$T_r = \sqrt{T_h^2 + T_v^2}$$

$$T_r = T_h * \sqrt{1 + \frac{T_v^2}{T_h^2}}$$

The following conventional approximation formula may be applied to the above equation for T_r. In the expression (1+a)^m, if "a" is much smaller than 1, then (1+a)^m ≈ (1+m*a). Then, by using this approximation and by substituting the values for T_h and T_v from the formulas above, the following simplified formula for T_r is derived.