ISO NEW ENGLAND PLANNING PROCEDURE NO. 7

PROCEDURES FOR DETERMINING AND IMPLEMENTING TRANSMISSION FACILITY RATINGS IN NEW ENGLAND

EFFECTIVE DATE: November 7, 2014

REFERENCES: ISO New England Operating Procedure No. 16, Transmission System Data

ISO New England Operating Procedure No. 19, Transmission Operations

NERC Standard FAC-008-2 – Facilities Rating Methodology

Transmission Operating Agreement (TOA)

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1.0 INTRODUCTION

These procedures describe:

1) The collaborative development of ratings for (a) transmission equipment connected at 69kV and above on the electric power system in New England and (b) all generator step up transformers attached to generators of 1 MW or greater that participate in the Energy Market; and

2) The provision for reviewing the ratings of individual transmission facilities prior to their permanent implementation by ISO New England (the ISO).

The Market Participants and the ISO are responsible for collaborating in both the development of rating procedures and establishment of ratings.

ISO New England Operating Procedure No. 16, Transmission System Data (OP 16), requires Market Participants to determine equipment ratings and provide them to the ISO. Ratings for new facilities and changes to ratings of existing facilities shall be determined in a manner consistent with the collaboratively developed ratings methodologies described in Section 2 and, as required, shall be collaboratively reviewed in accordance with Section 3.

The ISO is responsible for:

1) Maintaining documentation describing individual Market Participants' current rating methodologies,

2) Administering technical reviews of such methodologies and changes to them,

3) Initiating improvements in rating methodologies to gain consistency and system capacity, and

4) As required, coordinating technical reviews of new and revised ratings as they are submitted per OP 16.

The System Design Task Force of the Reliability Committee (SDTF), chaired by ISO staff, provides the structure for Market Participant/ISO collaboration in developing rating methodologies and establishing ratings. The task force is the primary source of technical advice on ratings methodologies and review of individual equipment ratings. The Reliability Committee will be informed of any such advisory recommendations provided to the ISO.

These procedures address only static ratings, which are determined based on a specific set of input assumptions that can be adjusted for ambient temperature conditions. Temporary ratings can be determined for use in particular situations; these are addressed in Section 2.6 below. Dynamic ratings are not employed in operating the New England power system or in administrating the electricity markets.

2.0 COLLABORATIVE DEVELOPMENT OF RATING PROCEDURES

2.1 APPROACH

1) Loadings in excess of a component's continuous capability will contribute to accelerated wear, reduced equipment life and potential failure and represent a risk to the equipment owner as well as those using the power system. While it is important that the methodologies reflect an acceptable level of equipment risk, it is also important that the methodologies be consistently applied throughout the transmission system since they ultimately determine the capacity of the system.

2) No single methodology is universally accepted for determining the thermal capability of each component of the transmission system. However, guidelines for rating transmission equipment were developed by NEPOOL in 1970 for use by individual equipment owners. There continues a general consistency in methods, although there are also some differences. This PP7 is established to reintroduce guidelines representative of "best ratings practices" and to initiate improvements in individual owners' rating methodologies, where appropriate, to gain consistency of application and to maximize transmission system capability while maintaining acceptable levels of risk to equipment and maintaining reliability.

3) Consistency of a Market Participant's rating practices with the collaboratively developed ratings methodologies is determined as described in Section 2.5, below.

2.2 TRANSMISSION EQUIPMENT TO BE RATED

Each Market Participant shall establish methodologies for rating the following components, as applicable:

Overhead Conductors
Underground Cables
Power Transformers
Series and Shunt Reactive Elements
Circuit Breakers
Disconnect Switches
Current Transformers
Line Traps
Substation Buses
Current Transformer Circuits
VAR Compensators
HVDC Systems

As described in Section 2.4 below, guidelines representative of "Best Rating Practices" for each of the above components are provided in the Appendices.

2.3 RATINGS AND LIMITS TO BE ASSIGNED

Transmission equipment shall be assigned ratings and limits for the conditions listed below:

- Winter Normal Rating (W NOR)
- Winter Long-Time Emergency Rating (W LTE)
- Winter Short-Time Emergency Rating (W STE)
- Winter Drastic Action Limit (W DAL)
- Summer Normal Rating (S NOR)
- Summer Long-Time Emergency Rating (W STE)
- Summer Short-Time Emergency Rating (S STE)
- Summer Drastic Action Limit (S DAL)

Where:

The Winter and Summer ratings are determined using the input assumptions of Appendix A, General Rating Parameters. The periods for which Winter and Summer ratings apply are defined in ISO Operating Procedure 16, Transmission System Data (OP16).

ISO Operating Procedure 19, Transmission Operations (OP19) describes the conditions in which the Normal Ratings and Emergency Ratings are applied, actions to be taken to maintain equipment loadings within ratings and limits and the associated allowable durations of time associated with operation at each rating. These conditions and times must be consistent with those used to determine the corresponding ratings. Thus,

The Normal Rating is the rating, adjusted for ambient conditions, which will allow maximum equipment loading without incurring loss of life above design criteria. The design criteria are described in Appendix A, General Rating Parameters.

Emergency Ratings, which exceed normal ratings, involve loss of life or loss of tensile strength in excess of design criteria. Consistent with OP19, the emergency ratings shall be calculated to using the following time durations.

Winter LTE (W LTE) - 4 hours
Summer LTE (S LTE) - 12 hours

Winter STE (W STE) - 15 minutes
Summer STE (S STE) - 15 minutes

Drastic Action Limits, unlike normal and emergency loading ratings, are limits that require immediate action to be taken to prevent damage to equipment. Their calculation is described below.

2.3.1 Calculation of Drastic Action Limits:

For purposes of calculation, the Drastic Action Limit is defined as the current flow, which would cause the circuit component to reach its 15-minute emergency thermal limit, if allowed to flow for five minutes, assuming the following conditions:

1) The summer and winter ambient conditions as described in paragraph 2.1 of Appendix A, General Rating Parameters; and

2) A pre-disturbance circuit loading of 75% of the normal terminal equipment rating or 75% of the conductor sag limitation, whichever is less, for the appropriate season.

The use of five minutes in computing the Drastic Action Limit does not indicate that five minutes, or any other time increment, exists for which current of the calculated magnitude may safely be allowed to flow. A prescribed "drastic action" is required to return the circuit loading to the long-time emergency rating for the appropriate season.

2.4 NEW ENGLAND "BEST RATING PRACTICES"

1) Rating methodologies for each equipment type specified in Section 2.2 shall be collaboratively developed and included as appendices to this PP7. Initially, reference will be made to applicable sections of the former rating guidelines (NEPOOL Capacity Rating Procedures) until the section is reviewed, updated and replaced.

2) Such methodologies shall be developed consistent with the requirements of Section 2.3 recognizing the previous NEPOOL rating guidelines, individual Market Participant practices, currently applicable equipment standards, equipment manufacturer recommendations and good utility practice.

3) The ISO shall initiate a SDTF review of each section of the appendix at least every 5 years or following a major revision of an applicable rating standard.

2.5 CONFORMANCE OF MARKET PARTICIPANT RATING METHODOLOGIES

1) Market Participants shall provide, to ISO New England, fully documented copies of the current methodologies used to rate each applicable equipment type specified in Section 2.2 within 15 business days of receipt of a request. Such documentation will include reference to standards employed and will allow determination of how ratings for each condition in Section 2.3 are computed. It will identify differences from the "Best Rating Practices" described above, including, as appropriate, the wind velocities, ambient temperatures, equipment temperatures and other pertinent assumptions used. Software deemed proprietary and not provided will be made available for on site inspection/testing. Whenever a Market Participant modifies their rating methodologies, this same information shall be provided to the ISO, as is pertinent to the change, before any rating using such methodology is submitted in accordance with OP16.

2) Such documentation shall be submitted electronically to an ISO mailbox established for this purpose.

3) Any differences from the requirements of Section 2.3 are violations of OP16 and will be dealt with accordingly.

4) Any differences in a Market Participant's methodologies from those of the "Best Rating Practices" shall be accompanied with either a statement of intent and schedule for introducing modifications to adhere to the "Best Rating Practices" or written justification for that Market Participant's continuing the non-conforming practice.

5) Within 30 days of receiving a Market Participant's written justification for a non-conforming practice, the SDTF Chair will solicit advice from the SDTF and, as appropriate, other task forces or subcommittees of the Reliability Committee. The SDTF will coordinate consideration of any justification for the non-conforming practice and evaluate and judge its continued use and provide a recommendation to the ISO. The ISO will act on all such SDTF recommendations within 60-days.

6) The ISO may also initiate a technical review of the documentation submitted by a Market Participant and may solicit advice from the SDTF or other task forces or subcommittees of the Reliability Committee in evaluating its conformance with the "Best Rating Practices".

7) Written comments regarding the conformance of a Market Participant' practices will be provided to the Market Participant.

   - Those differences deemed justifiable will be formalized by letter and recorded in Attachment 1 to this PP7 as an "Accepted Alternative Rating Practice" specific to that Market Participant.

   - Those differences determined to be unjustified will be identified and accompanied with a request they be modified to conform.

   - Communication with the Market Participant will be posted on the ISO webpage at the following location: http://www.iso-ne.com/committees/comm_wkgrps/relblty_comm/sysdesign_tf/excptns/index.html

8) Market Participants shall provide a written response to the ISO within 45 days, indicating:

   - Acknowledgement that an "Accepted Alternative Rating Practice" will be included in Attachment 1 of PP7, or

   - Acceptance of a request to modify the rating practice and a scope and schedule for introducing such modifications, or

- No change to that methodology will be forthcoming and why. This response may initiate a disagreement as described in Section 4, below.

9) The ISO shall maintain documentation of each Market Participant's current methodologies and comparisons with the requirements of Section 2.3 and the "Best Rating Practices" contained in the appendices to this PP7. Any differences and their disposition will be noted. Copies of all rating methodology documentation provided under this PP7 (including for methodologies later superseded), and documentation of all comparisons with the PP7 appendices, as well as any associated correspondence with Market Participants, shall be retained for 3 years.

10) SDTF discourse when evaluating exceptions to a "Best Rating Practice" should be considered when that methodology is next reviewed.

2.6 Temporary Ratings

1) The intent of these procedures is to provide uniform, well-documented methodologies for rating transmission line and terminal equipment. When a Market Participant deems it necessary to meet system events or unusual weather conditions, they may provide sets (Normal, LTE, STE) of temporary ratings for specific facilities as described in ISO New England Operating Procedure No. 19, Transmission Operations (OP19). Such ratings will typically recognize factors such as local ambient temperatures or and equipment preloading and would be available to be invoked by system operators.

2) If temporary ratings are employed, a description of the rating methodology shall be provided to the ISO, along with a description of any differences from the equipment owner's methodology provided in conformance of Section 2.5, above.

3.0 Collaborative Review of Transmission Facility Ratings

3.1 Approach

1) OP 16 requires that Market Participants supply ratings that are representative of all elements of the New England transmission network.

2) OP 16 also requires that, prior to implementation, ISO review all such data to verify that it is complete, reasonable and consistent with related data and reasons for the change.

3) In cases where ISO identifies a rating as questionable following discussion of such data with the equipment owner, the collaborative review procedure of Section 3.2 shall be employed. During the period of such a review, the new rating data will be granted provisional approval and its implementation will proceed.

3.2 COLLABORATIVE REVIEW OF TRANSMISSION FACILITY RATINGS

1) Upon determining that a rating remains questionable, ISO shall notify the Market Participant that a review of the rating has been initiated. The NX-9 Administrator shall then discuss the rating issue with the Chair of the SDTF.

2) Should it be decided that further review of the rating is not appropriate, the Market Participant shall be so notified and implementation of the rating data would continue.

3) Should it be decided that further review of the rating is appropriate, the Market Participant shall be notified that the rating has not been accepted pending outcome of a review by the SDTF. The rating would continue through the implementation process but with provisional approval.

4) The Chair of the SDTF shall then initiate a review of the rating by the task force, considering the rating submission and supporting information, the rating practices of the Market Participant, the "Best Rating Practices", and the applicable standards.

5) If the SDTF agrees that the rating as submitted is reasonable, and the ISO also agrees, ISO shall so notify the Market Participant and the rating shall be approved.

6) If the SDTF agrees the rating as submitted is unreasonable, and the Market Participant accepts the SDTF determination, the Market Participant shall initiate a revised data submittal.

7) If the SDTF agrees the rating as submitted is unreasonable, and the Market Participant does not accept the SDTF determination, the issue would be settled as described in Section 4, below.

8) If the SDTF agrees that the rating as submitted is reasonable, and the ISO disagrees, the issue would be settled as described in Section 4, below.

4.0 DISAGREEMENTS

Should there be disagreement between the ISO and any Market Participant regarding Sections 2.5 or 3.2, the language of Section 3.06 (a) (v) of the Transmission Operating Agreement shall govern the disagreement.

5.0 APPENDICES

The following is a list of the documents that describe the accepted practices for determining ratings of the indicated equipment types. The individual documents are updated from time to time as the SDTF modifies the "Best Rating Practices" per Section 2.4, above.

