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FOREWORD

The purpose of this document is to define the process for rating electrical lines and equipment.

Any questions or inquiries regarding information provided in this document should be referred to the Director, Engineering

Kevin Sprague — 12/28/2017
Director, Engineering — Date

John Bonazoli — DEC. 28, 2017
Manager, Distribution Engineering — Date

REVISION HISTORY

Revision #	Date	Description of Changes
1	04/04/2000	Revision 1
2	03/16/2012	Update to Power Transformer Rating Procedures and Guideline Consolidation
3	11/06/2012	Update to Ambient Conditions and Circuit Breaker Ratings
4	02/09/2016	Revised document number. This document supersedes PR-DT-TC-01
5	04/29/2016	Revised to include category for Facility Ratings
6	12/20/17	Updated to clarify compliance with NERC FAC-008-3

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1. Introduction

All electrical equipment have limits at which they can operate. The limits are based on current and length of time that cause the equipment to heat up to a point that the equipment may become damaged. In operating and planning the electric system it is important to create and know the ratings of all types of equipment.

1.1. Purpose

The purpose of this document is to serve as a guide for rating equipment and conductors under various conditions applied on the Unitil electrical system.

1.2. Applicability & Scope

This document provides detailed rating procedures for the following series-connected equipment:

- Transmission and Distribution Conductors
- Substation Power Transformers
- Relay Protection Settings
- Terminal Equipment[1]
  - Current Transformers
  - Switches
  - Breakers
  - Primary Fuses
- Series Reactors

All equipment installed on Unitil transmission/sub-transmission systems and within distribution substations shall be rated in accordance with these procedures. Alternate ratings may be assigned only if accordance with the manufacturer's recommendations and following approval from the Manager, Distribution Engineering.

1.3. Updating the Procedure

The Director of Engineering is responsible for approving this guideline and the Manager of Distribution Engineering is responsible for implementing this guideline. Material in the guideline will be updated or revised, as needed, in an attempt to stay current with changes in the company's organization, policies or to capture good utility practices. All revisions and/or

[1] Unitil does not own or operate any wave traps.

additions shall detail a revision date and number on the top right corner of each page within the header, as well as a brief description in the *Revision History* section on the cover.

Comments are welcomed and should be documented (using the Request for Procedure/Change Form reference in Appendix A) and addressed to the Director, Engineering. All documented comments shall be retained in a separate file and reviewed each time this procedure is revised. These comments will keep the contents of the procedure current and enhance its usefulness.

1.4. Revision Notes

This document is being issued as an update and supersedes all previous revisions of Unitil Electrical Equipment Rating Procedures. This revision also expands on the previous version incorporating the requirements of other stand-alone rating guidelines and consolidates these requirements into one comprehensive document. As a result, the following documents are now obsolete and shall no longer be referenced:

- *Power Transformer Rating Methodologies* – no revision date
- *Procedure for Rating Transformers* – 7/24/96
- *Overhead Conductor Rating Methodologies* – no revision date
- *Conductor Rating Procedure* – 7/24/96

1.5. Availability

Current copies of this procedure can be found on the Hampton Shared Drive. Hard copies are not version controlled.

NOTE: Only up-to-date versions of the documents are posted on the Hampton Shared Drive. All other revisions (both electronic and hardcopy) should not be referenced.

1.6. References

IEEE C57.91- Guide for Loading Mineral-Oil-Immersed Transformers

IEEE 738 - IEEE Standard for Calculating the Current-Temperature of Bare Overhead Conductors

IEEE C37.010 - Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

ISO NE Planning Procedure No. 7 - Procedures for Determining and Implementing Transmission Facility Ratings in New England

Code of Massachusetts Regulations 220 CMR 125.00 - Installation and Maintenance of Electric Transmission Lines

NERC Standard FAC-008 – Facility Ratings

2. General Information

2.1. Acronyms/Abbreviations

The following is a list of commonly used acronyms:

DAL – Drastic Action Limit

LTE – Long Time Emergency

STE – Short Term Emergency

2.2. Definitions

Facility – a set of electrical equipment that operates as a single system element.

