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IEEE Guide for Determining the Effects of High-Temperature Operation on Conductors, Connectors, and Accessories

IEEE Power Engineering Society

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Abstract: The purpose of this guide is to provide general recommendations for consideration when designing new overhead transmission lines that will be operated at high temperatures. It may also evaluate existing transmission lines for operation at higher temperatures. Although this guide is intended for overhead transmission lines, most of the discussion will also be applicable to distribution lines.

Keywords: conductors, conductor hardware, connectors, creep, high-temperature operation

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Introduction

This introduction is not part of IEEE Std 1283-2004, IEEE Guide for Determining the Effects of High-Temperature Operation on Conductors, Connectors, and Accessories.

All annexes are only an informative part of this guide. The annexes are provided as either information or representative examples of some computational techniques in use today within the industry; however, they are not the only accepted techniques available nor are they to be considered the recommended techniques by the Task Force on The Effects of High Temperature Operation. Other techniques can be found in the references, bibliography, and other sources that provide equally acceptable results. The reader is encouraged to investigate any and all techniques to determine which best suit anticipated applications.

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IEEE Guide for Determining the Effects of High-Temperature Operation on Conductors, Connectors, and Accessories

1. Overview

The purpose of this guide is to provide general recommendations for consideration when designing new overhead transmission lines that will be operated at high temperatures. It may also evaluate existing transmission lines for operation at higher temperatures. Although this guide is intended for overhead transmission lines, most of the discussion will also be applicable to distribution lines.

The trend in most utilities today is to increase the capacity of their transmission lines wherever practical. It has become increasingly difficult to build new lines because of increased costs to obtain rights of way, public intervention, and state licensing requirements. These obstacles have significantly increased the cost and lead times required to place new lines into service. The lost revenue opportunities from power purchase/sale agreements with other systems because of limited transmission facilities can be substantial. Therefore, utilities are attempting to get as much capacity as is practical from the addition of new high-capacity lines or from the modification of existing lines for high-temperature operation.

In the past, utilities have typically been conservative in rating their lines due to the uncertainties in parameters that influence conductor temperature. Today, with a better understanding of actual ambient conditions and improvements in monitoring instruments and sophisticated analysis tools, utilities are rating lines at higher temperatures with the same or higher level of confidence than in the past. Many utilities have been increasing their transmission line's maximum conductor operating temperature as a way of increasing line capacity. Often higher operating temperatures are needed only for a few hours during the year. General concerns with increasing maximum operating temperature relate to accelerating the aging process of conductors, connectors, and conductor hardware plus maintaining adequate ground clearance for the safe operation of a line. Operating at a higher conductor temperature is acceptable if the associated negative effects are adequately understood, considered, and mitigated in the design or analysis of a line. Some effects of high-temperature operation to consider are as follows:

- Loss of strength in the conductors and connectors
- Increase in conductor sag resulting in reduced clearances
- Reduction of life and integrity of connectors
- Acceleration of component aging with higher operating temperatures
- Increase in resistive losses
- Potential damage to equipment attached to conductors (e.g., wave traps)

This guide is limited to discussing the effects of high-temperature operation on bare overhead transmission conductors, connectors, and conductor hardware. These effects are discussed to identify their impacts on safety, reliability, and economy. A few methods to mitigate some of these negative effects of high-temperature operation are also discussed.

2. References

This standard shall be used in conjunction with the following publications.

Accredited Standards Committee C2-2002, National Electrical Safety Code® (NESC®).¹

Barrett, J. S., “High temperature operation of ACSR conductors,” *Proceedings of Seminar on Effects of Elevated Temperature Operation on Overhead Conductors and Accessories*, Atlanta, GA, pp. 25–36, May 1986

Bingham, A. H., Lambert, F. C., Monashkin, M. R., DeLuce, C. B., and Shaw, T. B., “An accelerated performance test of electrical connectors,” *IEEE Transactions on Power Delivery*, vol. PWRD-3, no. 2, pp. 762–768, Apr. 1988.

EEOI-NEMA Std CC 3-1973, Connectors for Use Between Aluminum or Aluminum-Copper Overhead Conductors.²

Harvey, J. R., “Creep of transmission line conductors,” *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-88, no. 4, pp. 281–285, Apr. 1969.

Harvey, J. R., “Effect of elevated temperature operation on the strength of aluminum conductors,” *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-91, no. 5, pp. 1769–1772, Sept./Oct. 1972.

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Harvey, J. R., and Larson, R. E., “Use of elevated temperature creep data in sag-tension calculations,” *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-89, no. 3, pp. 380–386, Mar. 1970.

Hickernell, F., Jones, A. A., and Snyder, C. J., “Hy-Therm copper—an improved overhead-line conductor,” *AIEE Transactions*, vol. 68, pp. 22–30, 1949.