Appendix A - General Rating Parameters

Appendix B	-	Overhead Conductors
Appendix C	-	Underground Cables
Appendix D	-	Power Transformers
Appendix E	-	Series and Shunt Reactive Elements
Appendix F	-	Circuit Breakers
Appendix G	-	Disconnect Switches
Appendix H	-	Current Transformers
Appendix I	-	Line Traps
Appendix J	-	Substation Buses
Appendix K	-	Current Transformer Circuits
Appendix L	-	VAR Compensators
Appendix M	-	HVDC Systems

Document History

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Rev. 1 4/11/06 Editorial changes to maintain consistency with Appendices
Rev. 2 2/14/07 Sections 2.4 and 2.5 modified to conform with NERC Standard FAC-008-1
Rev. 3 8/10/10 Update on entire Planning Procedure to conform with new IEEE standards and NERC Standard FAC-008-2
Rev. 4 11/7/2014 Document body clean up

APPENDIX A
GENERAL RATING PARAMETERS

1.0 INTRODUCTION

This Appendix A describes the general parameters that should be used in calculating ratings for (a) transmission equipment connected at 69kV and above on the electric power system in New England (except underground cables) and (b) all generator step up transformers attached to generators of 1 MW or greater that participate in the Energy Market.

Such parameters for underground cables are described in Appendix C, Underground Cables.

2.0 AMBIENT TEMPERATURES AND WIND VELOCITIES

A complete discussion of ambient temperatures and wind velocities will be found in Reference 1, "Ambient Temperatures and Wind Velocity for Rating Calculations."

AMBIENT TEMPERATURES

The following table of ambient temperatures should be used for determining normal and emergency equipment ratings:

Table A 1
Ambient Temperature For Determining Equipment Ratings

	Overhead Conductors		Power and Current Transformers		All Other Equipment	
	Normal	Emergency	Normal	Emergency	Normal	Emergency
Winter	10 °C	10 °C	5 °C	10 °C	10 °C	10 °C
Summer	38 °C	38 °C	25 °C	32 °C	28 °C	28 °C

With the exception of the summer ambient temperature for overhead conductors (addressed in Section 2.1.1, below), the above ambient temperatures were developed from Hartford, Connecticut area temperature statistics for the years 1905 to 1970 and reaffirmed following analysis of similar data from eight locations throughout New England for the years 1975-2004. This data is summarized in Table A2 (Hartford Area) and Table A3 (New England).

Table A 2
Hartford, CT Area Temperature Data
1905-1970

	Average of the Daily Maximums[1]		Average of the Monthly Maximums[2]		Daily Mean[3]	
	°F	ºC	°F	ºC	°F	ºC
January	35.1	1.7	54.0	12.2	27.2	-2.7
February	36.1	2.3	53.0	11.7	27.7	-2.4
March	45.5	7.5	66.1	18.9	36.9	2.7
April	58.0	14.4	79.0	26.1	48.0	9.0
May	69.6	20.9	86.9	30.5	58.6	14.8
June	78.3	24.6	92.0	33.3	67.8	19.9
July	83.2	28.4	94.0	34.4	70.8	21.6
August	82.5	28.1	91.0	32.8	70.8	21.6
September	77.1	25.1	87.0	30.6	62.2	16.8
October	63.9	17.7	81.0	27.2	51.1	10.6
November	50.5	10.3	66.0	18.9	42.0	5.5
December	38.0	3.3	57.0	13.9	30.4	-0.9

Table A 3
New England Temperature Data (Eight Locations[4])
1975-2004

	Average of the Daily Maximums[1]		Average of the Monthly Maximums[2]		Daily Mean[3]	
	°F	ºC	°F	ºC	°F	ºC
January	32.29	0.18	52.04	11.13	25.01	-3.88
February	36.89	2.71	54.78	12.65	29.23	-1.54
March	44.08	6.70	65.84	18.81	36.10	2.26
April	55.45	13.03	78.49	25.80	46.65	8.16
May	66.28	19.03	85.24	29.59	57.08	13.93
June	75.38	24.11	90.06	32.25	66.55	19.19
July	79.86	26.59	91.21	32.89	71.18	21.76
August	79.39	26.30	90.69	32.60	70.94	21.63
September	72.15	22.30	85.19	29.54	63.58	17.53
October	59.65	15.36	76.65	24.81	51.00	10.56
November	48.90	9.40	66.79	19.33	41.63	5.35
December	39.26	4.04	58.93	14.96	32.20	0.11

1 This is the average of the daily maximum temperatures for each month.
2 This is the average of the monthly maximum temperature over 65 years.
3 This is the average of the daily maximum and minimum temperatures over the month.
4 Based on eight New England locations of Hartford/Windsor Locks and Bridgeport in CT, Boston and Worcester in MA, Burlington VT, Providence RI, Concord NH and Portland ME.

The ambient temperature recommendations of Table A1 are based upon the following:

2.1.1 Overhead Conductors

The 38 ºC (100 °F) summer ambient temperature for overhead conductors conforms to the guidelines cited in Section 125.23 of Chapter 220 of the Code of Massachusetts Regulations, Installation and Maintenance of Transmission Lines (220 CMR 125.23) [Reference 2].

2.1.2 Power and Current Transformers

IEEE Standard C57.91-1995 (R2004), "Guide for Loading Mineral-Oil-Immersed Transformers" [Reference 3] recommends using "average daily temperatures" for the month involved in determining normal ratings and "average of maximum daily temperatures" for the month involved for emergency ratings. The Guide also recommends the use of a 5°C adder to be conservative. The ambient temperatures indicated in Table A1 are consistent with the recommendations for determining ambient temperatures set forth in the C57.91 including the recommended 5°C adder as based on the data of Table A2.

1) Normal ambient temperatures were derived from the Daily Mean temperatures of Table A2; Column 3 and emergency ambient temperatures were derived from the Average of the Daily Maximum temperatures of Table A2, Column 1.

2) However, weighted averages of temperatures appropriate to the summer and winter periods were used instead of monthly temperatures as suggested by the Guide. Winter temperatures were equally weighted over the 5-month period. Summer temperatures were determined by equal weighting of the temperatures for the months of June through September.

A recalculation of the ambient temperature values using the data of Table A3 compares favorably with the recommendations of Table A1. Only the Summer Emergency ambient temperature differed, being lower by less than 2ºC.

The criteria to be used for developing ambient temperature for current transformers will be the same as power transformers.

2.1.3 All Other Equipment

Conservative weighted averages of daily maximum ambient temperatures (Column 1 of Tables A2 and A3) should be used for determining ratings of all other line terminal equipment. Therefore, the average of August daily maximums should be used for summer ratings and the average of November daily maximums should be used for winter ratings.

Inspection of the August and November values in Column 1 of Tables A2 and A3 indicate that the New England temperatures are slightly lower than those of the Hartford area, being less than 2ºC lower in summer and less than 1ºC lower in winter.

After considering the data of Tables A2 and A3, the SDTF has determined that the longstanding ambient temperature recommendations of Table A1 should remain unchanged.

WIND VELOCITIES

A wind velocity of 3 fps should be assumed during both the winter and summer periods where applicable. These values were determined by the Conductor Rating Working Group of the System Design Task Force and accepted by NEPOOL and are documented in the report "An Analysis of Wind-Temperature Data and Their Effect on Current-Carrying Capacity of Overhead Conductors" [Reference 4].

3.0 EQUIPMENT TEMPERATURE

Equipment temperatures for normal loadings shall be in accordance with industry standards or loading guides where applicable. In cases where no industry approved guides exist for emergency loading, total equipment temperatures higher than design values may be allowed for emergency operation, at the discretion of the individual companies.

4.0 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
Long-Time Emergency (4 hour/12 hour) Rating	500 hours
Short-Time Emergency (15 minute) Rating	20 hours
Drastic Action Limit	Not Applicable

These estimates are based on the fact that annealing and loss of strength occur only when a device is operating at or near its rated temperature limit. 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, with the exception of Drastic Action Limits, reflects a conservative estimate for contingency.

It should be recognized that, at locations where the load cycle is more severe, such as in proximity to a base load generator, the hours of operation at rated temperature would be expected to increase under normal operation. With more annealing taking place under normal loading, emergency ratings should be assigned with care. In fact, it is recommended that base loaded equipment, which is rated on the basis of loss of strength due to annealing, be assigned emergency ratings equal to normal ratings.

5.0 REFERENCES

1) ISO New England Report, "Ambient Temperatures and Wind Velocity for Rating Calculations", June 7, 2005. This document is included as Attachment 2 to PP7.

2) Code of Massachusetts Regulations, Installation and Maintenance of Transmission Lines (220 CMR 125)

3) IEEE C57.91-1995 (R2004), "IEEE Guide for Loading Mineral-Oil-Immersed Transformers"

4) System Design Task Force, "An Analysis of Wind-Temperature Data and Their Effect on Current-Carrying Capacity of Overhead Conductors" (SDTF-20), August 1983. This document is included as Attachment 3 to PP7.

Document History

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Rev. 1	4/11/06 Introduction corrected; editorial and format changes
Rev. 2	RC – 8/10/10

APPENDIX B
OVERHEAD CONDUCTORS

1.0 INTRODUCTION

These procedures provide a "best ratings practice" to be used by equipment owners for determining normal and emergency load-current carrying capabilities of overhead conductors installed on the New England transmission system, 69kV and above.

2.0 STANDARDS

Overhead conductors are to be rated in accordance with IEEE Standard 738-2006, "IEEE Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors". This standard presents methods of relating current and temperature for bare overhead lines as a function of:

- conductor material
- conductor diameter
- conductor surface condition
- ambient weather conditions
- conductor electrical current

and indicates sources of the values to be used in the calculations. Included, but not part of the standard, are sample calculations and a computer program, RATEIEEE, that may be used for steady-state and transient calculations of temperature and thermal rating for bare overhead conductors.

3.0 APPLICATION GUIDE

Overhead conductor ratings shall be calculated as described below at a rated power frequency of 60 Hertz and nominal voltage, e.g. 69 kV, 115 kV, 230 kV or 345 kV.

MAXIMUM ALLOWABLE CONDUCTOR TEMPERATURE

Conductor ratings are dependent on choice of maximum allowable conductor temperature, which is normally selected to control two factors:

- loss of strength over time due to annealing, and
- adequate ground clearances due to conductor sag considering the effects of non-elastic elongation (creep).

3.1.1 Loss of Strength

Lines that are operated near their Normal rating continuously may be subjected to annealing. Ratings of such lines should be determined and reviewed on an individual basis so that any loss of strength remains within design limits as discussed in Section 4 of Appendix A.

An IEEE paper by J. R. Harvey, "Effect of Elevated Temperature on the Strength of Aluminum Conductors" [Reference 1] provides a verified method to determine conductor loss of strength.

3.1.2 Clearances

Clearance requirements are established by the National Electrical Safety Code [Reference 2] and applicable state codes. These codes also specify that ground clearances are to be calculated using the maximum conductor operating temperatures. Thus the reduced ground clearances due to sag and creep[1] must be considered in choosing a maximum allowable temperature.

3.1.3 Recommended Maximum Allowable Conductor Temperature

The determination of maximum allowable conductor temperatures is left to the discretion of each equipment owner, with due consideration for the conductor material; however, such temperatures must not be less than 100°C for any emergency rating.

Overhead Conductor Rating Methodology

IEEE Standard 738, first published in 1986, is based on the methods developed by House and Tuttle in their 1958 AIEE paper [Reference 3]. These same methods were used in the New England Electric System programs PG92 and PG108, which the System Design Task Force adopted for calculating conductor ratings in 1970, and from which some programs now in use evolved. Programs consistent with the methods of Standard 738-2006 are acceptable for use in rating overhead conductors in New England.

Standard 738-2006 and the included rating program, RATEIEEE, address both steady-state and transient ratings. Since the thermal time constant of a conductor is generally greater than 15 minutes, the steady-state calculation is to be applied in determining Normal and Long-Time Emergency ratings. The transient calculation is applied in determining Short-Time Emergency ratings and Drastic Action Limits. In all cases, adequate clearances must be maintained with conductor loadings at the rated values.

Overhead Conductor Rating Parameters

Overhead conductor rating calculations are based largely on the resistance and maximum allowable temperature of the conductor, and two environmental factors: ambient temperature and wind speed (the design values of which are discussed in Appendix A). However, other physical characteristics and environmental conditions also influence the calculation of conductor ratings. Some of these vary with the conductor or with location:

- Conductor Diameter
- Latitude
- Elevation

[1] Creep can cause permanent increased conductor sag and is defined as the non-elastic deformation or flow of material, which occurs with time under its installed tension and advanced by application of additional wind or ice load.

- Atmosphere (Clear/Industrial)
- Line Direction (North – South, East-West, etc.)
- and the appropriate parameters are left to the discretion of the facility owners.

Other parameters can be uniformly applied throughout New England:

- Wind direction: perpendicular to the conductor as discussed in the SDTF–20 report [Reference 4].
- Emissivity and Solar Absorptivity: While these parameters increase with conductor age and oxidation and are influenced by operating voltage and the condition of the atmospheric environment, a value of 0.75 is recommended for Emissivity. Absorptivity values of 0.5 to 0.7 are recommended as per IEEE Standard 738-2006.
- Azimuth: 90 degrees

CONNECTORS AND SPLICES

The loadability of connectors and splices must meet or exceed the loadability of the conductors for which they are sized. The individual owners are to confirm, with the manufacturers involved, that the connectors and splices, when installed in accordance with the methods actually used in each case, may be loaded safely to the proposed line ratings, without exceeding the maximum allowable temperature limits of the conductors.

