


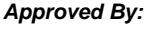
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CAUTION: Any hard copy reproductions of this specification should be verified against the on-line system for current revisions.

1.0 Scope

- 1.1 This document establishes American Transmission Company's (ATC) overhead Transmission Line conductor steady-state current capacity ratings criteria. It describes the determination of conductor current ratings for normal and emergency conditions during spring, summer, fall and winter seasons, for use in planning, operations, and design.
- 1.2 It does not consider system stability, voltage limits, operating economies, or capacity limits of substation equipment - all of which could otherwise limit or affect a facility rating.

2.0 Introduction

The electrical ampacity rating of an overhead Transmission Line is dependent upon the physical and metallurgical characteristics of the installed conductor and the vertical clearances between the conductor and ground and/or other objects.

3.0 References

The latest version of the following documents shall be applied when a version is not specifically addressed.

If there is any apparent contradiction or ambiguity among referenced documents and this document, the legislative code shall take first precedence followed by Procedure PR-0285 and this document. Bring the issue to the attention of the Asset Planning & Engineering – Transmission Line Services Department for resolution before application.

3.1 Regulatory Documents

- National Electric Safety Code (NESC), ANSI-C2, as adopted by the respective state code
- NERC Reliability Standard FAC-008-1, Facility Ratings Methodology
- NERC, Glossary of Terms Used in NERC Reliability Standards, March 15, 2011

3.2 Related ATC documents

- Criteria CR-0062; Underground Transmission Line Ampacity Ratings
- Criteria CR-0063; Substation Equipment Ampacity Ratings
- Procedure PR-0285; Facility Ratings
- Operating Procedure TOP-20-GN-000034, EMS Facility Seasonal Limit Transition

3.3 Industry Standards and Technical Bulletins

- ANSI C119.4 -1998 American National Standard for Electrical Connectors. Connectors to Use Between Aluminum-to-Aluminum or Aluminum-to-Copper Bare Overhead Conductors
- The Aluminum Association, Aluminum Electrical Conductor Handbook, Third Edition, 1989
- CIGRE Technical Bulletin 299, 2006
- IEEE 738 – 2006 Standard for Calculating the Current-Temperature of Bare Overhead Conductors
- Southwire Overhead Conductor Manual, Second Edition, 2007.
- Standard Handbook for Electrical Engineers, McGraw Hill, various editions, (primarily for copper conductor properties)

3.4 Computer software or programs

- PLS-CADD, Power Line Systems
- RateKit; NEXANS, The Valley Group, Inc.

4.0 Definitions¹

- 4.1 **Ambient Conditions:** The environmental conditions surrounding the conductor, including air temperature, wind speed, etc.
- 4.2 **Ampacity:** The current carrying capacity of a circuit or one of its components. This value is measured in amperes and is a rating for each phase of a three-phase circuit. This value may also be listed using apparent power (Mega-Volt-Amperes or MVA) based on the nominal system voltage.
- $$\text{MVA} = \frac{\sqrt{3}(\text{kV})(\text{amps})}{1000}$$
- 4.3 **Equipment Rating:** The maximum and minimum voltage, current, frequency, real and reactive power flows on individual equipment under steady state, short-circuit and transient conditions, as permitted or assigned by the equipment owner (ATC).
- 4.4 **MOT:** The conductor Maximum Operating Temperature (MOT) prescribed herein, if exceeded, might result in unacceptable damage to the conductor or the conductor might sag below prescribed limits.
- 4.5 **Rating:** The operational limits of a transmission system element under a set of specified conditions.
- 4.6 **Rating, Emergency:** The rating as defined by the equipment owner (ATC) that specifies the level of electrical loading or output, usually expressed in megawatts (MW) or Mvar or other appropriate units, that a system, facility, or element can support, produce, or withstand for a finite period (2 hours). The rating assumes acceptable loss of equipment life or other physical or safety limitations for the equipment involved.
- 4.7 **Rating, Normal:** The rating as defined by the equipment owner (ATC) that specifies the level of electrical loading, usually expressed in megawatts (MW) or other appropriate units that a system, facility, or element can support or withstand through the daily demand cycles without loss of equipment life.
- 4.8 **Rating, Seasonal:** ATC provide ratings for each of the four (4) seasons (Spring, Summer, Fall and Winter).
- 4.9 **SELD:** Substation Equipment and Line Database (SELD) is the primary ATC's computer application for maintaining ratings data.
- 4.10 **Steady-State Condition:** A theoretical condition with a constant electrical current—electrical load.
- 4.11 **Study-Based Rating:** Ratings based on weather parameters developed through a study following industry guidelines in CIGRE TB-299. See Appendix A for background on development.
- 4.12 **Transient Condition:** A theoretical condition with a fluctuating electrical current—electrical load.
- 4.13 **Transmission Line:** A system of structures, wires, insulators and associated hardware that carry electric energy from one point to another in an electric power system. Lines are operated at relatively high voltages varying from 69 kV up to 765 kV, and are capable of transmitting large quantities of electricity over long distances. (This document only pertains to overhead Transmission Lines).
- 4.14 **Transmission Owner:** American Transmission Company (ATC)