Howitt, W. B., and Simpkins, T. E., “Effect of elevated temperature on the performance of conductor accessories (abstract),” *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-72, no. 2, p. 1729, July/Aug. 1972.

Kidd, B. E., and Shaw, T. B., “Joint compounds and their relative effects in making good electrical connections,” *IEEE/PES T&D Conference*, Atlanta, GA, Apr. 1979.

“Limitations of the ruling span method for overhead line conductors at high operating temperatures,” *Report of IEEE WB on Thermal Aspects of Conductors, IEEE WPM 1998*, Tampa, FL, Feb. 3.

Morgan, V. T., *Effect of Elevated Temperature Operation on the Tensile Strength of Overhead Conductors*. IEEE Paper 95 WM 229-5 PWRD, 1995 IEEE/PES Winter Power Meeting.

¹The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

²NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

Nigol, O., and Barrett, J. S., "Characteristics of ACSR conductors as high temperatures and stresses," *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-100, no. 2, pp 485–493, Feb. 1981.

3. Definitions, acronyms, and abbreviations

For the purposes of this standard, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms* [B82] should be referenced for terms not defined in this clause.³

3.1 Definitions

3.1.1 annealing: A metallurgical process where high temperatures allow internal stress relaxation, which results in a softening and strength loss of the metal.

3.1.2 conductor: An overhead bare metal cable used to transmit electrical energy.

3.1.3 conductor hardware: Mechanical devices attached directly to the conductor that do not carry current.

3.1.4 connector: A current-carrying mechanical device used to join two or more conductors or a conductor to conductor hardware.

3.1.5 connector failure, electrical: Advanced connector aging where the locations for easily establishing current flow contact points are essentially exhausted.

3.1.6 connector failure, general: Thermal failure.

3.1.7 connector failure, mechanical: Advanced connector aging where the connector's operating temperature is high enough to soften and eventually part the adjacent conductor.

3.1.8 connector failure, thermal: Advanced connector aging where the connector's operating temperature is greater than the operating temperature of the conductor to which it is attached.

3.1.9 connector, full tension: A connector designed to join conductors and achieve at least 95% of the conductor's rated tensile strength.

3.1.10 connector, limited tension: A connector designed to join conductors for low-tension applications.

3.1.11 creep, accelerated rate: An increase in a conductor's creep rate over general creep rate, usually associated with elevated temperature operation.

3.1.12 creep, general: The accumulative nonelastic elongation of a conductor under tension over an extended period of time at modest temperatures usually not in excess of approximately 75 °C.

3.1.13 creep, high temperature: The creep a conductor experiences over a period of time operating at conductor temperatures in excess of approximately 75 °C.

3.1.14 high-temperature operation: Operating conductors and connectors at temperatures where thermal effects can impact the safety, reliability, and life of the transmission line.

3.1.15 loss of strength: The partial loss of a conductor's mechanical strength through annealing.

³The numbers in brackets correspond to those of the bibliography in Annex A.

3.1.16 maximum conductor operating temperature: The maximum conductor temperature at which the transmission line can operate with acceptable performance in safety and reliability. The line's maximum temperature is usually dictated by either ground clearance or loss of conductor strength.

3.1.17 ruling span: A representative level span for a line section of contiguous unequal suspension spans that approximates changing conductor temperature, creep, and weather conditions.

3.1.18 steel core: The inner strength member of a composite conductor composed of steel strand(s).

3.1.19 steel strands, aluminized: Steel core wire strands coated with aluminum to reduce corrosion of the steel strands.

3.1.20 steel strands, aluminum clad: Steel core wire strands clad with aluminum to reduce corrosion and increase conductance.

3.1.21 steel strands, galvanized: Steel core wire strands coated with zinc to reduce corrosion of the steel strands.

3.2 Acronyms and abbreviations

AAAC	all-aluminum alloy conductor
AAC	all-aluminum conductor
AACSR	aluminum alloy conductor steel reinforced
ACAR	aluminum conductor alloy reinforced
ACSR	aluminum conductor steel reinforced
ACSS	aluminum conductor steel supported
Cu	copper

4. Conductors

4.1 Conductor types

Many different types of bare overhead conductors transmit electrical energy. The most common bare overhead conductors are constructed from either copper, aluminum, or their alloys and can be further strength reinforced with steel. Most typical types are AAC, AAAC, ACAR, ACSR, AACSR, ACSS, and Cu.

4.2 Stranding types

The two conductor stranding types typically used to construct bare overhead conductors are round- and trapezoidal-shaped strands.

4.3 High-temperature creep

4.3.1 Introduction to creep

A conductor under tension undergoes nonelastic elongation over a period of time (usually measured in years). This elongation is called creep. The magnitude and rate of creep are a function of the conductor's composition, stranding, line tension, and operating temperature.