4.0 REFERENCES

1) Harvey, J.R., “Effect of Elevated Temperature on the Strength of Aluminum Conductors”, IEEE Transactions on Power Apparatus and Systems, T72-189-4.

2) ANSI C2-2002, National Electrical Safety Code

3) House, H. E. and Tuttle, P. D., “Current Carrying Capacity of ACSR”, AIEE Transactions, Power Apparatus and Systems, pp. 1169-1178, Feb.1958

4) System Design Task Force, “An Analysis of Wind-Temperature Data and Their Effect on Current-Carrying Capacity of Overhead Conductors” (SDTF-20), August 1983.

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Rev. 1 RC – 8/10/10

APPENDIX C
UNDERGROUND CABLES

1.0 INTRODUCTION

The following methodology applies to underground and submarine transmission lines, and covers the following type of cables and their accessories:

1) Impregnated paper or laminated paper - polypropylene insulated cables and accessories.
   - High Pressure Fluid Filled Pipe Type Cable (HPFF)
   - Low & Medium Pressure Self contained Liquid Filled Cable (LPOF)
   - High Pressure Gas Filled Cables (HPGF)

2) Extruded Solid dielectric cross linked polyethylene (XLPE) or Ethylene-Propylene-Rubber (EPR) insulated cables

2.0 UNDERGROUND CABLE STANDARDS

Underground cable facilities are generally designed per the following applicable industry standards. For impregnated paper or laminated paper polypropylene insulated cables and accessories, the industry standard and specifications include the following documents:

ASSOCIATION OF EDISON ILLUMINATING COMPANIES (AEIC)

1) AEIC CS 2-97, "Specification For Impregnated Paper And Laminated Paper Polypropylene Insulated Cable High Pressure Pipe Type" (6th Edition) dated March 1997 or latest revision thereof.

2) AEIC CS 31-95, "Specifications For Electrically Insulating Pipe Filling Liquids For High-Pressure Pipe-Type Cables" (2nd Edition) dated December, 1995 or latest revision thereof.

3) AEIC CS4-93, "Specifications For Impregnated-Paper-Insulated Low And Medium Pressure Self Contained Liquid Filled Cable" (8th Edition) dated January 1993 or latest revision thereof.

4) AEIC CG1-96, "Guide For Application Of Maximum Insulation Temperatures At The Conductor For Impregnated Paper Insulated Cables" (3rd Edition) dated April 1996 or latest revision thereof.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

1) IEEE 404-2006, "IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2500 V to 500 000 V".

2) IEEE 48-2009, "Standard Test Procedures And Requirements For Alternating Current Terminations 2.5 kV through 765 kV" dated September 30, 2009 or latest revision thereof.

INTERNATIONAL ELECTRO – TECHNICAL COMMISSION (IEC) SC 20.

Furthermore, for Oil Filled and Gas Pressure Transmission Cables, the industry standard and specifications include the following documents:

1) IEC 60141-1, "Tests On Oil - Filled And Gas Pressure Cables And Their Accessories – Part 1 Paper Or Polypropylene Paper"

Laminated Insulated, Metallic-Sheathed Cables And Accessories For Alternating Voltages Up To And Including 500 kV" (1993-09) and IEC 60141-1-am1 Amendment 1 (1995-02) and IEC 60141-1-am2 Amendment 2 (1998-08) or latest revisions thereof.

2) IEC 60141-4, "Tests On Oil - Filled And Gas Pressure Cables And Their Accessories – Part 4 Oil Impregnated Paper Insulated High Pressure Oil -Filled Pipe -Type Cables And Accessories For Alternating Voltages Up To And Including 400 kV" (1980-01) and IEC 60141-4-am1 Amendment 1 (1990-10) or latest revisions thereof.

ASSOCIATION OF EDISON ILLUMINATING COMPANIES (AEIC)

Furthermore, for extruded dielectric (cross linked polyethylene or ethylene propylene rubber insulated) cables and accessories, the industry standard and specifications include the following documents:

1) AEIC CS 7-93, "Specifications For Cross Linked Polyethylene Insulated Shielded Power Cables Rated 69 through 138 kV" (3rd Edition) dated June 1993 or latest revision thereof.

2) AEIC CG 6-95, "Guide For Establishing The Maximum Operating Temperatures Of Extruded Dielectric Insulated Shielded Power Cables" (1st edition) dated August 1995 or latest revision thereof.

3) AEIC CS 6-96, "Specifications For Ethylene Propylene Rubber Insulated Shielded Power Cables Rated 69 kV And Above" (6th edition) dated April 1996

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

1) IEEE 48-2009, "Standard Test Procedures And Requirements For Alternating – Current Terminations 2.5 kV through 765 kV" dated September 30, 2009 or latest revision thereof.

2) IEEE 404-2006, "Standard For Cable Joints For Use With Extruded Dielectric Cables Rated 5000-138 000 V and Cable Joints For Use With Laminated Dielectric Cable Rated 2500-500 000V".

INSULATED CABLE ENGINEERS ASSOCIATION (ICEA)

1) ICEA S-108-720, "Standard For Extruded Insulation Power Cables Rated Above 46 through 345 KV", dated 7/15/04 or latest revision thereof.

INTERNATIONAL ELECTRO – TECHNICAL COMMISSION (IEC) SC 20.

1) IEC 60840, "Power Cables With Extruded Insulation And Their Accessories For Rated Voltages Above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV) – Test Methods and Requirements" (2004-04) or latest revision thereof.

2) IEC 61443, "Short Circuit Temperature Limits Of Electric Cables With Rated Voltages Above 30 kV (36 kV) (1999-07)

3) IEC 62067, "Power Cables With Extruded Insulation And Their Accessories For Rated Voltages Above 150 kV (Um = 170 kV) up to 500 kV (Um = 550 kV) –Test Methods and Requirements" (2001-10) or latest revision thereof.

3.0 RATING ALGORITHMS

The AEIC cable standards listed in Section 2 specify the allowable temperatures for various types and voltages of cable insulations, which govern how much current may be transferred through the insulated conductor of the cable. The following are the two common algorithms used for calculating the predicted insulation temperature and thus the allowable operating ampacity for self cooled cable systems.

The preferred algorithm is that of the Neher-McGrath method outlined in "The Calculation Of Temperature Rise And Load Capability Of Cable Systems" [Reference 1]. An alternate method is that outlined in the International Electro-Technical Commission (IEC) Standard, "Calculation of the Continuous Current Ratings of Cables" (100% Load Factor) [Reference 2].

Calculation methods of the Continuous Current Ratings of Cables are outlined in the following Documents of the IEC.

1) IEC 60287-1-1, "Electric Cables – Calculation Of Continuous Current Ratings" Part 1-1: Current Rating Equations (100% Load Factor) And Calculation Of Losses – General" (2001-11) Ed. 1.2, IEC 60287-1-1-am1 AMENDMENT 1 (1995-08), and IEC 60287-1-1-am2 Amendment 2 (2001-08) or latest revisions thereof.

2) IEC 60287-1-2, "Electric Cables – Calculation Of Current Rating Part 1-1: Current Rating Equations (100% Load Factor) And Calculation Of Losses – Section 2 Sheath

Eddy Current Loss Factors For Two Circuits In Flat Configuration" (1993-12) or latest revision thereof.

3) IEC 60287-1-3, "Electric Cables – Calculation Of Current Rating Part 1-3: Current Rating Equations (100% Load Factor) And Calculation Of Loses – Current Sharing Between Parallel Single-Core Cables And Calculation Of Circulating Current Losses" (2002-05) or latest revision thereof.

4) IEC 60287-2-1, "Electric Cables – Calculation Of Current Rating Part 2-1 Thermal Resistance – Section 1: Calculation Of Thermal Resistance" (2001-11) Ed. 1.1, and IEC 60287-2-1-am1 Amendment 1 (2001-08) or latest revisions thereof.

5) IEC 60287-2-1, "Electric Cables – Calculation Of Current Rating Part 2 Thermal Resistance – Section 2: Method For Calculating Reduction Factors For Groups Of Cables In Free Air, Protected From Solar Radiation" (1995-05) or latest revision thereof.

6) IEC 60287-3-1, "Electric Cables – Calculation Of Current Rating Part 3-1 Sections On Operating Conditions – Section 1: Reference Operating Conditions And Selection Of Cable Type" (1999-05) Ed. 1.1, and IEC 60287-3-1-am1 Amendment 1 (1999-02) or latest revisions thereof.

7) IEC 60287-3-2, "Electric Cables – Calculation Of Current Rating – Part 3 Sections On Operating Conditions – Section 2: Economic Optimization Of Power Cable Size" (1995-07), and IEC 60287-3-2-am1 (1996-10) Amendment 1 or latest revisions thereof.

8) IEC 60853-2, "Calculation Of The Cyclic And Emergency Current Rating Of Cables Part 2: Cyclic Rating Of Cables Greater Than 18/30 (36) kV And Emergency Ratings For Cables Of All Voltages" (1989-09) or latest revision thereof.

9) IEC 60853-3, "Calculation Of The Cyclic And Emergency Current Rating Of Cables Part 3: Cyclic Rating Factor For Cables Of All Voltages, With Partial Drying Of The Soil" (2002-02) or latest revision thereof.

10) IEC 60986, "Calculation Of Thermally Permissible Short-Circuit Currents, Taking Into Account Non-Adiabatic Heating Effects" (1988-11) or latest revision thereof.

The ratings of High Pressure Fluid Filled Pipe Type Cable systems can be further increased by the circulation of the dielectric fluid through the line pipe and cooling units (heat exchangers) via forced cooling. Forced Cooled ratings are calculated in accordance with the following International Institute of Electrical and Electronics Engineers (IEEE), International Council on Large Electric Systems (CIGRE) and Electric Power Research Institute (EPRI) Documents.

1) IEEE Transaction Paper 31 TP 65-124, "Application Of Oil Cooling In High-Pressure, Oil-Filled, Pipe-Type Circuits" by Mr. R. W. Burrell, IEEE Winter Power Meeting, New York, NY, January 31- February 5, 1965.

2) EPRI Report no. EL-3624, "Designer's Handbook For Forced-Cooled High-Pressure Oil –Filled Pipe-Type Cable Systems" dated July 1984 by Mr. D.W. Purnhagen

3) CIGRE Study Committee 21 Working Group 08, "The Calculation Of Continuous Ratings For Forced-Cooled High-Pressure Oil-Filled Pipe-Type Cables" Electra no. 113, July 1987, pp. 97-121.

   The application of the above referenced algorithm is also explained Reference 3, EPRI *Underground Transmission Systems Reference Book* 1992 Edition, Chapter 5 pp. 197 - 273.

4.0 ACCEPTABLE RATING CALCULATION METHODS

Rating methods for cables using the above algorithms are modeled by commonly used and acceptable computer programs in the following ways:

1) CYMCAP for Windows by CYME International Inc., a computer program, which utilizes the above algorithms.

2) USAMP+ for Windows by Underground Systems Incorporated (USI)

3) TRAMP by Underground Systems Incorporated (USI), Limited to Pipe Type Cable Systems

4) EPRI ACE program

5) Certain conditions of cable installation not adequately modeled by existing software may be rated using numerical methods and other calculation techniques following the above standards quoted in Sections 2 and 3 above.

6) Cable manufacturer proprietary software that performs the cable rating calculations using the above algorithms are acceptable, if proof of meeting all the standards quoted in Sections 2 and 3 above are available.

5.0 INPUT ASSUMPTIONS

Inputs to the underground rating algorithms are as follows:

CABLE SYSTEM ENVIRONMENT

1) Earth Ambient Temperature: This is the temperature of the soil surrounding the cable. This temperature varies either cyclically through the year, with the maximum earth

ambient temperature generally lagging one or two months behind the corresponding air temperature or remains constant depending upon the depth of the burial. However, high ambient earth temperatures and heavy system loading tend to coincide in the late summer. Earth ambient temperatures can often be obtained either from local soil conservation services or by the use of thermal probes. Representative Maximum Summer Ambient Earth Temperatures are shown in Reference 3, EPRI *Underground Transmission Systems Reference Book* (1992 Edition).

2) Soil, Concrete and Backfill Thermal Resistivity: The thermal resistivity of the backfill material(s) is a function of several variables, including the intrinsic value of the material itself (or mixture of materials), the moisture content, and the degree of compaction around the cables. A backfill having low thermal resistivity will generally have the following characteristics:

   - High Moisture Content
   - Highly compacted
   - Uniform sizing of components (well-graded)

Typical cable system backfill materials include thermal sand, stone screenings, weak concrete and/or fluidized thermal backfill. Representative thermal resistivity of these materials, with 5% - 0% moisture, range from 30 - 100 C°-cm/watt, as shown in Reference 3, Table 5-11 on Page 236. Typical design values are 60 for weak concrete or fluidized thermal backfill and 90 –100 for thermal sand and stone screenings.