¹ Definitions of terms shown in bold text are from NERC, Glossary of Terms Used in NERC Reliability Standards, March 15, 2011. These terms are capitalized when the defined context is used within the document.

5.0 Transmission Line Capacity Rating Determination

5.1 Background

5.1.1 Conductor temperature rise above ambient is a thermodynamic heat balance function between heat input and heat dissipation. The thermal parameters consist of the following:

- Heat sources: electrical resistance heating with current and solar energy absorption
- Heat dissipation: airflow convection and surface radiation

5.1.2 ATC ratings are intended to restrict the current so as to not heat an overhead conductor above the maximum operating temperature (MOT) for a prescribed set of ambient and operating conditions. The MOT may be exceeded for ambient conditions different than what is assumed.

5.2 Industry Standard Methodology

ATC uses the methods and equations in IEEE Standard 738, to calculate capacity (amps) for a given conductor MOT and ambient conditions as stated herein.

Numerous commercial software programs and ATC's ratings database SELD utilize the methods (heat balance equations from IEEE 738). Although these programs may not provide identical results, the results from both are acceptable for ratings purposes. A variance of less than 3 percent is expected and reasonable.

5.3 Conductor MOT determination

Conductor MOT is based on either the physical properties of the conductor or the conductor sag (clearance) limit, whichever controls.

5.3.1 The conductor physical property limitation is loss of strength due to annealing, which for aluminum begins to occur at temperatures greater than 200°F (93°C). ATC has determined an acceptable loss of strength based on temperature as summarized in Table 1 – Maximum Conductor Temperature Limits.

Table 1 - Maximum Conductor Temperature Limits

| Conductor Material | Temperature Limits | |
|------------------------------|--------------------|------------------|
| | Normal Rating | Emergency Rating |
| ACSR, steel \geq 7.5% area | 200°F (93°C) | 300°F (149°C) |
| ACSR, steel < 7.5% area | 200°F (93°C) | 275°F (135°C) |
| AAAC, AAC, & ACAR | 200°F (93°C) | 230°F (110°C) |
| ACSS, steel \geq 7.5% area | 392°F (200°C) | 392°F (200°C) |
| Copper | 167°F (75°C) | 185°F (85°C) |
| Copperweld | 167°F (75°C) | 185°F (85°C) |
| Alumoweld | 200°F (93°C) | 275°F (135°C) |

5.3.2 ATC assumes that properly applied and installed conductor connector fittings do not control the rating. This assumption is based on manufacturer's tests that show current carrying conductor fittings operate at temperatures cooler than the conductor.

5.3.3 The maximum conductor sag limit is determined by the associated clearances prescribed by National Electric Safety Code (NESC), ANSI-C2, as adopted by the respective state code. (Note code considerations that are not relevant to the MOT are not considered under this ratings document.)

5.4 Ambient Conditions

ATC is transitioning from legacy weather parameters to study-based weather parameters. Either of the following two sets of parameters may be used.

Note "Special Exception Ratings", which is a temporary rating defined in PR-0285, may be applied using either set of ambient conditions.

