Electric Power Conductors Volume II: Mechanical Characteristics

An Online Continuing Education Course for Engineers

Course Number: E-4064

Credit: 4 Hours / 4 PDH / 4 CPD

Electric Power Conductors Volume II: Mechanical Characteristics

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Table of Contents

Section **Page**

This course is one of four courses on electrical power conductors.
The four courses are:

Volume I: **Electric Power Conductors – Electrical Characteristics**
Volume II: **Electric Power Conductors – Mechanical Characteristics**
Volume III: **Electric Power Conductors – Medium Voltage Cables**
Volume IV: **Electric Power Conductors – Low Voltage Cables**

Each course is written as a stand-alone course and it is not necessary to take them in order. Because they are written as stand-alone courses there is some duplication of material among the four courses.

Introduction

Electric conductors are a major cost component in electric utility line construction. In addition to the electrical loads placed on the conductors, they must be able to withstand the mechanical stresses imposed by stringing the wires above ground. Ground clearances, sag, galloping, vibration, ice loads, and creep are all factors that influence the selection of a conductor for electric utility lines.

The stranding of conductors, the number of layers of strands, and the type of metal used to affect the operational characteristics of conductors. Manufacturers use different metals—and some composite materials—to manufacture electrical conductors. The characteristics of the different materials influence the design and operation of a power line. The impacts of loading and temperature must also be considered in the design of a power line because conductors elongate based on stress and temperatures.

Perhaps the most important characteristic of a conductor in the mechanical design of an electric line sag. Sag is related to the weight of the conductor and the amount of tension that is developed in the conductor. These calculations are complex and today are almost always performed with computer algorithms. These computer programs simultaneously consider the impacts of the material's stress-strain relationship, the impact or creep in the conductor, and the impact of different temperatures and loads on the conductor. For educational purposes, this course presents a simplified process of sag and tension calculations to explain the process. While not exact, these simplified procedures should closely replicate the sag and tension characteristics of conductors. Both all-aluminum conductors and all-steel-reinforced conductors are considered.

This course begins with an explanation of what the National Electric Safety Code has to say about conductor loads and sag. The following chapters conductor characteristics, ruling span, sag and tension, how to check sag, and wind-induced conductor motions.

Chapter 1: National Electric Safety Code

The National Electric Safety Code (NESC) defines the limits for tensions in overhead conductors in section 261H2. The NESC limits prescribed in section 261H2 for conductor tensions are designed to prevent the conductor stresses from exceeding the elastic limit of the conductor when the conductor is loaded with ice and wind. The ice and wind loads used in the design of a conductor installation are defined in NESC Table 250-1.

NESC Districts

The NESC ice, wind, and temperatures are based on the loading district where the utility is located. There are three loading districts, and Figure 250-1 of the NESC explains the boundaries of each district. See Figure 1.