The cable system environment typically consists of a combination of backfill material around the cable and native soils having higher thermal resistivities as described on pages 206 – 208 of Reference 3.

LOAD FACTOR

The load factor of each underground line should be determined. It generally should not be less than 75% for typical transmission lines and should be 100% for dedicated generator leads.

ADJACENT HEAT SOURCES

Adjacent heat sources (i.e.: adjacent heat pipes, distribution lines, or transmission lines) are to be taken into account as outlined in Reference 3, p. 206 and pp. 227-229. Hot Spots should be identified throughout the cable system.

BONDING SCHEMES

Bonding schemes such as multipoint/single point/cross bonding etc. are to be taken into account for the rating of the cable.

CABLE AND DUCT/PIPE CHARACTERISTICS

The cable's characteristics (conductor size, type and stranding, insulation type and thickness, metallic shield type and thickness and/or size and number of wires, etc., jacket type and thickness) are to be taken into account. If the installation is in conduit or pipe, include the dimensions and type of conduit or pipe (if used), pipe or conduit filling medium (typically air, or dielectric fluid as in the case of high pressure dielectric fluid filled pipe type cable) as outlined in Reference 3, pp. 203-204. Installation Characteristics

INSTALLATION CHARACTERISTICS

The cross Section of the Cable Environment, depth of burial, spacing and configuration (vertical and/or horizontal spaced, close triangular etc) of adjacent phases, number of circuits, spacing and configuration of adjacent circuits and/or external heat sources, type of installation (direct burial or in conduit of pipe), type and dimensions of backfill material, type of native soil etc. as outlined in the EPRI *Underground Transmission Systems Reference Book* pp. 205-206 (1992 Edition).

6.0 CABLE RATINGS

The ratings of underground cables are largely influenced by the ambient earth temperature and properties of the surrounding soil and the way the cable is installed and operated.

Network operators need to know the amount of energy they are allowed to transport at normal and at emergency operation without causing excessive loss of life of the cable system. Rating calculations are made for normal and emergency operations.

NORMAL RATING

The Normal rating is that in which a cable operates continuously with negligible loss of life. Typically this is based on pipe limits and conductor temperatures:

PIPE TEMPERATURE LIMITS: Prevent Soil Thermal runaway.
  55° C Thermal Sand
  60° C Concrete
  60° C Forced Cooling
PAPER CABLES: Conductor Temperature Limit: 85° C
XLPE CABLES: Conductor Temperature Limit: 90° C

This calculation is based on either Neher – McGrath [Reference 1] or IEC 287 [Reference 2] as applied to high voltage cables. This is the current that the cable system is expected to carry through its normal load cycle for an indefinite period of time without exceeding its normal operating temperature.

EMERGENCY RATINGS

6.1.1 Long Time Emergency Rating (LTE)

Long Time Emergency Ratings (LTE) are defined in OP19. Conductor temperatures for paper and XLPE Cables are not to exceed 105°C for 300 Hrs./5Years. These calculations are based on Neher – McGrath [Reference 1] and/or IEC 60853, cited in Section 3.0.

6.1.2 Short Time Emergency Rating (STE)

Short Time Emergency Ratings (STE) are defined in OP19. Consistent with OP19, the 15-minute conductor rating shall not reach temperature limits as specified in LTE above. These calculations are based on Neher – McGrath [Reference 1] and/or IEC 60853, cited in Section 3.0.

6.1.3 Drastic Action Limit (DAL)

Drastic Action Limits (DAL) are defined in OP19. Consistent with OP19, the 5-minute conductor rating shall not reach temperature limits as specified in LTE above. These calculations are based on Neher – McGrath [Reference 1] and/or IEC 60853, cited in Section 3.0.

7.0 REFERENCES

1) Neher and McGrath, "The Calculation Of Temperature Rise And Load Capability Of Cable Systems", AIEE Transactions on Power Apparatus and Systems, vol. 76, October 1957.

2) International Electro-Technical Commission Publication 287, "Calculation of the Continuous Current Ratings of Cables" (100% Load Factor), 2nd Edition, 1982

3) Electric Power Research Institute, *Underground Transmission Systems Reference Book*, 1992

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APPENDIX D
POWER TRANSFORMERS

1.0 INTRODUCTION

The following methodology applies to power transformers with a least one winding connected at a voltage of 69 kV or higher. The methodology has four major sections, autotransformers, load serving transformers, phase-shifting transformers and generator step-up transformers.

2.0 STANDARDS

Ratings for power transformers shall be calculated consistent with IEEE Standard C57.91-1995 (R2004), "IEEE Guide for Loading Mineral-Oil-Immersed Transformers", and C57.91-1981, "IEEE Guide for Loading Mineral-Oil-Immersed Transformers".

3.0 APPLICATION GUIDE

AUTOTRANSFORMERS-SIXTY FIVE DEGREE RISE

Autotransformers shall be given four load-carrying ratings: normal, long time emergency (LTE), short time emergency (STE), and drastic-action limit (DAL). Autotransformer owners should use caution in assigning DAL limits higher than the STE limit because thermal models in transformer rating tools may not be designed to model very short time intervals.

The assumptions in Table D1 below shall be used to calculate these ratings for an oil-immersed, **sixty-five degree rise** autotransformer. The rating of the autotransformer shall be calculated at 60 Hertz, nominal voltage, at the fixed tap that will be utilized when the autotransformer is in service, and with any forced cooling (fans and/or pumps) in operation. If the autotransformer has a load tap changer the rating shall be calculated at the tap that gives the most conservative rating.

Table D 1
Assumptions for 65 Degree Rise Autotransformer Ratings

Assumptions	Summer Normal/LTE/STE/DAL	Winter Normal/LTE/STE/DAL	Notes
Ambient temperature (°C)	25/32/32/32	5/10/10/10	1
Duration in hours	8760/12/0.25/0.083	8760/4/0.25/0.083	2
Top oil temperature (°C)	105/110/110/110	105/110/110/110	3
Conductor hot spot temperature (°C)	120/140/150/150	120/140/150/150	3,4,5
Maximum loss of insulation life (LOL)	Excessive LOL should be avoided	Excessive LOL should be avoided	6
Maximum transformer rating (% of nameplate)	150-200	150-200	7
Minimum Preload (% of nameplate rating)	75%	75%	8
Minimum Post load (% of nameplate rating)	75%	75%	8

Notes:
1. Temperature is from PP7 Appendix A Section 2.1.
2. Duration is from PP7 Section 2.31.
3. Temperatures are from IEEE C57.91-1995 (R2004) Tables 7 and 8.
4. The hot spot temperature for normal ratings is based on IEEE C57.91-1995 (R2004) section 9.3.1 that states that transformers may be operated above 110 °C hot spot temperature for short periods provided that they are operated for much longer periods below 110 °C.
5. Conductor hot spot temperature limited to 150 degrees to prevent formation of gas bubbles in the autotransformer's insulating fluid. Refer to IEEE C57.91-1995 (2004) Annex A for more information.
6. IEEE C57.91-1995 (R2004) states in its introduction that the relationship between transformer life and transformer insulation life is a question that remains to be solved. Therefore no loss of autotransformer insulation life limit (LOL) has been specified. If LOL is calculated in their transformer-rating tool, autotransformer owners should review the calculated LOL and review the prudence of a rating that results in calculated LOL being much higher than is typical.
7. IEEE C57.91-1995 (R2004) Table 7 lists the suggested maximum transformer loading as 200% of the nameplate rating. This maximum should be not be exceeded. A maximum rating as low as 150% may be used because of manufacturer's recommendations, or the condition of the autotransformer. Autotransformer owners should ensure that autotransformer components such as tap changers; bushings and current transformers can withstand the ratings that are given to the autotransformer.
8. Flat pre-load and post-load levels of at least 75% of the autotransformer's nameplate rating or actual load cycle data should be use to calculate the ratings of an autotransformer. When pre-load or post-load levels will exceed 75% of nameplate, a higher flat pre-load and post-load level or actual load cycle data should be used.

AUTOTRANSFORMERS -FIFTY-FIVE DEGREE RISE

Transformers with fifty-five degree rise were generally replaced as a standard offering by most manufacturers about 1966. These autotransformers shall be given four load carrying ratings; normal, long time emergency (LTE), short time emergency (STE) and drastic-action limits (DAL). Autotransformer owners should use caution in assigning DAL limits higher than the STE limit because thermal models in transformer rating tools may not be designed to model very short time intervals.

The assumptions in the following table shall be used to calculate these ratings for an oil-immersed, **fifty-five degree rise** autotransformer. The rating of the autotransformer shall be calculated at 60 Hertz, nominal voltage, at the fixed tap that will be utilized when the autotransformer is in service, and with any forced cooling (fans and/or pumps) in operation. If the autotransformer has a load tap changer the rating shall be calculated at the tap that gives the most conservative rating.

Table D 2
Assumptions for 55 Degree Rise Autotransformer Ratings

Assumptions	Summer Normal/LTE/STE/DAL	Winter Normal/LTE/STE/DAL	Notes
Ambient temperature (°C)	25/32/32/32	5/10/10/10	1
Duration in hours	8760/12/0.25/0.083	8760/4/0.25/0.083	2
Top oil temperature (°C)	95/100/100/100	95/100/100/100	3
Conductor hot spot temperature (°C)	105/140/150/150	105/140/150/150	3,4,5
Maximum loss of insulation life (LOL)	Excessive LOL should be avoided	Excessive LOL should be avoided	6
Maximum transformer rating (% of nameplate)	150-200%	150-200%	7
Minimum Preload (% of nameplate rating)	75%	75%	8
Minimum Post load (% of nameplate rating)	75%%	75%	8

Notes:
1. Temperature is from PP7 Appendix A Section 2.1
2. Duration is from PP7 Section 2.31.
3. Temperatures are from IEEE C57.91-1981 and C57.91-1995 (R2004).
4. The hot spot temperature for normal ratings is based on IEEE C57.91-1981 section 4.1.3 that states that transformers may be operated above 95°C for short periods provided that they are operated for much longer periods below 95°C. The 105°C limit is derived by comparing the values in Figure 3 and Figure 4.
5. Conductor hot spot temperature limited to 150 degrees to prevent formation of gas bubbles in the autotransformer's insulating fluid. Refer to IEEE C57.91-1995 (R2004) Annex A for more information.
6. IEEE C57.91-1995 (R2004) states in its introduction that the relationship between transformer life and transformer insulation life is a question that remains to be solved. Therefore no loss of autotransformer insulation life limit (LOL) has been specified. If LOL is calculated in their transformer-rating tool,

autotransformer owners should review the calculated LOL and review the prudence of a rating that results in calculated LOL being much higher than is typical.

7. IEEE C57.91-1995 (R2004) Table 7 lists the suggested maximum transformer loading as 200% of the nameplate rating. This maximum should be not be exceeded. A maximum rating as low as 150% may be used because of manufacturer's recommendations, or the condition of the autotransformer. Autotransformer owners should ensure that autotransformer components such as tap changers; bushings and current transformers can withstand the ratings that are given to the autotransformer.
8. Flat pre-load and post-load levels of at least 75% of the autotransformer's nameplate rating or actual load cycle data should be use to calculate the ratings of an autotransformer. When pre-load or post-load levels will exceed 75% of nameplate, a higher flat pre-load and post-load level or actual load cycle data should be used.

LOAD SERVING TRANSFORMERS

Load serving transformers shall be given four load carrying ratings; normal, long time emergency (LTE), short time emergency (STE) and drastic-action limits (DAL). Since operation of load-serving transformers does not impact the high voltage transmission system, the transformer owner may determine the criteria for rating a load-serving transformer. Also the duration associated with LTE, STE and DAL limits may vary from the durations in PP7 Section 2.3.

PHASE SHIFTING TRANSFORMERS

Phase-shifting transformers shall be given four load carrying ratings; normal, long time emergency (LTE), short time emergency (STE) and drastic-action limits (DAL). These ratings shall be based on information provided by the manufacturer.

GENERATOR STEP-UP TRANSFORMERS

Generator step-up transformers shall be given a normal load carrying rating. This rating shall be based on information provided by the manufacturer and on IEEE C57.91-1995 (R2004).

4.0 REFERENCES

None

<u>**Document History**</u>

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Rev. 1 RC – 8/10/10

APPENDIX E
SERIES AND SHUNT REACTIVE ELEMENTS

1.0 INTRODUCTION

The following methodology applies to series capacitors, shunt capacitors, series reactors and shunt reactors connected at voltages 69 kV or above.

2.0 STANDARDS

Ratings for series capacitors shall be calculated consistent with IEEE Standard 824-2004, "IEEE Standard for Series Capacitors in Power Systems".

Ratings for shunt capacitors shall be calculated consistent with IEEE Standard 18-2002, "IEEE Standard for Shunt Power Capacitors".

Ratings for series reactors shall be calculated consistent with IEEE Standard C57.16-1996, "IEEE Standard Requirements, Terminology, and Test Code for Dry-Type Air-Core Series-Connected Reactors".

Ratings for shunt reactors shall be calculated consistent with IEEE Standard C57.21-2008 "IEEE Standard Requirements, Terminology, and Test Code for Shunt Reactors Rated Over 500 kVA".