5.4.1 Legacy Weather Parameters

- 5.4.1.1 Legacy ratings are based on the ambient weather conditions shown in Table 2a according to the respective season.
- 5.4.1.2 ATC uses four (4) seasonal rating periods: Spring, Summer, Fall, and Winter as defined in ATC Transmission Operating Procedure TOP-20-GN-000034, EMS Facility Seasonal Limit Transition.
- 5.4.1.3 For rating of overhead lines, ATC considers the same ambient conditions for both Spring and Fall seasons.

Table 2a- Legacy Parameters for Rating Overhead Transmission Conductors

| Criteria | Summer | Fall | Winter | Spring |
|--|---------------|---------------|---------------|---------------|
| Ambient temperature | 90°F (32.2°C) | 60°F (15.6°C) | 30°F (-1.1°C) | 60°F (15.6°C) |
| Wind velocity | 4.4 fps | 4.4 fps | 4.4 fps | 4.4 fps |
| Wind direction relative to conductor direction | Perpendicular | Perpendicular | Perpendicular | Perpendicular |
| Latitude | 44°N | 44°N | 44°N | 44°N |
| Conductor orientation | E-W | E-W | E-W | E-W |
| Elevation above sea level | 800 ft. | 800 ft. | 800 ft. | 800 ft. |
| Atmosphere Clear vs. Industrial (cloudy) | Clear | Clear | Industrial* | Clear |
| Date (for solar conditions) | June 30 | October 21 | December 31 | October 21 |
| Time of Day (for solar conditions) | 12:00 Noon | 12:00 Noon | 12:00 Noon | 12:00 Noon |
| Flux | 100% | 100% | 100% | 100% |
| Coefficient of radiant emission | 0.8 | 0.8 | 0.8 | 0.8 |
| Coefficient of solar absorption | 0.8 | 0.8 | 0.8 | 0.8 |

*Similar reduced solar absorption can be achieved by applying a flux factor to what RateKit provides assuming "Industrial" sky.

5.4.2 Study-Based Weather Parameters

- 5.4.2.1 Study-based ratings are based on the ambient conditions shown in Table 2b according to the prescribed seasons defined in ATC Transmission Operating Procedure TOP-20-GN-000034, EMS Facility Seasonal Limit Transition.
- 5.4.2.1 Study Based Weather Parameters were developed through a study following industry guidelines in CIGRE TB-299. See Appendix A for an explanation of the development of study-based rating parameters.

Table 2b- Study-Based Parameters for Rating Overhead Transmission Conductors

| Criteria | Summer | Fall | Winter | Spring |
|--|---------------|---------------|---------------|---------------|
| Ambient temperature | 90°F (32.2°C) | 59°F (15°C) | 38°F (3.3°C) | 77°F (25°C) |
| Wind velocity | 1.2 fps | 1.1 fps | 1.15 fps | 1.3 fps |
| Wind direction relative to conductor direction | Perpendicular | Perpendicular | Perpendicular | Perpendicular |
| Latitude | 44°N | 44°N | 44°N | 44°N |
| Conductor orientation | E-W | E-W | E-W | E-W |
| Elevation above sea level | 800 ft. | 800 ft. | 800 ft. | 800 ft. |
| Atmosphere | Clear | Clear | Clear | Clear |
| Date (for solar conditions) | Aug 15 | Oct 15 | Nov 15 | May 15 |
| Time of Day | 12:00 Noon | 12:00 Noon | 12:00 Noon | 12:00 Noon |
| Flux (percent of noon radiation) | 18% | 14% | 24% | 12% |
| Coefficient of radiant emission | 0.8 | 0.8 | 0.8 | 0.8 |
| Coefficient of solar absorption | 0.8 | 0.8 | 0.8 | 0.8 |

5.5 Electrical Loading and Duration

5.5.1 Steady-State Conductor Rating (Ampacity)

All ATC published Ratings assume a steady-state (constant) load for the following specified durations:

- Continuous for Normal Ratings
- 2-hours for Emergency Ratings

6.0 Line Jumpers

6.1 Jumpers used in Transmission Line applications can operate continuously to the maximum temperature for the respective type of conductor. For jumpers the normal temperature limit or the emergency temperature limit may be used in determination of the normal rating. See Table 1 for Emergency Rating.

