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Applications Engineering Note

Sag and Tension - Results

AEN 15, Revision 5

Revised: November, 2002

Sag and tension calculations come in a variety of formats; however, most calculations use a common terminology. Common terms used in sag and tension calculations are explained below to promote understanding when interpreting the results. For an additional explanation of sag and tension, please refer to Applications Engineering Note 14.

Span length - The straight line-of-sight distance between poles.

Tension - Axial tensile force applied to the messenger or other cable strength member(s). This value is affected by the amount of cable sag and by the mechanical and environmental loading. Tension is inversely proportional to amount of sag.

Sag - Defined by various texts (IEEE Std 100-1996, IEEE Std 524-1992, NESC) as the vertical distance between the cable and an imaginary horizontal line extending between the points where the cable is attached to the poles. This measure assumes a zero elevation difference between the pole attachment points. Many sag and tension algorithms will compute sag as the total displacement due to ice and wind loading and cable weight. This value for sag is the combination of vertical sag and horizontal displacement. Unless otherwise stated, sag is referenced to the midpoint of the span.

Vertical displacement – The vertical distance (droop) resulting from the combined weight of the cable, messenger, and any ice on the cable.

Horizontal displacement - The distance the cable deflects horizontally when subjected to a wind force.

Strain - The elongation of a cable or messenger due to an applied tensile force. The elongation is referenced to the cable length in an unstressed condition. This value is affected by the modulus of elasticity for the cable. In a dedicated messenger, overlashed, or figure-8 application, the messenger is subject to more strain than the cable itself as it is the load bearing structure.

Creep - a permanent change in the length of the cable from the length measured when in an unstressed condition. There are two basic types of creep:

Installation (short term) creep – A result of the rearrangement of components in the supporting element(s) of a cable after the first high stress is applied. This rearrangement places the strands of the support element(s) in a more linear relationship with each other, causing the supporting element to be longer than before the stress application.

Long term creep - The result of the plastic deformation of the cable components over time. The level and duration of the stress determine the amount of plastic deformation. The stress is placed on the cable by such things as a winter of ice loading or by the cable's own weight.

Creep follows a logarithmic progression with respect to time. This means that the majority of creep will actually take place very early in cable life. The amount of creep the cable will experience in the first year easily exceeds the combined creep the cable will experience over the subsequent 10 years.

The existence of creep in a cable installation can be an important factor. If the cable is installed with a given amount of sag, and then checked two years later, the resulting sag will be greater than the installation sag. This is due to cable creep.

Environmental Considerations

When performing sag and tension calculations, environmental factors to which the cable will be subjected (temperature, ice, and wind) are key in understanding long-term performance. Each factor contributes to changes in the amount of sag and tension the cable will experience.

Most materials will expand or contract as a result of changes in temperature based on their coefficient of thermal expansion. Aerial cables are particularly susceptible to this effect as they are directly exposed to the elements. As temperatures increase metallic messengers expand, in effect becoming longer. This expansion leads to a slight increase in cable sag, coupled with a slight decrease in the amount of tension. The effect is reversed for decreasing temperature. As the temperatures decrease metallic messengers contract, thereby becoming shorter. The contraction decreases the amount of cable sag, but increases the amount of tension. In ADSS cables, the aramid yarn strength member has a negative coefficient of thermal expansion. Therefore an ADSS cable will actually expand in cold temperatures and contract in warm temperatures.

Temperature can play an important role when the optical cable is hung below a power conductor. In colder temperatures optical cables with metallic messengers can contract, decreasing the amount of sag. However, a power conductor carrying a significant amount of current will actually be heated and will expand due to internally generated heat. The thermal expansion will increase the power conductor's sag, while simultaneously the optical cable experiences decreased sag. The two cables will therefore be closer in proximity than initial calculations may have determined and an uneven sag appearance may result.

Environmental loading conditions fall under two categories. The first is referred to as ice and wind loading. The National Electrical Safety Code® (NESC®) gives three suggested combinations (light, medium, and heavy) of ice, wind, and temperature. The second category is a wind-only condition referred to as extreme wind. Extreme wind becomes a concern when pole heights exceed 18 meters (60 feet), in coastal areas subject to high storm winds, and in other areas that may be subject to high winds such as with some river crossings or mountain ranges.

Each NESC loading condition (light, medium, and heavy) defines a specific radial ice thickness, temperature, and wind pressure. These values are summarized in the table below.

	Loading Districts		
	Heavy	**Medium**	**Light**
Radial thickness of ice (mm)	12.5	6.5	0.0
Horizontal wind pressure (Pa)	190	190	430
Temperature (°C)	-20	-10	-1
Constant, K (N/m)	4.4	2.5	0.73

Because the NESC loading conditions consider both ice and wind loading, the resulting sag calculations will have both a vertical and horizontal component; the vertical sag is caused by the addition of ice and temperature, while the wind pressure causes the horizontal displacement. NESC standards are often used to determine design conditions for ice and wind, but specific conditions may be used for a particular application.

Extreme wind loading is usually considered where the cable may be subject to higher than normal wind velocities as may be brought on by hurricanes, cyclones, or other ocean borne storms. Cables are exposed to wind not blocked by other structures, and the presence of unique geography can channel the wind, intensifying the effect. These resulting higher wind speeds will cause the cable to deflect horizontally. Typically, the vertical sag contribution for wind will be small. Still, the large horizontal force will cause the tension on the cable to increase.

In general, ice and wind loading have the greatest effect on sag and tension. The contribution of each depends on the amount of ice and wind speed factored in. The table below summarizes which conditions will increase or decrease sag, tension, and strain. Arrows are used to show an increase or decrease. The table assumes that the messenger and cable are at a given initial sag and tension. Changes due to creep are referenced to the initial sag and tension. Changes due to NESC loading and extreme wind conditions are referenced to the value for long term creep.

	Tension	Sag (total)	Strain
Additional Cables (overlashed only)	↑	↑	↑
Installation Creep	↓	↑	↑
Long Term Creep	↓	↑	↑
NESC Loading	↑	↑	↑
Extreme Wind	↑	↑	↑

Corning Cable Systems Applications Engineers can assist with sag and tension calculations on a case-by-case basis. Requests for assistance can be handled by facsimile at (828) 901-5533 addressed to Applications Engineering, or by phone at (828) 901-5000 or (800) 743-2671.

REFERENCES

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