3.0 APPLICATION GUIDE

SERIES CAPACITORS

The impedance, normal rating, long time emergency rating, short time emergency rating, drastic action limit, and short circuit current withstand rating of a series capacitor bank shall be the values provided by the manufacturer or calculated by the owner at 60 Hertz and nominal system voltage e.g. 69 kV, 115 kV, 230 kV or 345 kV consistent with IEEE Standard 824.

SHUNT CAPACITORS

The kVA rating of a shunt capacitor bank shall be the rating provided by the manufacturer or calculated by the owner at 60 Hertz and nominal system voltage e.g. 69 kV, 115 kV, 230 kV or 345 kV consistent with IEEE Standard 18.

SERIES REACTORS

The impedance, losses, normal rating, long time emergency rating, short time emergency rating, drastic action limit, and short circuit current withstand rating of a series reactor bank shall be the values provided by the manufacturer or calculated by the owner at 60 Hertz and nominal system voltage e.g. 69 kV, 115 kV, 230 kV or 345 kV consistent with IEEE Standard C57.21.

SHUNT REACTORS

The kVA rating, losses and impedance of a shunt reactor shall be the values provided by the manufacturer or calculated by the owner at 60 Hertz and nominal system voltage e.g. 69 kV, 115 kV, 230 kV or 345 kV. The impedance of the shunt reactor shall be measured at full voltage as described in IEEE Standard C57.21.

4.0 REFERENCES

None.

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APPENDIX F
CIRCUIT BREAKERS

1.0 INTRODUCTION

These procedures provide a "best ratings practice" to be used by equipment owners for determining normal and emergency load-current carrying capabilities of circuit breakers installed on the New England transmission system, 69kV and above.

2.0 STANDARDS

Circuit breakers are to be rated in accordance with the latest edition of ANSI/IEEE Standard C37.010-1999, "Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis" and any supplements to the standard as issued. This Standard deals with general service and temperature conditions and provides calculations of continuous and emergency load current capability, based on the methods of ANSI/IEEE Standard C37.04-1999, "Rating Structure for AC High-Voltage Circuit Breakers". ANSI/IEEE Standard C37.04-1999 also establishes the basis for all other assigned ratings, including short circuit current which establishes the highest currents that the circuit breaker shall be required to close and latch against, to carry, and to interrupt. Both ANSI/IEEE Standards C37.010 and C37.04 apply to circuit breakers manufactured and tested in accordance with ANSI Standard C37.06-2000, "AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis – Preferred Ratings and Related Required Capabilities", and any supplements to the standard, as issued. Circuit breakers designed, manufactured, or installed to meet other standards should be applied and assigned ratings in accordance with the manufacturer's recommendations.

The formulae of ANSI/IEEE Standard C37.010 are to be applied as described and illustrated in Section 3.0, Application Guide.

3.0 APPLICATION GUIDE

Circuit Breaker load current ratings shall be calculated as described below at a rated power frequency of 60 Hertz and nominal voltage, e.g. 69 kV, 115 kV, 230 kV or 345 kV. Required fault interrupting capability, rated closing, latching and short-circuit current capability, reclosing capability, interrupting performance and rated transient recovery voltage shall be as specified in Sections 5.8 and 5.9 of ANSI/IEEE Standard C37.04. Current transformers that are part of the circuit breaker installation are normally selected so they will not limit the circuit breaker continuous or emergency ratings. Refer to Appendix H for current transformer rating procedures.

CONTINUOUS LOAD CURRENT CAPABILITY

ANSI/IEEE Standard C37.04-1999 establishes rated continuous current at an ambient design temperature of 40 °C, based on maximum permissible total temperature limitations within the breaker. The continuous current that can be carried at a given ambient temperature while not exceeding the permissible total temperature limitations is given by:

$$I_s = I_r \left(\frac{\theta \max - \theta a}{\theta r} \right)^{\frac{1}{1.8}} \tag{1}$$

Where:

I_s is allowable continuous current at the actual ambient temperature θa
I_r is rated continuous current at 40 °C (Nameplate Rating)
$\theta \max$ is allowable hottest-spot total temperature ($\theta \max = \theta r + 40$ °C)
θa is actual ambient temperature expected (between –30 °C and 60 °C)
θr is allowable hottest-spot temperature rise at rated current

Values of $\theta \max$ are provided in ANSI/IEEE Standard 37.04-1999, Table 1, "Limits of temperature and temperature rise for various parts and materials of circuit breakers"

EMERGENCY LOAD CURRENT CAPABILITY

Operation at a current higher than rated continuous current is permissible for short periods following operation at a current less than that permitted by the existing ambient temperature. The higher current is calculated using an increased hot-spot total temperature, $\theta \max(1)$, and temperature rise, θr, of breaker components above that used in calculating continuous current ratings. Such emergency ratings are only to be applied to outdoor circuit breakers, which must be maintained in essentially new condition. Following the emergency period, the load current must be limited to 95% of the rated continuous current (adjusted for ambient temperature) for at least 2 hours.

3.1.1 Extended Period Emergencies

Equation (1), above, can be adjusted to calculate current loadings for the periods associated with Long Time Emergency (LTE) conditions:

$$I_s = I_r \left(\frac{\theta \max(1) - \theta a}{\theta r} \right)^{\frac{1}{1.8}} \tag{2}$$

Where:

$\theta \max(1)$ is maximum allowable hottest-spot total temperature under emergency

conditions. $\theta \max(1) = (\theta r + k$ °C$) + 40$ °C; use k = 15 °C for 0 to 4 hours duration (Winter LTE) and 10 °C for 4 to12 hours duration (Summer LTE) Short Time Emergencies.

3.1.2 Short Time Emergencies

A circuit breaker can be subjected to currents higher than those calculated using Equation (2), above, for shorter periods, provided that no component exceeds the limits of total temperature specified in Table 1 of ANSI/IEEE Standard 37.04-1999 by more than 15 °C. The permissible time for carrying short-time current is given by Equation (3), which can be restated to determine the permissible short-time current in terms of time and temperature (Equation (4)).

$$t_s = \tau \left[-\ln \left(1 - \frac{\theta\max(1) - Y - \theta a}{Y \left[\left(\frac{I_s}{I_i} \right)^{1.8} - 1 \right]} \right) \right] \tag{3}$$

$$I_s = I \left[\frac{\theta\max(1) - Y e^{\frac{-t_s}{\tau}} - \theta_a}{(\theta\max - 40)\left(1 - e^{\frac{-t_s}{\tau}}\right)} \right]^{\frac{1}{1.8}} \tag{4}$$

$$\text{Where } Y = (\theta\max - 40)(I_i / Ir)^{1.8} \tag{5}$$

And:

$\theta\max(1)$ = (θr + k °C) + 40 °C; use k = 15 °C for short periods (<4 hours)

t_s is permissible time for carrying current I_s at ambient θa after initial current I_i
τ is the thermal time constant of the circuit breaker
I_s is short-time load current
I_i is the maximum initial current carried in the 4 hour period prior to application of I_s
Values of τ for circuit breakers rated 123 kV and above are given in ANSI/IEEE Standard 37.04-1999, Table 4, "Typical thermal time constants", as 0.5 hours.

LOADABILITY MULTIPLIERS

The following Table F1 has been prepared using the methods of ANSI/IEEE Standard C37.010-1999 and the conditions described below. The resulting loadability multipliers are used to adjust nameplate ratings to conform to the New England rating definitions consistent with the stated ambient temperatures, equipment temperatures and operational conditions.

3.1.3 Conditions:

1) The typical breaker may be an oil or oilless type with silver-to-silver contacts, ANSI Standard bushings, and Class A insulated current transformers. It is designed and

rated for operation in an ambient temperature of 40 °C. The thermal time constant (τ) is 0.5 hour. (Since the 65 °C rating of the bushings and CTs are limiting, copper-to-copper contacts can be used.)

2) Use 10 °C for winter ambient and 28 °C for summer ambient temperatures as specified in Appendix A.

3) During a designated emergency overloading period the breaker owner will allow a 10°C or 15°C increase above the normal θmax for the hottest spot temperature of the applicable breaker component.

4) All components of the breaker subject to these thermal limitations shall be well maintained and in essentially new condition.

5) The allowable emergency loadings follow a period of 4 hours or more, during which the loading does not exceed 75 percent of the normal rating at the designated winter or summer ambient temperature.

Table F 1
Loadability Multipliers

	Loadability Multipliers to be Applied to Nameplate Rating	
Ratings	**Winter**	**Summer**
Normal	1.23	1.10
Emergency – 15 Minutes (STE)	1.83	1.67
Emergency – 4 hours (LTE)	1.34	-
Emergency – 12 hours (LTE)	-	1.18
Drastic Action Limit (DAL)	2.00	2.00

Note: ANSI Standard C37.010-1999 limits the loadability multiplier to a maximum value of 2.00.

EXAMPLE - LOADABILITY MULTIPLIER CALCULATIONS

Data Used:

$$\theta \max = 105\ °C$$

$$\theta \max(1) = 105\ °C + 15\ °C = 120\ °C \text{ (for DAL, STE and Winter LTE)}$$

$$= 105\ °C + 10\ °C = 115\ °C \text{ (for Summer LTE)}$$

$$\theta r = 65\ °C$$

$$\theta a = 10\ °C \text{ Winter and } 28\ °C \text{ Summer}$$

$$ts = 15 \text{ Minutes (for STE)}$$

$$= 5 \text{ Minutes (for DAL)}$$

τ = 0.5 hour = 30 minutes

e = 2.7183

1. Normal rating

$$I_s = I_r \left(\frac{\theta_{max} - \theta_a}{\theta_r}\right)^{\frac{1}{1.8}} \qquad \text{Equation (1)}$$

Winter

$$I_s = I_r \left(\frac{105 - 10}{65}\right)^{\frac{1}{1.8}} = 1.23\, I_r$$

Summer

$$I_s = I_r \left(\frac{105 - 28}{65}\right)^{\frac{1}{1.8}} = 1.10\, I_r$$

2. Long-Time Emergency rating

$$I_s = I_r \left(\frac{\theta_{max(1)} - \theta_a}{\theta_r}\right)^{\frac{1}{1.8}} \qquad \text{Equation (2)}$$

Winter (4 hours)

$$I_s = I_r \left(\frac{120 - 10}{65}\right)^{\frac{1}{1.8}} = 1.34\, I_r$$

Summer (12 hours)

$$I_s = I_r \left(\frac{115 - 28}{65}\right)^{\frac{1}{1.8}} = 1.18\, I_r$$

3. Short-Time Emergency rating

$$I_s = I_r \left[\frac{\theta_{max(1)} - Y e^{\frac{-t_s}{\tau}} - \theta_a}{(\theta \quad)\left(\quad -t_s \right)}\right]^{\frac{1}{1.8}} \qquad \text{Equation (4)}$$

$$\left\lfloor \quad \max - 40 \left(1 - e \frac{}{\tau} \right) \right\rfloor$$

And $Y = (\theta \max - 40)(I_i / Ir)\ 1.8$ Equation (5)

<u>Winter (15 minutes)</u>

Where $I_i = (0.75 \times 1.23\ I_r) = 0.9225\ I_r$

$$I_s = I_r \left(\frac{120 - (105-40)(\frac{0.9225 I_r}{I_r})^{1.8} (e^{\frac{-15}{30}} - 10}{(105-40)(1-e^{\frac{-15}{30}})} \right)^{\frac{1}{1.8}}$$

$$I_s = I_r \left[\frac{120 - 34.09 - 10}{25.58} \right]^{\frac{1}{1.8}} = 1.83\ I_r$$

<u>Summer (15 minutes)</u>

Where I_i = (0.75 x 1.10_r) = 8.25 I_r

$$I_s = I_r \left(\frac{120 - (105-40)(\frac{0.825 I_r}{I_r})^{1.8} (e)^{\frac{-15}{30}} - 28}{25.58} \right)^{\frac{1}{1.8}}$$

$$I_s = I_r \left[\frac{120 - 27.88 - 28}{25.58} \right]^{\frac{1}{1.8}} = 1.67\ I_r$$

4. <u>Drastic Action Limit</u>

Use equations (4) and (5) as above

<u>Winter (5 minutes)</u>

Where I_i = (0.75 x 1.23 I_r) = 0.9225 I_r

$$I_s = I_r \left[\frac{120 - (105-40)\left(\frac{0.9225 I_r}{I_r}\right)^{1.8} e^{\frac{-5}{30}} - 10}{(105-40)(1-e^{\frac{-5}{30}})} \right]^{\frac{1}{1.8}}$$

$$= I_r \left[\frac{120 - 47.58 - 10}{9.98} \right]^{\frac{1}{1.8}}$$

$= 2.77\ I_r$, so use $2.0\ I_r$

<u>Summer (5 minutes)</u>

Where $I_i = (0.75 \times 1.10\ I_r) = 0.825\ I_r$

$$I_s = I_r \left[\frac{120 - (105 - 40)\left(\frac{0.825 I_r}{I_r}\right)^{1.8} e^{\frac{-5}{30}}}{9.98} - 28 \right]^{\frac{1}{1.8}}$$

$$I_s = I_r \left[\frac{120 - 38.92 - 28}{9.98} \right]^{\frac{1}{1.8}}$$

$= 2.53\ I_r$, so use $2.0\ I_r$

Document History

Rev. 0 App.: SDTF – 9/9/05; RC – 10/4/05; NPC – 11/4/05; ISO-NE – 11/30/05
Rev. 1 4/11/06 Editorial changes
Rev. 2 RC – 8/10/10

APPENDIX G
DISCONNECT SWITCHES

1.0 INTRODUCTION

These procedures provide a "best ratings practice" to be used by equipment owners for determining normal and emergency load-current carrying capabilities of disconnect switches installed on the New England transmission system, 69kV and above.