6.2 Loss of strength or annealing is not a concern for jumpers.

7.0 Line Switches

7.1 The Ratings for Transmission Line switches shall be similar to those used in substation applications. Refer to ATC Criteria CR-0063; Substation Equipment Ampacity Ratings for Switch Ratings.

8.0 Publication of Ratings

8.1 ATC tabulates its steady-state Ratings in a database (SELD)

8.2 Operators and other stakeholders are notified according to ATC Procedure PR-0285.

8.3 Transient ratings for overhead lines are not published and are only provided upon special operator request. The Rating may be given as an ampacity, a percent increase above Emergency Rating or load duration curve, which may include a maximum preload, load duration, etc.

9.0 Revision Information

9.1 Document Review

This Criteria will be reviewed annually in accordance with review requirement in GD-480, Document Control. The review is performed to ensure the Criteria remains current and meets any new or revised NERC Standard listed in Section 3.

| Version | Author | Date | Section | Description |
|---------|--------------|------------|-------------------------------------|--|
| 01 | S. Newton | 3-27-2007 | All | Reformatted and replaces former Operating Procedure 02-02. |
| 02 | R. Knapwurst | 8-04-2008 | 3, 4, 6, 7, 8, 9, 13 & Appendix | Revised seasons and added switch section, various minor corrections/changes. |
| 03 | R. Knapwurst | 10-06-2009 | Title, 6, 7, 8, 11, 12 & Appendix A | Title change, remove standard conductor designation, conductor characteristics, conductor fittings, various minor clarifications and updates. Annual review as required by NERC Standards. |
| 04 | R. Knapwurst | 5-24-2010 | 3, 4, 8 & Appendix A | Removed season definition, added season comment to Ambient Conditions Section, other minor corrections / changes. Annual review as required by NERC Standards. |
| 05 | R Kluge | 8-16-2011 | All sections & Appendix A | Revised definitions, added separate jumper section, other minor reformatting /corrections / changes. Deleted appendix table of ratings. |
| 06 | R Kluge | 3-09-2012 | 3.3, 4.11, 5.2, 5.4 | Define Study-Based Ratings methodology. Add ambient conditions for study-based ratings. |
| 07 | R Kluge | 4-30-2012 | 5.2; 5.3; Table 2b; 6.0; Appendix A | Include SELD rating calculations; Transition to and parameters for Study-Based Ratings; Jumper clarification; Study-Based Rating development. |

Appendix A: Study-Based Rating Development

1.0 Study Objectives

- Develop weather parameters appropriate for ATC's service territory using industry guidance.
- Develop rating methodology consistent with FAC-008 and recognized industry standards.
- This study was designed to utilize study-based rating concepts as described CIGRE 299 to develop regional weather parameters for rating bare overhead conductors. This was accomplished by processing Conductor Sag and Weather data collected at three monitoring sites along three different transmission line corridors.

1.1 FAC-008 requires

R 3.1 The methodology... shall be consistent with at least one of the following:

- Ratings... obtained from equipment manufacturer specifications such as nameplate rating.
- One or more industry standards (such as IEEE or CIGRE).
- A practice that has been verified by testing, performance history or engineering analysis.

R 3.2 The underlying assumptions... considered (including)

R 3.2.2 Ambient conditions

1.2 CIGRE TB-299, Guide for Selection of Weather Parameters for Bare Overhead Conductor Ratings

3.2.2 Regional rating assumptions may be based on actual weather studies, provided that weather studies

- are conducted in the actual transmission line environment,
- use methods recommended in Section 5 of CIGRE TB-299, and
- include the respective seasons if seasonal ratings are applied.

2.0 EPRI-ATC Study (Monitoring, Data collection and analysis)

2.1 ATC commissioned EPRI to conduct a local weather study for establishing weather parameters for conductor ratings consistent with CIGRE TB-299. The study consisted of collecting weather and conductor sag data, analyzing the data, and advising on applying that data to developing rating methodology. The principal contractors included Cermak Peterka Peterson Inc. (CPP), Engineering Data Mgt (EDM), and Dale Douglass (Power Delivery Consultants, CIGRE WG-B2.12 member, IEEE Std-738 Co-Chair). Bernie Clairmont (EPRI) was project manager.