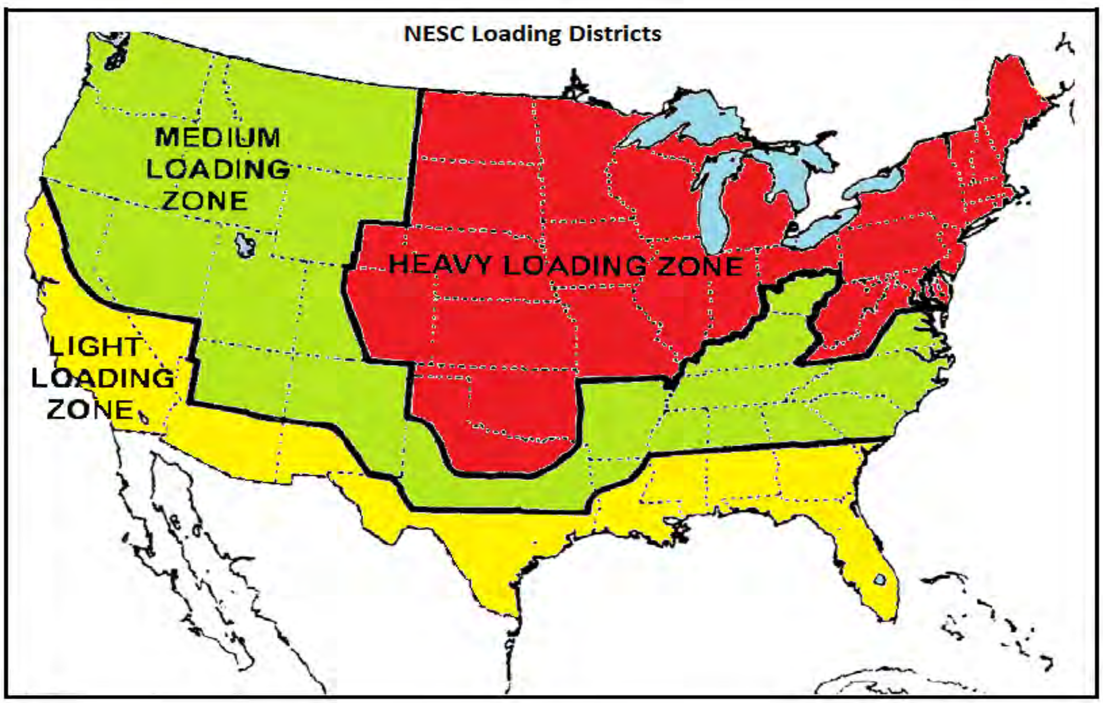


Figure 1

Note: Figure 1 is taken from IEEE C2-2012, National Electric Safety Code® (NESC®), Copyright IEEE 2012. All rights reserved.

The three loading districts are defined as “light,” “medium,” and “heavy.” Table 1 is taken from Table 250-1 of the NESC and shows the ice, wind, and temperatures that must be considered based on the loading district.

Table 1 **NESC Loading Districts** **Ice & Wind Loads** (Adapted from NESC Table 250-1)			
Condition	**Light**	**Medium**	**Heavy**
Ice Radial (in)	0.0”	0.25”	0.5”
Wind (lbs./sq. ft.)	9	4	4
Temperature (F)	30	15	0

In Table 1, we see that in the medium loading district, a load of 0.25” of radial ice and a load of 4-lbs/sq ft of wind must be considered. In the light district, no ice needs to be considered, but a wind load of 9-lbs/sq ft is required.

The ice loads are found for the appropriate loading district in Table 1 above, and the conductor weight with an ice load is found by using,

$$\mathbf{W_C = 0.396 * \left[\frac{3.14 * (Dia_{cond} + 2 * Ice)^2}{4} - \frac{3.14 * (Dia_{cond})^2}{4}\right] + Cond_{wt}}$$

Where,

W_C = Weight of Conductor, with Ice, lbs/ft

Dia_{cond} = Diameter of the conductor, in

Ice = Ice thickness, in

$Cond_{wt}$ = Conductor weight, lbs./ft

Example. What is the iced-weight of a 4/0 ACSR, Penguin conductor in the medium-loading district?

From Table 1, the ice load in the medium loading district is 0.25”. The diameter and weight of the conductor are 0.563” and 0.291 lbs./ft, respectively (Table 5) has details on conductors).

$$W_C = 0.396 * \left[\frac{3.14 * (Dia_{cond} + 2 * Ice)^2}{4} - \frac{3.14 * (Dia_{cond})^2}{4}\right] + Cond_{wt}$$

$$W_C = 0.396 * \left[\frac{3.14 * (0.563 + 2 * 0.25)^2}{4} - \frac{3.14 * (0.563)^2}{4}\right] + .291$$

$W_c = 0.396 * [(3.14*(0.398 + 2 * 0.25)^2 / 4) – (3.14 * 0.398^2 / 4)] + 0.145$

$W_c = 0.544$ lbs./ft.

The weight of the conductor without ice is 0.291 lbs./ft, and with ¼" of ice, the weight is 0.544 lbs./ft.