2.0 STANDARDS

Disconnect switches are to be rated in accordance with ANSI/IEEE Standard C37.30-1997, "IEEE Standard Requirements for High-Voltage Switches" and IEEE Standard C37.37-1996, "IEEE Loading Guide for AC High-Voltage Air Switches (in Excess of 1000 V). ANSI/IEEE Standard C37.30-1997 establishes limits of allowable temperature rise and provides calculations of continuous load current capability, while IEEE Standard C37.37-1996 provides continuous and emergency loadability factor curves and calculations of emergency load current capability. Many disconnect switches manufactured under ANSI Standard C37.30-1962 and prior standards contain materials that may not permit rating to temperature limitations of more recent standards; this equipment should be assigned ratings in accordance with manufacturers' recommendations.

The formulae of the above Standards are to be applied as described and illustrated in Section 3.0, Application Guide, which uses the temperature limitations for air switches established by Table 2 of ANSI/IEEE Standard C37.30-1997.

3.0 APPLICATION GUIDE

Disconnect switch load current ratings shall be calculated as described below at a rated power frequency of 60 Hertz and nominal voltage, e.g. 69 kV, 115 kV, 230 kV or 345 kV. Rated voltages and withstand and load-making current capabilities shall be as specified in Section 5 ANSI/IEEE Standard C37.30-1997.

CONTINUOUS LOAD CURRENT CAPABILITY

ANSI/IEEE Standard C37.30-1997 establishes rated continuous current at an ambient design temperature of 25 °C, based on permissible temperature limitations for the materials used in each switch part. The allowable continuous current that can be carried at a given ambient temperature while not exceeding the permissible total temperature limitations is given by:

$$I_s = I_r \left(\frac{\theta \max - \theta a}{\theta r} \right)^{0.5} \qquad \text{Equation (1)}$$

Where:

I_s is allowable continuous current at the actual ambient temperature θa

I_r is rated continuous current (Nameplate Rating)

θmax is allowable maximum temperature of the limiting switch part

θa is actual ambient temperature expected (between –30 °C and 40 °C)

θr is the limit of observable temperature rise at rated current of the switch part

Values of θmax and θr are provided in ANSI/IEEE Standard 37.30-1997, Table 2, "Temperature limitations for air switches". When switch test data is available and observable temperature rise is less than guaranteed (θr), all ratings may be adjusted as follows for each material class:

$$I = I_r \left(\frac{\theta r}{\theta} \right)^{0.5} \qquad \text{Equation (2)}$$

Where:

I is adjusted rated continuous current

I_r is rated continuous current at 25 °C (Nameplate Rating)

θ is test observable temperature rise at nameplate rated continuous current

θr is the limit of observable temperature rise at rated current of the switch part

For subsequent calculations, the adjusted rated continuous current (I) should be used. When test data is not available, rated continuous current (I_r) should be used.

EMERGENCY LOAD CURRENT CAPABILITY

Operation at a current higher than allowable continuous current is permissible for limited periods following at least a 2 hour period of operation at a current less than that permitted by the existing ambient temperature. The higher current is calculated using a maximum emergency temperature, $\theta max(e)$, of the switch components that is 20 °C above the maximum temperature used in calculating continuous current ratings. Emergency ratings are to be limited to 200 percent of the rated continuous current (adjusted for specific temperature rise and ambient temperature) and are only to be applied to switches that are maintained in essentially new condition.

3.1.1 Extended Period Emergencies

Equation (1), above, can be adjusted to calculate current loadings for the periods associated with Long Time Emergency (LTE) conditions:

$$I_{e(lt)} = I_r \left(\frac{\theta max(e) - \theta a}{\theta r} \right)^{0.5} \qquad \text{Equation (3)}$$

Where:

$I_{e(lt)}$ is the permissible Long Time Emergency current, and $\theta\max(e)$ is the allowable maximum temperature under emergency conditions, being 20°C greater than the values of $\theta\max$ as provided in Table 2 of ANSI/IEEE Standard 37.30-1997.

3.2.2 Short Time Emergencies

Disconnect switches can be subjected to currents higher than those calculated using Equation (3), above, for periods not exceeding the thermal time constant of the switch, generally 30 minutes. The permissible Short-Time Emergency (STE) and Drastic Action Limit (DAL) currents can be calculated using the following Equation (4) and substituting 15 minutes or 5 minutes, respectively, for the time duration, *d*:

$$I_{e(st)} = I_r \left[\frac{1}{\theta r} \left(\frac{\theta\max_e - \theta\max}{1 - e^{-d/\tau}} + \theta\max - \theta a \right) \right]^{0.5} \qquad \text{Equation (4)}$$

Where:

$I_{e(st)}$ is the permissible short time current, and
d is the appropriate time duration (15 minutes for STE and 5 minutes for DAL)
τ is the thermal time constant of the switch in minutes

Values of τ may be conservatively assumed to be 30 minutes for switches rated 1200 Amperes or greater. Contact the manufacturer for switches rated less than 1200 Amperes.

LOADABILITY MULTIPLIERS

The following Table G1 has been prepared using the methods of ANSI/IEEE Standards C37.37-1996 and C37.30-1997 for the switch and conditions described below. The resulting loadability multipliers are used to adjust nameplate ratings to conform to the New England rating definitions consistent with the stated ambient temperatures, equipment temperatures and operational conditions.

Conditions:

1) The subject disconnect switch has an Allowable Continuous Current Class (ACCC) of DO6 (consult C37.37-1996 for other switches with different material classes and ACCC designations). It has a nameplate rating of 1200 Amperes and a thermal time constant (τ) of 30 minutes.

2) Use 10 °C for winter ambient and 28 °C for summer ambient temperatures as specified in Appendix A.

3) During an emergency period, the owner will allow switch component temperatures to increase 20 °C above their normal allowable maximum temperatures.

4) All components of the switch subject to these thermal limitations shall be properly maintained to carry rated current without exceeding their limit of observable temperature rise.

5) The allowable emergency loadings follow a period of 2 hours or more, during which the loading does not exceed the normal rating at the designated winter or summer ambient temperature.

Table G 1
Loadability Multipliers

Ratings	Loadability Multipliers To be Applied to Nameplate Rating	
	Winter	Summer
Normal	1.34	1.20
Emergency – 12 hours (LTE)	-	1.38
Emergency – 4 hours (LTE)	1.47	-
Emergency – 15 Minutes (STE)	1.66	1.62
Drastic Action Limit (DAL)	2.00	2.00

NOTE: ANSI Standard C37.37-1996 limits the loadability multiplier to a maximum value of 2.00 times the rated continuous current at a given ambient temperature.

EXAMPLE - LOADABILITY MULTIPLIER CALCULATIONS

Table 2 of ANSI/IEEE Standard 37.30-1997 indicates that a switch with an ACCC designation of DO6 (as described above) has components with different temperature limitations as follows:

Switch-part Class Designation	Allowable Max Temperature °C θmax	Limit of Observable Temp Rise °C θr
DO4	90	43
FO6	105	53

Loadability multipliers are calculated for both component classes and applied as follows:

1) The switch part having the lowest θr determines loadability with ambient temperatures above 25 °C (i.e., Summer conditions); and

2) the switch part having the highest θr determines loadability with ambient temperatures below 25 °C (i.e., Winter conditions).

Data for the switch described above:

$$\theta max(e) = \theta max + 20\ °C$$

θ_a = 10 °C Winter and 28 °C Summer

t_s = 15 Minutes (for STE)
= 5 Minutes (for DAL)

τ = 30 minutes

e = 2.7183

1) Normal rating

$$I_s = I_r\left(\frac{\theta\max - \theta a}{\theta r}\right)^{0.5}$$ Equation (1)

Winter

For FO6 components:

$$I_s = I_r\left(\frac{105-10}{53}\right)^{0.5} = 1.34\ I_r$$

Summer

For DO4 components:

$$I_s = I_r\left(\frac{90-28}{43}\right)^{0.5} = 1.20\ I_r$$

2) Long-Time Emergency rating

$$I_{e(lt)} = I_r\left(\frac{\theta\max(e) - \theta a}{\theta r}\right)^{0.5}$$ Equation (3)

Winter (4 hours)
For FO6 components:

$$I_{e(lt)} = I_r\left(\frac{105+20-10}{53}\right)^{0.5} = 1.47\ I_r$$

Summer (12 hours)
For DO4 components:

$$I_{e(lt)} = I_r\left(\frac{90+20-28}{}\right)^{0.5}$$

43)

$$= 1.38\ I_r$$

3) Short-Time Emergency Rating (15 minutes)

$$I_{e(st)} = I_r \left[\frac{1}{\theta r} \left(\frac{\theta \max_e - \theta \max}{1 - e^{-d/\tau}} + \theta \max - \theta a \right) \right]^{0.5} \qquad \text{Equation (4)}$$

Winter
For FO6 components:

$$I_{e(st)} = I_r \left[\frac{1}{53} \left(\frac{105 + 20 - 105}{1 - e^{-15/30}} + 105 - 10 \right) \right]^{0.5} = 1.66\, I_r$$

Summer
For DO4 components:

$$I_{e(st)} = I_r \left[\frac{1}{43} \left(\frac{90 + 20 - 90}{1 - e^{-15/30}} + 90 - 28 \right) \right]^{0.5} = 1.62\, I_r$$

4) Drastic Action Limit (5 minutes)

Use equation (4) as above. But since, from Appendix A, Drastic Action Limits are calculated based on a pre-disturbance circuit loading of 75% of the normal terminal equipment rating, the initial current (at 75% of allowable current) and its corresponding initial maximum temperature are first determined:

Winter
Initial current at 75% of Normal rating $= I_i = 0.75\,(1.34\, I_r) = 1.0\, I_r$

Corresponding initial maximum temperature θmax_i :

$$I_i = I_r \left(\frac{\theta \max_i - \theta a}{\theta r} \right)^{0.5} \qquad \text{Form of Equation (1)}$$

$$I_i / I_r = 1.0 = \left(\frac{\theta \max_i - 10}{53} \right)^{0.5} ; \ \theta \max_i = 63\ ^\circ C$$

For FO6 components:

$$I_{e(dal)} = I_r \left[\frac{1}{53} \left(\frac{105 + 20 - 63}{1 - e^{-5/30}} + 63 - 10 \right) \right]^{0.5} = 2.93\, I_r$$

However, emergency ratings cannot exceed 200% of rated continuous current (nameplate) rating. Thus, $I_{e(dal)}$ is limited to 2.00 I_r.

Summer

Initial current at 75% of Normal rating = $I_i = 0.75\ (1.20\ I_r) = 0.90\ I_r$

Corresponding initial maximum temperature θmax_i:

$$I_i = I_r \left(\frac{\theta max_i - \theta a}{\theta r} \right)^{0.5}$$ Form of Equation (1)

$$I_i / I_r = 0.90 = \left(\frac{\theta max_i - 28}{43} \right)^{0.5}; \quad \theta max_i = 63\ C$$

For DO4 components:

$$I_{e(dal)} = I_r \left[\frac{1}{43} \left(\frac{90 + 20 - 63}{1 - e^{-5/30}} + 63 - 28 \right) \right]^{0.5} = 2.81\ I_r$$

However, emergency ratings cannot exceed 200% of rated continuous current (nameplate) rating. Thus, $I_{e(dal)}$ is limited to 2.00 I_r.

4.0 References

None

Document History

Rev. 0 App.: SDTF – 2/22/06; RC – 3/14/06; NPC –4/ 7/06; ISO-NE – 4/10/06
Rev. 2 RC – 8/10/10

APPENDIX H
CURRENT TRANSFORMERS

1.0 INTRODUCTION

These procedures provide a "best ratings practice" to be used by equipment owners for determining normal and emergency load-current carrying capabilities of current transformers installed on the New England transmission system, 69kV and above.

2.0 STANDARDS

Current transformers are to be rated in accordance with ANSI/IEEE Standard C57.13-2008, "IEEE Standard Requirements for Instrument Transformers". As this standard does not provide methods to determine emergency ratings, such rating practices were developed by the System Design Task Force and are described in the following application guide.

3.0 APPLICATION GUIDE

Current transformer ratings shall be calculated as described below at a rated power frequency of 60 Hertz and nominal voltage, e.g. 69 kV, 115 kV, 230 kV or 345 kV.