Equipment Rating – The maximum current on individual equipment under steady state conditions as permitted or assigned by the equipment owner.

Normal Rating – equipment rating adjusted for ambient conditions, which will allow maximum equipment loading without incurring loss of life above design criteria.

Emergency Ratings – equipment rating above normal rating, which may involve loss of life or loss of tensile strength in excess of design criteria.

3. Responsibilities

3.1. Department Responsibilities

- Use only current versions of guidelines
- Ensure guideline updates, revisions, or corrections are conducted as needed
- When assigned to write or review guidelines, use only appropriate references

4. Rating Categories

This section describes the required ratings to be assigned to specified electrical components.

4.1. Equipment Ratings

All transmission/sub-transmission line elements (conductors, breakers, switches, terminal equipment, etc.) and substation power transformers shall be assigned normal and LTE ratings

for winter and summer operating conditions. Facility ratings shall respect the most limiting applicable Equipment Rating of the individual equipment that comprises that facility. The Winter Period is defined as November 1 to March 31. The Summer Period is defined as April 1 to October 31.

STE and DAL ratings will be assigned to transmission/sub-transmission elements that interface with systems under the jurisdiction of ISO-NE. Typically, STE and DAL equipment ratings will be equivalent.

Electrical equipment shall be operated at these ratings in accordance with the limitations described in the Unitil Electric System Planning Guide and as summarized in the table below:

Season	Rating	Operational Limitation
Summer	Normal	Continuous (normal load cycle)
	LTE/Emergency	12 Hours (one non-repeating load cycle)
	STE	15 Minutes
	DAL	Requires immediate action
Winter	Normal	Continuous (normal load cycle)
	LTE/Emergency	4 Hours (one non-repeating load cycle)
	STE	15 Minutes
	DAL	Requires immediate action

NOTES:

1. In practice, operating equipment at load levels above its Normal rating but below LTE rating shall be considered operation at LTE. Similarly, operation above LTE but below the STE rating should be considered operation at STE. Operation at or above the STE limit should be considered operation at DAL.

2. Equipment operating above the Short Term Emergency limit for more than five minutes may suffer unacceptable damage.

4.2. Facility Ratings

Transmission Facility Ratings shall be determined per ISO NE Planning Procedure No. 7 and shall respect the most limiting applicable Equipment Rating of the individual equipment that comprises that Facility per latest NERC Standard FAC-008. Each rating (Normal/LTE/STE/DAL) shall be determined separately such that the limiting equipment may differ for each rating assigned to that facility.

4.3. Temporary Ratings

Temporary ratings of newly installed equipment may be used until permanent rating calculations are established. The temporary ratings will be based on the manufacturers' continuous ratings.

5. Calculation Assumptions

5.1. Ambient Conditions

Normal and Emergency ratings shall be established for both summer and winter seasons based on a wind velocity of 3 feet per second (fps), where applicable, and the ambient temperatures outlined in the table below.

	Overhead Conductors		Power and Current Transformer		All other Equipment	
Season	Normal	Emergency	Normal	Emergency	Normal	Emergency
Winter (11/1 to 3/31)	10ºC	10ºC	10ºC	10ºC	10ºC	10ºC
Summer (4/1 to 10/31)	37.8ºC	37.8ºC	25ºC	32ºC	28ºC	28ºC

These ambient temperatures listed above were developed based on recommendations from the following IEEE guidelines, ISO-NE PP7, and state regulations:

A. Power and Current Transformers

IEEE C57.91 – Guide for Loading Mineral-Oil-Immersed Transformers recommends the use of either the average temperature2 or the maximum daily temperature3 for the month involved in determining Normal and Emergency ratings. C57.91 also recommends the use of a 5ºC adder for conservatism. The ambient temperatures indicated in the preceding table are based on historical temperatures experienced throughout Unitil service territories and these recommendations.

B. Overhead Transmission and Distribution Line Conductor

IEEE 738 – Standard for Calculating the Current-Temperature of Bare Overhead Conductors. Massachusetts Department of Public Utilities, CMR 220, 125.23 (3)

5.2. Equipment Temperature

Equipment temperatures for normal loading shall be in accordance with industry standards or loading guides where applicable. In cases where no industry approved guides exist for emergency loading, maximum equipment temperatures higher than design values may be allowed for emergency operation, at the discretion of Unitil Service Corp. It is noted that operation at total temperatures above design values may violate manufacturers' warranties and/or may result in undesirable changes in operating characteristics.