Loading Conditions

There are three loading conditions defined by the NESC:

1. Initial unloaded
2. Final unloaded
3. Loaded

The *initial unloaded condition* is when the conductor is first installed and does not include any ice or wind load. For the initial unloaded condition, the NESC says that the conductor tension should not exceed 35% of the ultimate strength of the conductor at 60F.

When the conductor has been subjected to ice and wind load for some time, the conductor receives a permanent stretch. This is known as the *final unloaded condition*, and the Code says that the tension should not exceed 25% of the ultimate rating at 60F.

The *loaded condition* is the tension limit while the conductor is loaded with the ice and wind load as specified in the appropriate NESC loading district. In this condition, the conductor cannot exceed 60% of the ultimate strength of the conductor. The temperature for the loaded condition is based on the NESC loading district.

Wire and cable manufacturers generally use more conservative tension limits for aluminum conductors as well as different limits for ACSR and all-aluminum conductors than those shown in the NESC. The manufacturer's recommendations also include different temperatures based on the NESC loading conditions. Many utilities have accepted the manufacturer's recommendations for standard conductor loading tensions.

Table 2 shows the NESC conductor tension limits along with the limits based on industry practice.

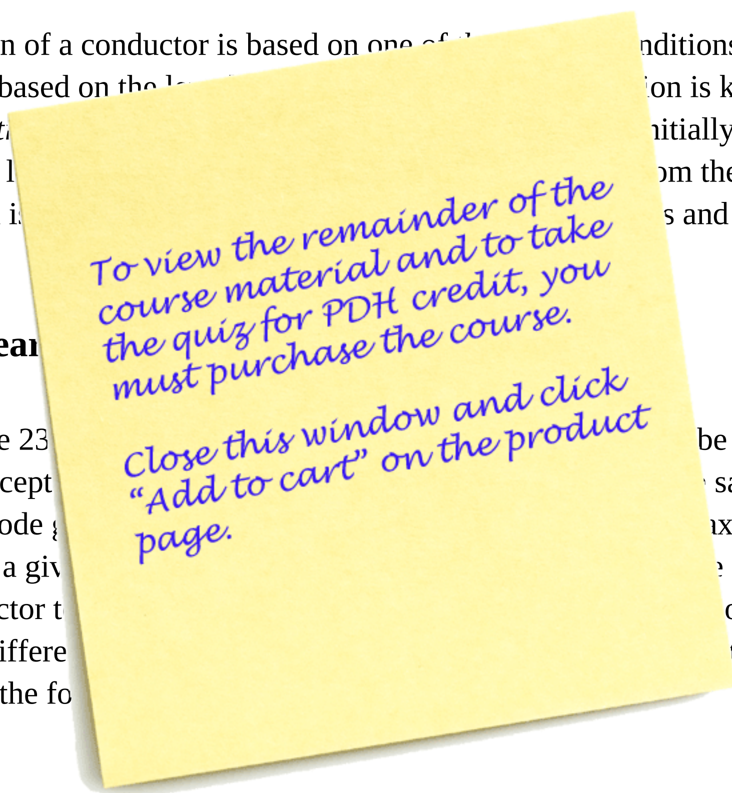
Table 2
Conductor Tension Limits

Condition	NESC		Industry Practice				
	All Conductors		ACSR	AAC[1]	NESC Loading District		
	Tension	Temp	Tension	Tension	Light	Medium	Heavy
Initial Unloaded	35%	60F	33.30%	30%	0F	15F	30F
Final Unloaded	25%	60F	25%	20%	0F	15F	30F
Loaded	60%	NESC[2]	50%	50%	0F	15F	30F

1. This applies to both AAC and AAAC conductors.
2. Based on NESC loading district.

Controlling Conditions

The design tension of a conductor is based on one of t nditions mentioned
above and varies based on the l ion is known as the
controlling conditi nitially developed
when designing a l om the ruling span.
Once the sag data i s and conditions can
be analyzed.



Horizontal Clear

According to Rule 23 be adequate to
prevent loss of accept sag in the
conductor. The Code aximum
allowable sag for a giv Code are
based on a conductor t o wind. The
calculations are differe tors smaller
than #2AWG for the fo