2.2 EPRI-ATC study team chose three representative locations along ATC's transmission line corridors to study weather parameters. The transmission lines included: Paris—Albers, North Appleton—White Clay, and Highway V—Tower Drive. The three locations were in Kenosha, Outagamie and Brown counties. Selection criteria included:

- Lines carrying consistently, heavily loads, and
- Traversing various geographic and environmental features.

2.3 One year of data was collected and tallied for each of the four seasons.

2.4 A relationship between the weather data collected at these sites and nearby airport stations was established to expand the data with long-term meteorological data.

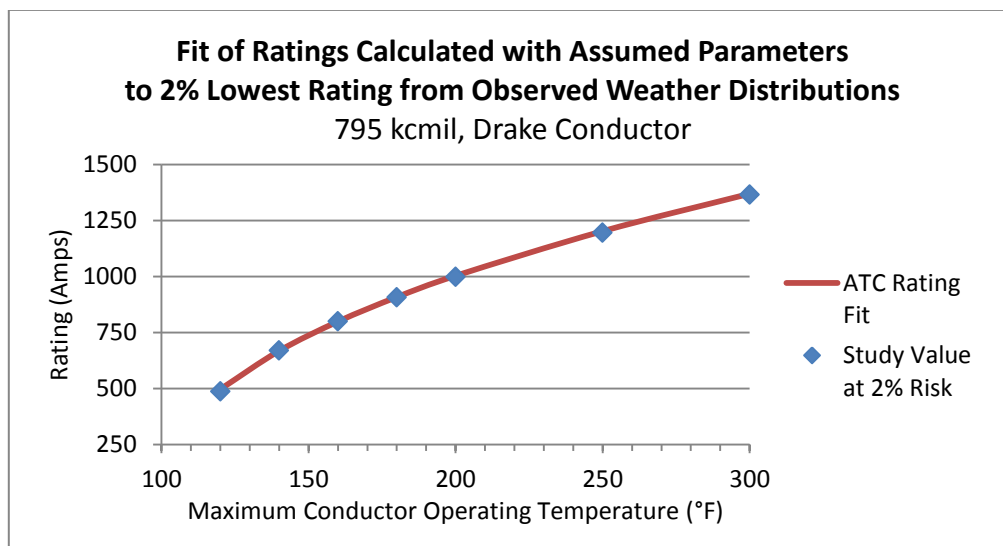
2.5 Statistical distributions were derived for wind, temperature and solar conditions and their relationships to line ratings that could be used in Monte Carlo simulations.

2.6 Ambient conditions were considered through Monte Carlo simulations replicating actual weather data representative of ATC transmission line corridors. These simulations were used to produce ampacity values for conductors commonly applied on ATC's system and at operating temperatures ranging from 120°F to 300°F. Separate simulations were done for all four seasons.

3.0 Establishing Study-Based Rating Methodology

- 3.1 The most critical cooling conditions were ranked by tabulating the line ratings in ascending order for each conductor size and max operating temperature. The most critical cooling condition is defined as the weather parameters resulting in the lowest conductor rating.
- 3.2 ATC chose a target rating level at the lowest 2% of the combined ratings statistics. The study values at this level were selected as appropriate considering:
- Confidence in the data set to represent actual conditions on any line, at any time and on any day in accordance with guidelines presented in CIGRE TB-299, and
 - The reliability objectives of ATC.
- 3.3 Then weather parameters (ambient conditions) were determined that best describing this target risk level. These are the weather parameters that would be used for rating ATC's overhead transmission conductors. Ambient conditions were back fit to match the results of the Monte Carlo assessment and to provide a 98% confidence level.
- 3.3.1 Graphs for each season were generated for the risk level selected by ATC. The graphs compare calculated ratings for assumed weather parameters to the study values at the 2% risk level that were statically generated using Monte Carlo simulations of the weather distributions.
- 3.3.2 Weather parameters were selected that best fit a range of conductor sizes and maximum operating temperatures.
- 3.3.3 For lines with maximum operating temperatures above 167°F, solar influence is greatly reduced consistent with industry data where nighttime conditions control due to low wind levels. This reduced solar influence is accomplished by using a solar flux factor (percent of noontime radiation) to describe the level of solar heating during morning and evening hours.
- 3.4 As an example, a graph (see Figure 1) shows the summer rating for drake conductor across a range of maximum operating temperatures. As can be seen, a very good fit was achieved.
- The points on the graph represent the 2% lowest rating values that were statically generate in the ATC-EPRI study.
 - The line (fit through the points) represents ATC Study-Based Ratings calculated using the ambient conditions in Table 2b of this document.