5.3. Temperature Measurements

The temperature of line terminal equipment which experience maximum rated loads may be measured with infrared equipment or other appropriate devices during these maximum rated loads.

Ratings based on reliable infrared observations, or any other reliable temperature measurements, obtained under operating conditions, will be considered to take precedence over all other ratings.

5.4. Nonconforming Equipment

Equipment not designed, not manufactured, not installed, or not maintained in accordance with these Procedures is assigned ratings in accordance with the manufacturer's recommendations.

[2] IEEE C57.91 defines *Average Temperature* as the average daily temperature for the month involved, averaged over several years.
[3] IEEE C57.91 defines *Maximum Daily Temperature* as the maximum daily temperatures for the month involved averaged over several years.

5.5. Assumed Loading Conditions

Where time-temperature relationships for annealing characteristics have been applied, the following estimated hours of operation at allowable equipment temperatures have been assumed, over a 30-year equipment life:

Normal Rating	13,200 hours
Emergency (4-12 hour) Rating	500 hours
Emergency (15 minute) Rating	20 hours
Drastic Action Limit	N/A

These estimates are based on the fact that annealing and loss of strength occur only when a device is operating at or near its emergency rated temperature limits. For most locations on the transmission system, ambient temperature variations together with daily and seasonal cycling of load current will result in conditions where the equipment operates at temperatures considerably lower than rated values, most of the time.

The total duration of operation at emergency temperatures reflects a conservative estimate for the time that the rated elements are expected to operate under contingency conditions. In regards to conductors, the common rule of thumb for loss of tensile strength is to limit the loss to 10 % over the 30-yr equipment life.

6. Equipment Rating Procedures

6.1. Substation Power Transformers

The ratings described in this section apply substation power transformers with nameplate ratings of 100 MVA and below. Substation power transformers shall be rated in accordance with the following standards and noted exceptions.

a. Transformers are to be rated in accordance with ANSI Standards and IEEE loading guidelines. Transformers not conforming to ANSI Standards shall be assigned ratings in accordance with the manufacturer's recommendations.

b. Transformers shall be rated within the following operational limitation derived directly from ANSI C57.91 – 1995.

Criteria	55°C Rise Transformers		65°C Rise Transformers	
	Normal	LTE	Normal	LTE
Acceptable Loss of Life (% per day)	No Limit[4]	No Limit[3]	No Limit[3]	No Limit[3]
Top Oil Temperature	100°C	100°C	110°C	110°C
Hottest-Spot Temperature	115°C	125°C	130°C	140°C
Max Loading (P.U. of nameplate)	2	2	2	2

6.2. Current Transformers

Current transformers are to be rated in accordance with the following procedures outlined in the example below:

6.2.1. Independent Current Transformers

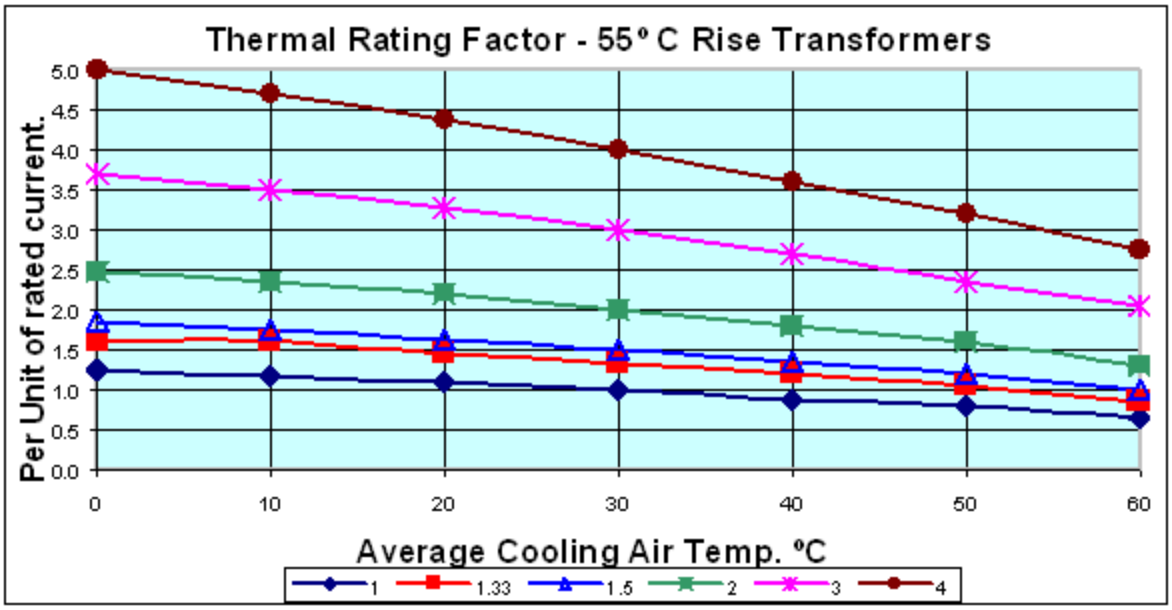
These are current transformers which are purchased and installed as independent units.

A. Normal and Emergency Continuous Capability – The normal and emergency continuous capability of a current transformer depends on its thermal rating factor and the average cooling air temperature. At the present time the normal and emergency ratings are the same. The rating can be found by choosing the appropriate thermal rating factor and average ambient temperature in Figure 1, (reproduction of Figure 6 of IEEE Standard C57.13-1978) and then reading the per unit of rated current at the left of the curve.

Design temperature limits will not be exceeded if this loading procedure is followed.

[4] The following loss of life values shall be used to quantify excessive loss of life: Normal Loading = 0.0369 per day, LTE Loading = 1% per day

Figure #1: Independent CT Thermal Rating Factors



6.2.2. Internal Bushing Current Transformers

These are current transformers which use the current-carrying parts of major equipment as their primary windings and are usually purchased as integral parts of such equipment. On a multi-ratio transformer, the secondary winding is tapped.

A. Normal Continuous Capability - Most manufacturers state that internal bushing current transformers furnished with a piece of equipment have thermal capabilities which equal the capability of the equipment.

1) For a single-ratio or multi-ratio internal bushing current transformer operating at a nominal primary current rating equal to the nameplate rating of the equipment with which it is used, the current transformer should be considered to have the same thermal capability as the equipment.

2) For a single-ratio internal bushing current transformer with a rating less than that of the equipment in which it is installed, the calculated equipment capability should be reduced by the factor

$$\sqrt{I_{ct} / I_e}$$

Where Ict is the current transformer nameplate primary current rating and Ie is the equipment nameplate current rating.

3) For a multi-ratio internal bushing current transformer with a maximum rating equal to the nameplate rating of the equipment in which it is installed, but which is operating on a reduced tap, the calculated equipment capability should be reduced by the factor

$$\sqrt{I_t / I_n}$$

Where It is the reduced tap current rating, and In is the maximum current rating of the current transformer.

Information is not readily available on the continuous thermal rating factor of a bushing current transformer, the manufacturer should be consulted.

6.2.3. External Bushing Current Transformers

These are current transformers which use the current-carrying parts of major equipment as their primary windings, and are not usually purchased as integral parts of such equipment. These current transformers are to be assigned ratings in accordance with the manufacturer's recommendations.

6.2.4. Loading of Secondary Devices

In all cases devices connected to the secondary circuit of a current transformer shall be checked with respect to both accuracy and thermal capability.

6.2.5. CT Rating Example

The following example is provided to illustrate these procedures:

1. The sample current transformer is an independent, oil filled, current transformer, with thermal rating factor of 1.5.

2. Ambient temperatures:

	Normal	Emergency
Winter	10˚C	N/A
Summer	32˚C	N/A

3. Loadability Multipliers Observed From Figure 1

	Winter	Summer
Normal	1.7	1.5
Emergency	N/A	N/A

4. devices connected to the secondary circuit of a current transformer shall be checked with respect to both accuracy and thermal capability.