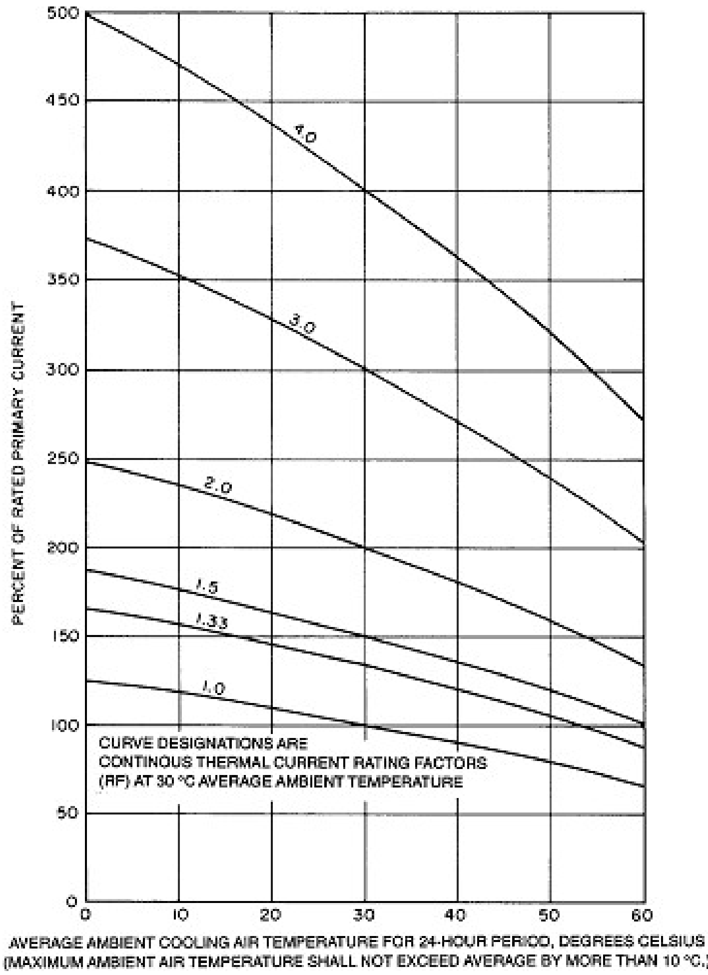
INDEPENDENT (FREE-STANDING) CURRENT TRANSFORMERS

These are current transformers that are purchased and installed separately from other equipment.

3.1.1 Normal Rating

The Normal Rating of an independent current transformer is its rated continuous current capability, which is determined by its continuous thermal current rating factor (RF; this is standard nameplate information) and the average cooling air temperature. ANSI/IEEE Standard C57.13-2008establishes rated continuous current for current transformers according to thermal current rating factor at a design temperature rise of 55 °C above an ambient temperature of 30 °C. Figure 1 is reproduced from the ANSI/IEEE Standard and provides the percent of rated primary current that can be carried continuously by devices of that design without causing established temperature limits to be exceeded. For example, Normal summer and winter ratings for independent current transformers with an RF of 1.5 are found to be 160% and 180% of nameplate, respectively, using the ambient temperatures specified in Appendix A of Planning Procedure No. 7.

Figure 1
55°C Rise Current Transformer Basic Loading Characteristics (In Air)[1]



3.1.2 Emergency Ratings

If emergency conditions require temporary loading beyond normal continuous current capability, the multiplying factors in Table H1 can be applied, recognizing that such loadings may produce moderate loss of life. Before this is done, revised continuous rating values should be determined using Figure 1 and the emergency ambient temperatures specified in Appendix A. The appropriate factors in Table H1 then are applied to the revised continuous rating values to determine the emergency ratings.

Table 1 was originally prepared for the NEPOOL Capacity Rating Procedures using a major manufacturer's curve of allowable overload following rated load to produce not more than a 1 percent loss of life for an oil-filled current transformer. Values for butyl-molded and compound

[1] These curves are based on the assumption that average winding temperature rise are proportional to current squared.

filled transformers were extrapolated on the basis of correspondingly shorter thermal time constants than for oil-filled units.

Table H 1
Emergency Rating Multiplying Factors

Duration of Emergency	Transformer Type		
	Oil-Filled	Butyl-Molded	Compound
0-1 ½ Hr.	1.7	1.6	1.4
4-24 Hr.	1.4	1.3	1.2

3.1.2 Loadability Multipliers

Table H2 has been prepared using the above methods and the conditions described below. The resulting loadability multipliers are used to adjust nameplate ratings to conform to the New England rating definitions consistent with the stated ambient temperatures and stated conditions.

Conditions:

(1) The current transformer is an independent, oil filled, current transformer, with thermal rating factor of 1.5.
(2) Use 5 ºC for winter and 25 ºC for summer ambient temperature to determine Normal ratings and 10 ºC for winter and 32 ºC for summer ambient temperature to determine Emergency ratings, all as specified in Appendix A of Planning Procedure No. 7.
(3) Accuracy and thermal capability of the secondary circuit and the secondary devices is satisfactory at the ratings in Table H2.
(4) The loss of life associated with the emergency ratings in Table H2 is acceptable.

Table H 2
Loadability Multipliers To Be Applied To Nameplate Rating of an Independent, Oil-Filled Current Transformer with a 1.5 Rating Factor

Ratings	Winter	Summer
Normal	1.8	1.6
Emergency – 15 Minutes (STE)	3.0	2.5
Emergency – 4 Hours (LTE)	2.5	----
Emergency – 12 Hours (LTE)	----	2.1
Drastic Action Limit (DAL)[2]	3.2	2.6

[2] A higher DAL multiplier is permitted since the current transformer thermal time constant is typically several times longer than the 5 minutes used in determining the DAL.

INTERNAL BUSHING CURRENT TRANSFORMERS

These are current transformers that 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.

3.1.3 Normal Continuous Capability

Most manufacturers state that internal bushing current transformers furnished with a piece of equipment have thermal capabilities that 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 shall be rated as having 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 I_{ct} is the current transformer nameplate primary current rating and I_e 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 I_t is the reduced tap current rating, and In is the maximum current rating of the current transformer.

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

3.1.4 Emergency Loading

The emergency capability of the equipment in which the bushing current transformer is installed is first calculated. With this value as a base, apply the applicable principle outlined in Section 3.2.1, above, to determine how the emergency capability of that equipment should be modified, because of the current transformer.

EXTERNAL BUSHING CURRENT TRANSFORMERS

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

DEVICES CONNECTED TO CURRENT TRANSFORMER SECONDARY CIRCUITS

In all cases where current transformer secondaries may be loaded in excess of 5 amperes, a careful check should be made of the effect this will have on the devices connected in the secondary circuits, with respect to both accuracy and thermal capability. Refer to Appendix K, Current Transformer Circuit Components for accepted practices for determining ratings of such equipment.

4.0 REFERENCES

None.

Document History

Rev. 0 App.: SDTF – 10/18/05; RC – 11/1/05; NPC – 12/2/05; ISO-NE – 12/30/05
Rev. 1 RC – 8/10/10 RC – 8/10/10

APPENDIX I
LINE TRAPS

1.0 INTRODUCTION

These procedures provide a "best ratings practice" to be used by equipment owners for determining normal and emergency load-current carrying capabilities of Line Traps installed on the New England transmission system, at 69kV and above.

2.0 STANDARDS

Line traps are to be rated according to the current version of: ANSI Standard C93.3-1995, "Requirements for Power Line Carrier Line Traps."

3.0 APPLICATION GUIDE

Line trap ratings shall be calculated using one of the methods described below at a rated power frequency of 60 Hertz and nominal voltage, e.g. 69 kV, 115 kV, 230 kV or 345 kV. Line Traps have limited overload capacity; therefore the continuous current rating should be selected to be above the winter four-hour emergency rating of the circuit in which it is installed. Furthermore, Line Traps must have a higher short-circuit capability and a continuous current rating greater than other any of the other components in the circuit (i.e. circuit breakers, disconnect switches, etc).

RATING ALGORITHMS

The rating methods used by various manufacturers are based on the following common elements:

- Ambient temperature (θ_a);
- Temperature rise, which is a function of the I^2R losses;
- A pre-determined maximum temperature acceptable for various line traps under normal and emergency conditions;
- Acceptable limits of loss of life of line trap due to the above.

NORMAL RATINGS

The primary considerations in defining the normal current rating of a line trap are ambient temperature and maximum allowable temperature rise. In the absence of a heat run tests, the manufacturer can calculate the normal current rating by a compensation method for a specific ambient temperature.

Based on the premise that hottest spot temperature rise is proportional to I^2R losses, the following equation can be used to determine a normal capability at any ambient temperature without exceeding the hottest spot design limit:

$$I_A = I_D \sqrt{\frac{T_H - T_A}{T_H - T_D}}$$

Where,

I_A = capability at ambient T_A (amperes)
I_D = nominal rating of line trap, rated continuous current (amperes)
T_H = maximum hottest spot design temperature[1] (°C)
T_A = ambient temperature[2] (°C)
T_D = design ambient temperature[3] (°C)

EMERGENCY RATINGS

When defining the emergency current rating of a line trap, for ratings of twenty-four hours and less in duration, the emergency allowable maximum temperature limits of 30°C above the normal allowable maximum temperature shall be utilized.

Operation at the specified emergency allowable maximum temperatures shall not affect the accuracy of the tuning pack in the line trap. NEMA Standard SG-11 [Reference 1] specifies that the resonant frequency shall not vary more than two percent for ambient temperatures within the range of minus 40°C to plus 40°C.

Emergency ratings for durations of less than two hours are determined based on the line trap's Thermal Time Constant, which is a function of the heat storage capacity of the line trap. Loading prior to applying less than two-hour emergency rating is assumed to be 100-percent of the normal rating for the prevailing ambient temperature.

If manufacturer data for heat run tests are not available then the Line Trap ratings can be calculated using the assumptions in Section 3.3.1 and Table I1. If the Line Trap manufacturer is known, Line Trap ratings can be calculated using the assumptions in Section 3.3.2, referring to Table I3 to determine the Line Trap identification number and then Table I4 to determine the ratings.

[1] Hottest spot temperature rise from ANSI Standard C93.3-1995 Table 6, plus 40°C design ambient, if manufactured to ANSI standards.
[2] As defined in Appendix A, section 2.1.
[3] If manufactured to ANSI standards, 40°C

3.1.1 Ratings Using Multiplying Factors

The methodology identified in this section is based on information provided by leading manufacturers of Line Traps and is documented in the Report of the Ad Hoc Line Trap Rating Procedure Working Group of the System Design Task Force [Reference 1].

Table I 1
Loadability Multipliers to be Applied to Nameplate Rating

Ratings	Winter	Summer
Normal	1.13	1.05
Emergency – 12 Hours	-	1.21
Emergency – 4 Hours	1.30	-
Emergency – 15 Minutes	1.69	1.58
D.A.L.	1.86	1.73

Where,

- The Line Traps meet the design requirements of ANSI Standard C93.3-1995.
- The maximum winter ambient is 10°C, and the maximum summer ambient is 28°C.
- The Line Trap is designed for a hottest spot temperature rise of 110°C over a 40°C ambient.[4] (Insulation Temperature Index of 130)
- Normal ratings are determined by using the methods introduced in Section 3.2 above
- Emergency ratings are found by applying the multiplying factors of Table I2 below to the Normal ratings

Table I 2
Multipliers to be Applied to Normal rating to Determine Emergency Ratings

Duration of Emergency	Multiplying Factor
4-48 Hours	1.15
15 Minutes	1.50
D.A.L.	1.65

3.1.2 Ratings Using Identification Numbers

Line Trap ratings shall be calculated by referring to Table I3 to determine the Line Trap identification number and then Table I4 to determine the ratings.

[4] Taken from ANSI Standard C93.3-1995, Table 6

Table I 3
Line Trap Identification

Line Trap Identification	Line Trap Identifying Number & Nomograph Number	Limit of Observable Temperature Rise at Rated Current θ_r	Normal Allowable Maximum Temperature $\theta\max_n$	Emergency Allowable Maximum Temperature $(\theta\max_e 2)$ Rating Durations: Greater than 24 Hours $(\theta\max_e 2)$	Emergency Allowable Maximum Temperature $(\theta\max_e 2)$ Rating Durations: 24 Hours or Less $(\theta\max_e 2)$
		ºC	ºC	ºC	ºC
General Electric Type CF (1954-1965)	1	90	130	145	160
Westinghouse Type M	2	110	150	165	180
Trench Type L	3	110	150	170	190
General Electric Type CF (after 1965)	4	115	155	170	190

Table I 4
Percent Of Adjusted Rated Continuous Current[5]

Line Trap Identifying Number[6]	1		2		3		4	
Rating Duration	**W[7]**	**S[8]**	**W[7]**	**S[8]**	**W[7]**	**S[8]**	**W[7]**	**S[8]**
Normal	115	105	112	104	112	104	112	104
Emergency greater than 24 Hrs	123	113	119	110	120	110	118	110
Emergency 2 to 24 Hrs	130	118	125	116	129	119	126	117
Emergency 15 Minutes	149	141	142	135	150	144	144	138

ADDITIONAL FORMULAS

ANSI C93.3-1995 Table A1 indicates short time overload capabilities for line traps. The 15-minute capabilities according to Table I1 of this procedure are more generous than those arrived by the calculation methods described in Section 3.3.2 of this procedure. In contrast, the 4-hour and 12-hour capabilities in Table I1 are more conservative than those arrived by the calculation methods described in section 3.3.2 of this procedure.

[5] Percent of rated continuous current if heat run test data is available

[6] Refer to Table I3 for line trap identifying number

[7] Winter ambient temperature is 10°C for all rating durations

[8] Summer ambient temperatures are 30°C for rating durations greater than 24 hours and 35°C for rating durations 24 hours and less

3.1.3 Correction of Rated Continuous Current

When a line trap test temperature rise is not provided by the manufacturer, the ratings may be adjusted as follows:

$$I = Ir(\theta_r/\theta)^{1/n}$$

Where,

I = Adjusted rated continuous current corrected to the maximum temperature rise allowed for a normal rating in the event the temperature rise tested at the factory is less than the maximum allowed temperature rise.

Ir = Rated continuous current (nameplate rating) that a line trap can carry continuously without exceeding its limits of observable temperature rise. This value is given by the manufacturer.

θ = The Steady-state temperature-rise above ambient temperature when tested at rated continuous current (nameplate rating) in the factory.

θ_r = Limit of observable temperature rise at rated continuous current corresponding to I.

n = 1.8 (A factor or constant)

For subsequent calculations, the adjusted rated continuous current should be used when test data are available.

3.1.4 Calculation of Current Ratings for Durations Greater Than 2 Hours

Winter and summer ratings for durations greater than 2 hours can be determined as follows:

$$I_a = I(\theta \max_{\max h} - \theta_a/\theta)^{1/n}$$

Where,

I = Adjusted rated current (amperes)

I_a = Current rating to be calculated for a specific duration (amperes)

θ_a = Ambient temperature (°C)

$\theta \max h$ = Allowable maximum hottest spot temperature[9] (°C)

θ_r = Allowable temperature rise at rated current (°C)

[9] 40°C plus applicable maximum temperature rise, which varies based on expected duration

3.1.5 Calculation of Emergency Ratings of Less Than 2 Hours Duration

Winter and summer emergency ratings of less than 2 hours duration can be determined as follows:

$$I_{e2} = I\left[I/\theta_r\left[\theta\max_{e2} - \theta\max_n/(I - e - t/\tau) + \theta\max_n - \theta\right]\right]^{1/n}$$

Where,

I_{e2} = Emergency rating of less than 2 hours (amperes)

t = Rating duration (minutes)

θ_0 = Winter minimum temperature (°C)

$\theta\max_n$ = Summer maximum Temperature (°C)

τ = Thermal time constant of a line trap[10] (minutes)

4.0 References

1) NEMA Standard SG-11 (1955) "Coupling Capacitor Potential Devices and Line Traps"

2) Report of the Ad Hoc Line Trap Rating Procedure Working Group of the System Design Task Force, June 1990

Document History

Rev. 0 App.: SDTF – 10/18/05; RC – 11/1/05; NPC – 12/2/05; ISO-NE – 12/30/05
Rev. 1 4/11/06 Editorial and format changes
Rev. 2 RC – 8/10/10

[10] The thermal time constant of a line trap preferably should be obtained from the manufacturer's test data or it can be conservatively used as 30-minutes. The length of time required for the temperature to change from the initial

value to the ultimate value if the initial rate of change was continued until the ultimate temperature was reached.

APPENDIX J
SUBSTATION BUSES

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1.0 Introduction

These procedures provide a "best rating practice" to be used by equipment owners for determining normal and emergency load-current capabilities of buses on the New England transmission system, 69 kV and above.

2.0 Standards

2.1 Substation Buses

Bare, outdoor, non-enclosed buses and cables of circular cross section will be rated in accordance with the following:

1. IEEE Standard 605-1998, "Guide for Design of Substation Rigid Bus Structures" is a primary reference for ampacity ratings for tubular bus and bare circular wire cables /conductors used in substations.
2. IEEE Standard 738-2006, "Guide for Calculating the Current-Temperature relationship of Bare Overhead Conductors".
3. Methods outlined in Sections 6-2 through 6-9 of the "*Alcoa Conductor Engineering Handbook*, 1957."

Buses and cables which do not have a circular cross section, or which are forced cooled, enclosed, indoors, or insulation covered are to be assigned ratings by their owners, in accordance with manufacturer recommendations.

3.0 Application Guide

3.1 Rigid Substation Buses

The ampacity rating calculations of rigid, Aluminum or Copper, outdoor, exposed non-enclosed buses and conductors involves parameters such as ambient temperature, maximum conductor temperature limitations, wind speed, wind direction, solar gain, emissivity, and absorptivity. The maximum temperature at which the bus can operate is limited by loss of strength (loss of life) due to temperature cycles and mechanical movement due to expansion. Rigid substation bus ratings shall be assigned in accordance with IEEE Standard 605-1998.

3.1.1 Ambient Temperature

Ratings should be based on the ambient conditions as defined in Appendix A to this procedure.

3.1.2 Maximum Allowable Temperature

The maximum temperature limit at which the rigid bus is permitted to operate should be determined with consideration of the following:

- Loss of life over a period of rigid bus life
- Maximum allowable movement due to expansion and contraction.
- Unbalanced loading effects due to paralleling of buses

The maximum temperature at which the bus can operate varies with the rigid bus material (e.g. copper, aluminum and its alloys) and is best determined by consulting manufacturer recommendations.

3.1.3 Wind Speed and Wind Direction

The wind direction and wind speed are integral components of the calculation of Rigid Substation Bus thermal ratings. Wind direction perpendicular to the conductor (a 90-degree cross wind) shall be utilized. With regard to wind speed, IEEE Standard 605-2008 includes the mathematical models to be used to calculate Substation Rigid Bus thermal ratings, where a wind speed of 2 fps is used. However, for New England, a wind speed up to 3 fps shall be allowed.

3.2 FLEXIBLE SUBSTATION BUSES

Flexible substation bus ratings shall be assigned in accordance with IEEE Standard 738-2006. IEEE Standard 738-2006, and the included rating program RATEIEEE, address both steady-state and transient ratings. Since the thermal time constant of a flexible bus conductor is generally greater than 15 minutes, the steady-state calculation is to be applied in determining Normal and Long-Time Emergency ratings. The transient calculation is applied in determining Short-Time Emergency ratings and Drastic Action Limits. In all cases, adequate clearances must be maintained with flexible bus conductor loadings at the rated values.

3.2.1 Ambient Temperature

Ratings should be based on the ambient conditions as defined in Appendix A to this procedure.

3.2.2 Maximum Allowable Temperature

The maximum temperature limit at which the flexible bus is permitted to operate should be determined with consideration of the following:

- The maximum loss of strength due to annealing
- Loss of life over a period of flexible bus life
- Unbalanced loading effects due to paralleling of buses

The maximum temperature at which the bus can operate varies with the flexible bus material (e.g. copper, aluminum and its alloys) and is best determined by consulting manufacturer recommendations.

3.2.3 Wind Speed and Wind Direction

The wind direction and wind speed are integral components of the calculation of flexible substation bus thermal ratings. Wind direction perpendicular to the conductor (a 90-degree cross wind) shall be used and a wind speed up to 3 fps shall be allowed.

3.3 Connectors

The loadability of connectors and splices must meet or exceed the loadability of the conductors for which they are sized. The individual owners are to confirm, with the manufacturers involved, that the connectors and splices, when installed in accordance with the methods actually used in each case, may be loaded safely to the proposed line terminal ratings, without exceeding the maximum allowable temperature limits of the conductors.

4.0 References

1) Anderson Electric Corporation, *Technical Data: A Reference for the Electrical Power Industry*. Leeds, Ala.: Anderson Electric Corporation, 1964.

2) The Aluminum Association, *Aluminum Electrical Conductor Handbook*. New York: The Aluminum Association, 1971.

3) NEMA Standard Publication No. CC-1-2005, "Electric Power Connection for Substations". This publication provides "standard test methods and performance requirements for the electrical and mechanical characteristics of connectors under normal operating conditions."

4) ANSI Standard C119.4-2003, "Electric Connectors – Connectors for Use Between Aluminum and Aluminum or Aluminum to Copper Bare Overhead Connectors". "This standard establishes the current-carrying and mechanical performance requirements for connectors used for continuous service on conductors under normal operating conditions."

<u>Document History</u>

Rev. 0 App.: SDTF – 4/3/06; RC – 4/4/06; ISO-NE – 5/8/06
Rev. 1 RC – 8/10/10

APPENDIX K
CURRENT TRANSFORMER CIRCUIT COMPONENTS

1.0 INTRODUCTION

These procedures provide a "best ratings practice" to be used by equipment owners for determining normal and emergency load-current carrying capabilities of current transformer circuit components, including relay protective devices, installed on the New England transmission system, at 69kV and above.

2.0 STANDARDS

None

3.0 APPLICATION GUIDE

Current Transformer (CT) circuit component ratings shall be determined as described below at a rated power frequency of 60 Hertz.

While the thermal capabilities of relays vary by manufacturer and application, the relays and associated equipment conform to the applicable ANSI/IEEE and IEC Standards noted in References 1, 2, 3 and 4. Therefore, ratings shall be based on information provided by the manufacturer. Furthermore, the individual owners are to confirm, with the manufacturers involved, that the associated current transformer circuit components (i.e. meters, transducers, relays, etc…) are not the limiting component of the transmission circuit.

Guidance on the thermal capabilities of older relays and other connected equipment used in CT secondary circuits is provided in Attachment 4 of this document [Reference 5]. However, these lists do not include all possible or more recently available current transformer circuit components.

4.0 REFERENCES

1) ANSI/IEEE Standard C57.13-2008, "IEEE Standard Requirements for Instrument Transformers"

2) ANSI/IEEE C37.90-2005, "Standard for Relays and Relay Systems Associated with Electric Power Apparatus"

3) International Electrotechnical Commission (IEC) 60255, Protective Relay Standards

4) ANSI C2-2002, *National Electrical Safety Code*

5) Relay Working Group of the System Design Task Force Report, "Thermal Capabilities of Components in the Current Circuit Starting at the CT Terminals", Revised July 1980, Corrected October 2004 and included as Attachment 4 of this document.

Document History

Rev. 0 App.: SDTF – 4/3/06; RC – 4/4/06; ISO-NE – 5/8/06
Rev. 1 RC – 8/10/10

APPENDIX L
VAR COMPENSATORS

1.0 INTRODUCTION

The following methodology applies to VAR compensators such as Static Synchronous Compensator (Statcoms), Static Var Compensators (SVCs), Dynamic Volt-Ampere Reactive (D-VAR), and synchronous condensers connected at voltages 69 kV or above.

2.0 STANDARDS

None.

3.0 APPLICATION GUIDE

The kVA rating of a VAR compensator shall be the rating provided by the manufacturer as calculated at 60 Hertz and nominal system voltage e.g. 69 kV, 115 kV, 230 kV or 345 kV.

4.0 REFERENCES

None.

<u>**Document History**</u>

Rev. 0 App.: SDTF – 10/18/05; RC – 11/1/05; NPC – 12/2/05; ISO-NE – 12/30/05
Rev. 1 RC – 8/10/10

APPENDIX M
HVDC SYSTEMS

1.0 INTRODUCTION

The following methodology applies to HVDC converters and associated transmission systems connected to the New England transmission system at 69 kV or above.

2.0 STANDARDS

None.

3.0 APPLICATION GUIDE

The rating of an HVDC system (which includes converters, converter transformers, conductors and associated equipment such as filters, switches and busses) is one aspect of its performance protocol, being determined by the facility's specifications, design and operation. Accordingly, ratings shall be based on information provided by the manufacturer.

The rating to be assigned is the Maximum Continuous Capacity, which is the maximum capacity (MW), excluding the added capacity available through means of redundant equipment, for which continuous operation under normal conditions is possible [Reference 1]. Since power flows through an HVDC system are continuously controlled, the LTE, STE and DAL ratings are the same as the Maximum Continuous Capacity.

4.0 REFERENCES

1) CIGRE Working Group 14-04 Report, Protocol for Reporting the Operational Performance of HVDC Transmission Systems, included as Annex B (Informative) of IEEE Standard 1240-2000, IEEE Guide for the Evaluation of the Reliability of HVDC Converter Stations

Document History

Rev. 0 App.: SDTF – 3/21/06; RC – 4/4/06; ISO-NE – 5/8/06
Rev. 1 RC – 8/10/10

ATTACHMENT 1

ACCEPTABLE ALTERNATIVE RATING PRACTICES

These documents can be found at
http://www.iso-ne.com/rules_proceds/isone_plan/

ATTACHMENT 2

AMBIENT TEMPERATURES AND WIND VELOCITY FOR RATING CALCULATIONS

This document can be found at
http://www.iso-ne.com/rules_proceds/isone_plan/

ATTACHMENT 3

ANALYSIS OF WIND-TEMPERATURE DATA AND EFFECT ON CURRENT-CARRYING CAPACITY OF OVERHEAD CONDUCTORS

This document can be found at
http://www.iso-ne.com/rules_proceds/isone_plan/

ATTACHMENT 4

CAPACITY RATING PROCEDURES

This document can be found at
http://www.iso-ne.com/rules_proceds/isone_plan/

ATTACHMENT 5

REPORT OF THE LINE TRAP RATING PROCEDURE WORKING GROUP OF THE SYSTEM DESIGN TASK FORCE

This document can be found at
http://www.iso-ne.com/rules_proceds/isone_plan/