Figure 1

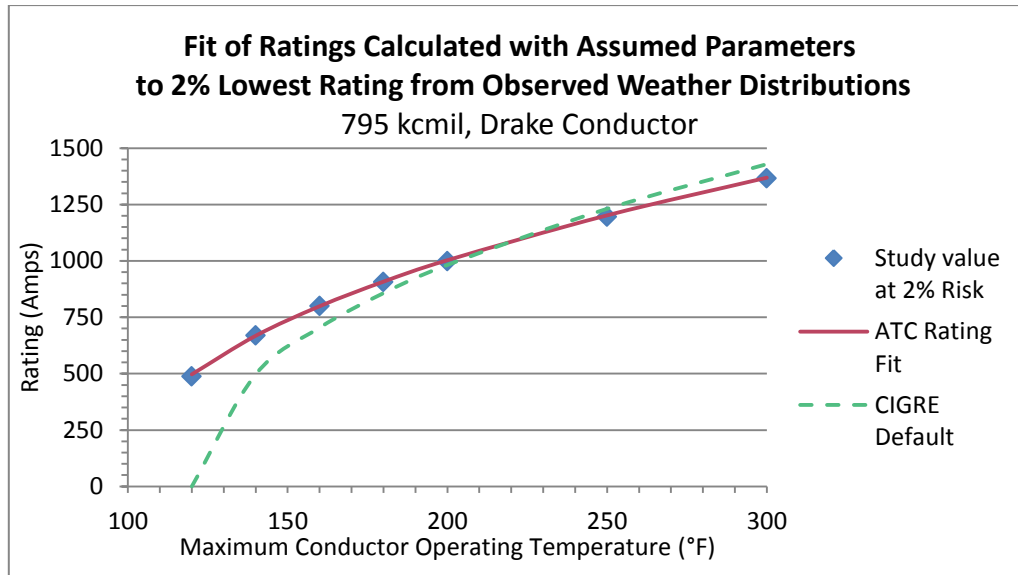


- 3.5 Similar curves (not shown) illustrate that these same ambient conditions can be applied when rating other conductor sizes.
- 3.6 The process was repeated to develop ambient conditions (weather parameters) for all four seasons.

4.0 Study-Based Ratings Compared to CIGRE Base Ratings

The best fit was attained assuming calmer winds, less solar radiation and more moderate temperatures than the CIGRE base-rating (default) parameters. This agrees with observations by CIGRE Working Group B2.12 that states lowest ratings occur during morning and evening coincident with calmer wind and moderate temperatures, for lines with higher maximum conductor temperatures. This observation becomes more evident in cooler climates or seasons where the temperature differential between ambient air and the conductors is greater. In other words, CIGRE (default) base-rating parameters did not fit the study results as well particularly at both high and low conductor maximum operating temperatures as illustrated below in Figure 2.

Figure 2



It is also reassuring to note that both study-based and default parameters provide approximately the same rating at moderate conductor temperatures of about 200°F, which shows that ATC's results are consistent with other studies at moderate conductor temperatures.

For conductors with high maximum operating temperature limits, wind is a dominant consideration for rating. Since winds are lower at night, controlling ratings for these lines were observed at night, which is consistent with published studies.

Conversely, conductors with lower maximum operating temperature limits (<140°F), ambient air temperature is a dominant consideration for summer ratings. For these lines, it is reasonable to expect summer ratings would be greater than that provided by the default ambient assumptions because ATC is located in a cooler (more northern) location.