6.3. Overhead Line Conductors

6.3.1. Rating Procedure

The capacity rating calculation procedures are designed to achieve uniformity. All ratings shall be determined using the ambient air temperature and wind velocity described in Section 5. Ratings shall be developed using the following procedures:

a. Conductor ratings shall be calculated in accordance with IEEE 738 - IEEE Standard for Calculating the Current-Temperature of Bare Overhead Conductors.

b. Conductor ratings should include:

Summer Normal
Summer Long-term Emergency
Summer Short-term Emergency
Winter Normal
Winter Long-term Emergency
Winter Short-term Emergency

c. The following values for equation parameters are specified below:

Parameter	Name	Value
D	Conductor Diameter	As required
E	Emissivity Factor	0.75
A	Absorbtivity Factor	0.50
R	Conductor AC Resistance @ 75ºC/25ºC	As required
Ta	Ambient Temperature	37.8ºC/10ºC
Tc	Conductor Temperature	
	(Normal Rating)	80ºC
	(Long-time Emergency Rating)	100ºC
	(Short-time Emergency Rating)	120ºC
V	Wind Velocity (perpendicular to line)	3.0 fps
	Atmosphere	Clear
	Local Sun Time	2:00PM
	Latitude	42.5 degrees
	Elevation	1000ft

6.3.2. Line Constants

Line constants are developed using LineProp software developed by Siemens Power Technologies International. This program is used to determine positive and zero sequence by
section of each transmission line currently within the Unitil System. It was determined by USC-Engineering and Planning that the ground resistance would beset to an average of 100 ohm-meters and resistance and reactance values are used at 50 degrees Celsius. All summer and winter conductor ratings are developed as stated above and entered into the program. This program will serve to be the database for all transmission conductors within the Unitil System.

6.4. Underground Line Conductors

Underground line conductors are assigned ratings in accordance with the manufacturer's recommendations.[5]

[5] Unitil does not own or operate any underground primary conductors that are directly connected to the New England transmission system and under the jurisdiction of ISO-NE.

6.5. Breakers, switches, circuit switchers, regulators, and series reactors

Breakers, switches, circuit switchers, regulators, and series reactors are to be assigned ratings in accordance with the manufacturer's recommendations. These ratings are typically the nameplate ratings of the device.

Breakers, and any associated internal bushing CTs, operating at 69kV and above that are directly connected to the New England transmission system and under the jurisdiction of ISO-NE shall be rated based on ANSI C37.010 adjusted for the ambient conditions detailed in Section 5.1.

6.6. Relay Protective Settings

Whenever possible protective device settings and fuses do not limit the loadability of a Facility. Loading of protective devices is reviewed during the annual planning process to determine if any protective settings or fuses exceed the following limits.

Fuses - 90% of continuous current rating or 67% of minimum melt, whichever is lower.

Relay Protection Setting – 67% of pick-up in normal configurations and 80% of pickup in contingency configurations.

Any device that exceeds these ratings shall be reviewed in more detail to determine if settings or fusing should be modified.

In the event that a protection setting is the most limiting element the facility rating shall be limited to the reflect the protection setting limitations.

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Appendix A: Request for Procedure/Change Form

Requestor: _____ Item(s)/Section to be changed (if applicable):
Title: _____ Section: _____
Department: _____ Page: _____
Location/DOC: _____ Figure: _____
Date: _____ Appendix _____
Procedure No.: _____ Other: _____

For New Procedures
Description of new procedure to be developed: _____

Reason for new procedure: _____

For Changes to Existing Procedures
Description of requested change(s): _____

Reason for requested change(s): _____

Instructions: The individual requesting a new procedure or change(s) to existing procedures shall complete this form and submit it to the Director of the applicable department. For changes to procedures please attach a copy of the existing procedure with revisions marked on the copy.

Requestors Signature: _____ Date: _____

For Reviewers Use Only
Change(s) Approved? YES NO If No, briefly explain _____
Changes Implemented? YES NO Date Implemented: _____
Reviewers Signature: Date: