MidAmerican Energy Company 100 kV and Above Facility Ratings Methodology

For NERC Standard FAC-008-3

Version 3.4

2 100kV Transmission Facility Ratings Methodology

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1. <u>SCOPE</u>

This document provides MidAmerican Energy Company's (MidAmerican's) Transmission Owner methodology used for developing and communicating Facility Ratings (Facility Ratings Methodology) of its solely and jointly owned facilities. This document defines the basis for the calculation of normal and emergency ratings of MidAmerican facilities on the 100 kV and above system to satisfy the requirements of NERC Standard FAC-008-3.

- 1.1. The scope of the facilities addressed in this document includes, but is not limited to, line conductors, transformers, relay protective devices, terminal equipment, and series and shunt compensation devices.
- 1.2. The scope of the ratings addressed in this document includes both Normal and Emergency Ratings.

2. <u>ESTABLISHMENT AND COMMUNICATION OF FACILITY</u> <u>RATINGS:</u>

MidAmerican establishes 100 kV and above facility ratings consistent with its Facility Rating Methodology. MidAmerican submits ratings information to the Midwest Reliability Organization (MRO) and Midcontinent Independent System Operator (MISO) model building processes on a periodic basis as required by the NERC MOD standards and annual MRO and MISO model building requirements.

2.1. Communication

MidAmerican will communicate facility ratings information to its Regional Reliability Organization (the MRO), its Reliability Coordinator (MISO) and to other Transmission Owners / Operators upon request.

When MidAmerican has confirmed that updated ratings of its facilities are applicable, it will communicate those new ratings to the MRO, MISO, and MidAmerican System Operations via appropriate mechanisms such as by submitting updated ratings to model data bases, by electronic mail, by web-based tools, or, in the event of real-time system loading issues, by telephone. MidAmerican will maintain records of updated facility ratings submittals for documentation purposes for the applicable FAC-008-3 retention period.

Within 30 calendar days (or later if specified by the requestor) MidAmerican will provide the following for any requested facility with a Thermal Rating that limits the use of Facilities under the requestor's authority by causing 1) an interconnection reliability operating limit, 2) a limitation of total transfer capability, 3) an impediment to generator deliverability, or 4) an impediment to service to a major load center:

- 1. Identify the existing next most limiting equipment of the facility
- 2. The thermal rating for the next most limiting equipment of the facility

2.2. Hierarchy of Reference Sources for Manufacturer/Nameplate Ratings

Several reference sources may be used to establish equipment ratings based on manufacturer or nameplate ratings. The following list establishes a hierarchy of reference sources used when establishing equipment nameplate or manufacturer ratings.

- 1) Manufacturer data or correspondence
- 2) Nameplate drawing or image
- 3) Engineering single line diagram
- 4) Other engineering drawings (plan view, section views, bill of materials, etc)
- 5) Purchase Orders
- 6) Field inspection

3. FACILITIES RATING METHODOLOGY

3.1. Definition

This section defines the basis for the calculation of seasonal normal and emergency ratings of MidAmerican facilities rated 100 kV and above. This section also defines the basis for ambient adjusted operational ratings developed for certain types of equipment.

3.2. Determination of Most Limiting Equipment

All series equipment that together make up a facility (line section, or bulk power substation transformer circuit) are reviewed to determine which equipment has the most limiting rating, which will be used as the most limiting equipment in determining the facility's normal and emergency ratings.

If information is received suggesting that a more limiting equipment exists on a facility, MidAmerican will take steps to verify the information, which may include field inspections. Once review and field verification, if applicable, is complete, MidAmerican will take steps to mitigate any differences identified for either the facility normal rating or the facility emergency rating. Mitigation may include replacing or upgrading the limiting equipment or updating the normal and/or emergency rating to reflect the latest available information.

3.3. Jointly-Owned Facility Ratings

3.3.1. In cases where a 100 kV and above facility is owned in segments (such as a line terminal being owned by one party and the line conductor by another party), MidAmerican takes into account rating data provided by the owner(s)

of the other segment(s) of the line and applies the most limiting rating as the rating of the facility.

3.3.2. In cases where a facility is jointly owned (such as two owners each owning an undivided 50% ownership interest in a facility), the operator of the facility determines the facility rating and shares this rating information with the other joint owners.

3.4. Procedures for Ring Buses and Breaker-and-a-Half Configurations

In the event that a facility (line section or bulk power transformer) terminates on a substation configured as a ring bus or a breaker-and-half, the facility rating scope shall include series bus equipment extending to the next adjacent terminal for a transmission line, transmission transformer terminal, or breaker-and-a half main bus. It may be necessary to extend beyond the immediately adjacent terminal position if that position is for a distribution transformer, shunt device, or empty terminal position. The following figures provide examples of ring bus or break-and-a-half equipment included in facility ratings under different configurations.







Figure 2: Breaker-and-a-half Equipment Example

In order to account for the flow split when entering a closed ring or closed breakerand-a-half, a multiplier is used to adjust the ratings of the ring bus or breaker-anda-half equipment. The multiplier assumes a split of 75%-25%, meaning that 75% of the line section flow or bulk transformer flow is assumed to be transferred onto one leg of the ring bus or breaker-and-a-half. This results in the ring bus limit or breaker-and-a-half limit being adjusted by 133% (100/75%) to account for the flow split of a closed ring or a closed breaker-and-a-half.

Both closed and open ratings are calculated for facilities terminating at ring bus or breaker-and-half substations . The ratings used for long-range planning models assume a closed ring bus or closed breaker-and-a-half. Both closed and open ratings are made available to operations. During near-term operations, the status of the ring bus or breaker-and-a-half breakers is monitored and the corresponding closed or open rating is used.

3.5. Assumptions

MidAmerican will consider certain assumptions as necessary including:

3.5.1. For transmission lines ambient temperatures will be assumed at 100 degrees Fahrenheit (F) for summer seasonal ratings and 32 degrees F for winter seasonal ratings unless otherwise specified. Additional ambient assumptions used in calculating certain ambient adjusted equipment ratings are included in section 3.6. For other equipment, manufacturer or industry standard ambient conditions are used unless otherwise specified.

- 3.5.2. Equipment ratings will be set considering manufacturer/nameplate ratings and recommendations.
- 3.5.3. Equipment ratings will be set considering industry standards.
- 3.5.4. Equipment ratings will be set considering other operational limitations as applicable and necessary.

3.6. Ambient Temperature Adjusted Operational Ratings

Ambient temperature adjusted operational ratings are made available for use in the near-term operation of the system when appropriate. The ambient temperature adjusted ratings are calculated in 10 degree F increments from 100 degrees F to 0 degrees F. In determination of ambient temperature adjusted ratings, only the ambient temperature assumption is modified. In determination of the overall ambient adjusted facility rating all series equipment limits are observed.

The ambient temperature adjusted facility ratings are determined only for the timeframe of the near-term operating condition; typically only the next hour an hour at a time or the next day a day at a time. As the ambient temperature changes with time, the ambient adjusted facility rating is adjusted to reflect current ambient temperature conditions. Ambient temperature adjusted ratings are not utilized in planning models or in total flowgate capability (TFC) calculations which apply to periods beyond those for near-term operation.

In the fall of 2013, MidAmerican will begin transitioning to the use of ambient temperature adjusted operating ratings for certain equipment. These include ambient adjusted normal ratings for circuit breakers, disconnects, wavetraps, and current transformers. Prior to issuing these ambient temperature adjusted normal ratings for a facility it is determined if relay loadability may limit the rating after applying the additional ambient temperature adjusted equipment normal ratings. For facilities in which the relaying would limit the line, the ambient temperature adjusted normal ratings will not be applied to the additional equipment until relay settings have been changed such that the relay loadability will not limit the line rating when the ambient temperature adjustments are applied.

3.7. Operational Short Term Emergency Rating

At the request of MidAmerican System Control, a specific facility may be reviewed for application of an operational short term emergency rating. Typically such a rating will be 15 minutes in duration and be applicable only during a specified operational condition, for example a scheduled outage. The facility will be reviewed based on current and expected ambient and loading conditions. On a case by case basis, a short term rating will be issued only for use during that specific operational condition and the rating will expire after this condition is eliminated.

4. EQUIPMENT RATING METHODOLOGY

4.1. Bulk Power Substation Transformers and Auto-Transformers (with primary and secondary windings >100 kV) including 345-161 kV transformers and 161-138 kV transformers

The ratings in the section apply to bulk power substation transformers and autotransformers including ancillary and internal components such as bushings, leads, windings, tap changers, and current transformers.

4.1.1. Normal Rating

The normal rating shall be the normal rating provided by the equipment manufacturer or obtained from manufacturer specifications such as the top nameplate rating of the transformer.

4.1.2. Emergency Rating

Transformer emergency ratings are established on a transformer by transformer basis with consideration of manufacturer specifications, the condition of the transformer, and IEEE standard 756 and C57.91(latest revisions).

If the transformer manufacturer specifications included emergency rating(s) and duration(s), the emergency rating(s) of the transformer shall be the emergency rating(s) and duration(s) described in the transformer manufacturer specifications.

In situations where emergency ratings were not originally specified with the transformer purchase, emergency ratings may be calculated by the manufacturer or by MidAmerican using IEEE Standard 756 and ANSI/IEEE Standard C57.91-(latest revision). When calculating emergency ratings, consideration of the condition of the transformer is taken into account. If possible the manufacturer's review of the capability of transformer internals including internal leads and auxiliaries should be obtained. If the manufacturer or MidAmerican Substation Operations group is aware of detrimental circumstances, such as indication of deteriorating conditions, the emergency rating of the transformer may be reduced in magnitude and/or duration from the calculated value using the IEEE standards or limited to the top nameplate of the transformer. If the emergency rating cannot be obtained from the manufacturer specifications or calculated, the emergency rating will be assumed to be the top nameplate rating of the transformer.

4.1.3. Operating limitations.

Emergency ratings will be based on the transformer loading profile and assumed ambient temperature profile for each transformer, and the top oil or hot-spot temperatures as defined in the transformer purchasing specifications. Emergency ratings will consider transformer internal equipment limitations by obtaining a transformer manufacturer's assessment when possible.

4.2. Bare Overhead Line Conductors

4.2.1. Ambient Assumptions

The normal and emergency bare overhead conductor rating shall be calculated under the following assumed atmospheric conditions:

- 4.2.1.1. Ambient air temperature of 100 degrees F for summer seasonal ratings and 32 degrees F for winter seasonal ratings
- 4.2.1.2. A wind velocity of 7 ft/sec
- 4.2.1.3. An incident wind angle of 20 degrees
- 4.2.1.4. The following solar factors:
 - 4.2.1.4.1. Latitude of 41 degrees north and longitude of 95 degrees west (these are the approximate values for Des Moines)
 - 4.2.1.4.2. Time of day of 2:00 p.m. on July 15th for summer season ratings and 2:00 p.m. on January 15th for winter ratings
 - 4.2.1.4.3. Elevation of 900 feet above sea level
 - 4.2.1.4.4. East-west line orientation
 - 4.2.1.4.5. Clear skies
- 4.2.1.5. Conductor absorptivity and emissivity coefficients of 0.5
- 4.2.2. Sag Limit

The rating calculation for the line conductor also considers the maximum operating temperature of the line conductor, which may be sag limited based on minimum clearances specified in the National Electrical Safety Code. The maximum operating temperature is based on best available data for the line construction and the topography within the line corridor, which may be based on line design plan and profiles, as-built drawings, field measurements, or LiDAR surveys. MidAmerican typical practice is to include a two (2) foot margin above the minimum clearances specified in the National Electric Safety Code.

4.2.3. Normal Conductor Operating Temperature

If clearances are not a factor, the normal conductor ratings are based on 100 degrees Celsius (C) conductor operating temperature for ACSR, 93.3 degrees C for AAC and ACAR, and 180 degrees C for ACSS conductor.

4.2.4. Emergency Conductor Operating Temperature

If conductor clearances are not an issue, the emergency conductor rating may be calculated for AAC and ACAR conductors at a 100 degrees C conductor operating temperature. A one-hour duration shall be used for any application of the emergency conductor rating.

4.2.5. Bare Overhead Line Conductor Ampacity Calculation Methodology

Prior to 2003, MidAmerican utilized the DYNAMP bare overhead conductor methodology. In 2003, MidAmerican began utilizing the IEEE Standard 738-1993 methodology, and presently uses the updated methodology in IEEE Standard 738-2006¹.

- 4.2.6. Reasons for Adoption of Conductor Rating Assumptions
 - 4.2.6.1. There were only three instances in the 10-year period from 1983 through 1992 in Des Moines, Sioux City or Davenport when the temperature was at or above 100 degrees F and the wind speed was below 7 feet/second, in accordance with information from the Midwest Climate Center in Champaign, Illinois.
 - 4.2.6.2. An assumed wind incident angle of 20 degrees will likely be smaller than the actual angle approximately 7/9, or 78%, of the time, if random wind direction and line orientation are assumed. Also, IEEE calculations are performed with an assumed east-west line orientation, which is a worst-case assumption.

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¹ As calculated using the RateKit computer program.

- 4.2.6.3. The only temperature limitations for ACSS are those which may cause damage to the protective coatings of steel wires or which may cause some loss of strength in the steel. These limitations, as advised by steel manufacturers, are 245 degrees C for Class A galvanized and 260 degrees C for aluminum clad. It is important to note however that there is significant uncertainty regarding the long-term effects of operating ACSS conductor at temperatures above 180 degrees C. MidAmerican will assume a maximum operating temperature of 180 degrees C for ACSS lines based on this uncertainty. However, a specific line with ACSS conductor could be limited to something less than 180 degrees C due to sag limits or other equipment limits.
- 4.2.7. Ambient Temperature Adjusted Operational Conductor Ratings

Ambient temperature adjusted conductor ratings are made available for use in the near-term operation of the system when appropriate. The rating of the bare overhead conductor is calculated at ambient temperatures in 10 degrees F increments from 100 degrees F down to 0 degrees F. In the determination of the ambient temperature adjusted rating of the bare overhead conductor, only the ambient temperature assumption is modified; the other atmospheric conditions and the maximum operating temperature of the conductor are not changed.

4.2.8. Assumptions for Underbuild Lines in Ambient Adjusted Ratings

In situations where a transmission line has underbuild the following procedures are practiced in the rating process.

- 4.2.8.1. The transmission line is modeled at its maximum conductor operating temperature. The ambient temperature used to sag the underbuild line(s) is reduced in 10 degree F increments (starting at 100 degrees F) until the first clearance violation appears between the line conductor in question and the underbuild line(s), or until an ambient of 0 degrees F is reached for the underbuild line(s)
- 4.2.8.2. At a minimum, clearance violations between the transmission line and the underbuild line(s) occurring at the maximum conductor operating temperature of the subject line assuming a 100 degree F ambient sag on the under-build sections are addressed
- 4.2.8.3. Ambient temperature adjusted ratings are calculated down to a value at which there are no sag violations to the underbuild. For example, if the first sag violation to the under-build appears at an ambient temperature of 40 degrees F, then ambient adjusted ratings are calculated only down to 50 degrees F.

4.3. Cables as Line Conductor

Underground cables used as transmission line conductor shall be rated as follows:

4.3.1. Normal Rating

The normal rating shall be the rating supplied by the cable manufacturer in accordance with IEEE Standard 835.

4.3.2. Emergency Rating

The emergency rating shall be the rating supplied by the cable manufacturer in accordance with IEEE Standard 835

4.4. Series and Shunt Capacitors and Reactors

4.4.1. Normal Rating

The normal rating shall be the continuous rating provided by the equipment manufacturer or obtained from manufacturer specifications such as the top nameplate rating of the capacitor, reactor, or that of the most limiting device (e.g., a disconnect switch) in the series circuit for series compensation or in the shunt circuit for shunt compensation.

4.4.2. Emergency Rating

The emergency rating shall be the continuous rating provided by the equipment manufacturer or obtained from manufacturer specifications such as the top nameplate rating of the capacitor, reactor, or that of the most limiting device (e.g., a disconnect switch) in the series circuit for series compensation or in the shunt circuit for shunt compensation.

4.5. Terminal Equipment

Terminal equipment includes all other series equipment that must be considered in rating and completing an electrical circuit including, breakers, cables, circuit switchers/linebackers, current transformers, jumpers, switches, tubular bus, bus duct, wavetraps, fuses, and potential devices.

- 4.5.1. Breakers
 - 4.5.1.1. Normal Rating

The normal rating shall be the continuous rating provided by the equipment manufacturer or obtained from the manufacturer

specifications such as the top nameplate rating in accordance with ANSI Standard C37.04 and C37.010.

4.5.1.2. Emergency Rating

The emergency rating shall be the continuous rating provided by the equipment manufacturer or obtained from the manufacturer specifications such as the top nameplate rating provided by the manufacturer in accordance with ANSI Standard C37.04 and C37.010

4.5.1.3. Ambient Temperature Adjusted Operational Ratings

Ambient adjusted breaker ratings are made available for use in the nearterm operation of the system when appropriate. The breaker rating is calculated in 10 degree F increments from 100 degrees F down to 0 degrees F. The 100 degrees F rating is equal to the Normal Rating. For ambient temperature less than 100 degrees F the following equation from IEEE standard C37.010-1999 is used:

$$I_a = I_r \left[\frac{\theta_{\max} - \theta_a}{\theta_r} \right]^{\frac{1}{1.8}}$$

Where $\theta_{\text{max}} = 115^{\circ}\text{C}$ and $\theta_r = 75^{\circ}\text{C}$

Ambient adjusted breaker ratings are applied only to breakers manufactured after 1971.

4.5.2. Cables

4.5.2.1. Normal Rating

The normal rating shall be the rating supplied by the cable manufacturer in accordance with IEEE Standard 835.

4.5.2.2. Emergency Rating

The emergency rating shall be the rating supplied by the cable manufacturer in accordance with IEEE Standard 835

4.5.3. Circuit Switchers and Line Backers

4.5.3.1. Normal Rating

The summer normal rating shall be the rating supplied by the manufacturer or obtained from the manufacturer specifications such as the nameplate rating of the circuit switcher or line backer. The winter normal rating shall be based on manufacturer-supplied information.

4.5.3.2. Emergency Rating

The emergency rating shall be based on manufacturer-supplied information.

4.5.3.3. Ambient Temperature Adjusted Operational Ratings

Ambient adjusted circuit switcher or line backer ratings are made available for use in the near-term operation of the system when appropriate. The circuit switcher or line backer rating is calculated in 10 degree F increments from 100 degrees F down to 0 degrees F. The 100 degrees F rating is equal to the Normal Rating. For ambient temperature less than 100 degrees F the following equation from IEEE standard C37.010-1999 is used:

$$I_{a} = I_{r} \left[\frac{\theta_{\max} - \theta_{a}}{\theta_{r}} \right]^{\frac{1}{1}}$$

Where $\theta_{\text{max}} = 115^{\circ}\text{C}$ and $\theta_r = 75^{\circ}\text{C}$

Ambient adjusted ratings are applied only to circuit switchers and line backers manufactured after 1971.

4.5.4. Current Transformers

This section applies to stand alone current transformers and current transformers associated with circuit breakers. This section does not apply to current transformers associated with bulk power substation transformers which are observed in the transformer equipment rating.

4.5.4.1. Normal Rating

The normal rating shall be the rating provided by the manufacturer or obtained from the manufacturer specifications such as the nameplate rating of the current transformer (CT). Continuous overload thermal rating factors will be applied to tapped windings per manufacturer's data and recommendations.

For CTs with thermal rating factors no greater than 1.0 and with distributed windings not set on the highest available tap, a continuous overload rating will be calculated based on manufacturer data. The CT will have a rating equal to the square root of the product of the tap setting currently in use and the highest available tap setting, provided that the resultant rating does not exceed two times the tap winding value, or the circuit breaker rating (in cases where the CT is associated with a circuit breaker). An example of this rating follows: if a multi-ratio current transformer with distributed windings is set on a 1200 Ampere (A) tap and the highest available tap setting is 2000 Amps, the CT rating would be the square root of (1200 x 2000), or 1549 Amps.

In situations where the CT is associated with a circuit breaker and the circuit breaker rating is less than the highest available tap setting of a multi-ratio CT, the CT rating will be equal to the square root of the product of the tap setting currently in use and the circuit breaker rating, provided that the resultant rating does not exceed two times the tap winding value, the maximum CT rating increased by the continuous thermal rating factor, or the circuit breaker rating. An example of this rating follows: if a multi-ratio current transformer with distributed windings is set on a 1200 A tap and the highest available tap setting is 2000 Amps, but the circuit breaker rating is 1600 Amps the CT rating would be the square root of (1200 x 1600), or 1385 Amps.

The normal rating of the current transformer shall not exceed twice the tapped winding unless the secondary circuit has been reviewed for adequate thermal capability.

4.5.4.2. Emergency Rating

Based on manufacturer data, the emergency rating shall be 110% of the normal rating/continuous overload rating as long as the circuit breaker rating (if the CT is associated with a circuit breaker) is not exceeded. Emergency ratings of the current transformer shall not exceed twice the tapped winding unless the secondary circuit has been reviewed for adequate thermal capability.

4.5.4.3. Ambient Temperature Adjusted Rating

Ambient adjusted current transformer ratings are made available for use in the near-term operation of the system when appropriate. The current transformer ratings are calculated in 10 degree F increments from 100 degrees F down to 0 degrees F. The 100 degrees F rating is equal to the Normal Rating. For ambient temperatures less than 100 degrees F the current transformer normal rating is adjusted based on Figure 1 of IEEE Standard C57.91.

No ambient temperature adjustments are applied at 100, 90, or 80 degrees F. Ambient temperature adjustments are applied at 70 degrees F and below. Based on historical weather data from 2010 through 2013, the typical difference between low and high daily temperatures is 23 degrees

F. Given this, and assuming the temperature at which the ambient rating is to be established is the low temperature a simple average between the high and low temperature is calculated and used to establish the ambient adjustment factor based on IEEE Standard C57.91. Ambient adjustments shall not exceed two times the tap setting unless the secondary circuit has been reviewed for adequate thermal capability.

4.5.5. Jumpers

4.5.5.1. Normal Rating

The normal rating is calculated utilizing the IEEE Standard 738-2006 methodology, assuming the ambient conditions listed in section 4.2.1. A maximum operating temperature of 70 degrees C is used for jumpers which connect to condenser bushings, and the maximum operating temperature for all other jumpers is 90 degrees C.

4.5.5.2. Emergency Rating

The emergency rating of substation equipment jumpers is equal to the normal rating.

4.5.5.2.1. Ambient Temperature Adjusted Operational Ratings

Ambient temperature adjusted jumper ratings are made available for use in the near-term operation of the system when appropriate. The rating of the jumper is calculated at ambient temperatures in 10 degrees F increments from 100 degrees F down to 0 degrees F. In the determination of the ambient temperature adjusted rating of the equipment jumpers, only the ambient temperature assumption is modified; the other atmospheric conditions are not changed, nor is the maximum operating temperature of the conductor.

4.5.6. Switches

4.5.6.1. Normal Rating

For switches manufactured under the ANSI standards, the normal rating shall be the rating provided by the manufacturer or obtained from the manufacturer specifications such as the nameplate rating of the switch. For some switches manufactured under the NEMA standards (a predecessor to the ANSI standards), a higher rating may be assigned based on the recommended method provided in ANSI Standard C37.37.

The formula given in the ANSI standard which relate the NEMA rating to the ANSI rating is:

$$(I1/I2)^{1.8} = T1/T2$$

where:

I1 = NEMA continuous rating
I2 = ANSI continuous rating
T1 = NEMA temperature rise in ° C
T2 = ANSI temperature rise in ° C

Information from the switch manufacturer is used to determine the temperature rise of the switch manufactured under NEMA standards. The ANSI temperature rise is based on the allowable temperature rise in ANSI C37.37 for the specific switch contact material utilized in the switch (e.g., copper/copper alloy or aluminum).

4.5.6.2. Emergency Rating

The emergency rating shall be in accordance with ANSI Standard C37.37. Emergency ratings are applicable to switches for which the rating has been converted from a NEMA rating to an ANSI rating. In such cases, the full emergency rating percentage is applicable to the ANSI rating of such switches.

4.5.6.3. Ambient Temperature Adjusted Operating Ratings

Ambient adjusted switch ratings are made available for use in the nearterm operation of the system when appropriate. The switch ratings are calculated in 10 degree F increments from 100 degrees F down to 0 degrees F. The 100 degrees F rating is equal to the Normal Rating. For ambient temperatures less than 100 degrees F the switch normal rating is adjusted based on the following equation from IEEE Standard C37.37-1996:

$$L_{E2} = \left[\frac{\theta_{\max} + \Delta \theta_{E2} - \theta_A}{\theta_r}\right]^{0.5}$$

Where
$$\theta_{\text{max}} = 105^{\circ}\text{C}$$
 and $\theta_r = 53^{\circ}\text{C}$

4.5.7. Tubular Bus

4.5.7.1. Normal

2 100kV Transmission Facility Ratings Methodology The normal rating shall be calculated utilizing the IEEE Standard 738-2006 methodology, assuming and the ambient conditions listed in section 4.2.1. A maximum operating temperature of 70 degrees C is used for tubular bus connecting to condenser bushings, and a maximum operating temperature for all other tubular bus is 90 degrees C.

4.5.7.2. Emergency

The emergency rating of aluminum tubular bus is equal to the normal rating.

4.5.7.3. Ambient Temperature Adjusted Operational Ratings

Ambient temperature adjusted tubular bus ratings are made available for use in the near-term operation of the system when appropriate. The rating of the tubular bus is calculated at ambient temperatures in 10 degrees F increments from 100 degrees F down to 0 degrees F. In the determination of the ambient temperature adjusted rating of the bare overhead conductor, only the ambient temperature assumption is modified; the other atmospheric conditions are not changed, nor is the maximum operating temperature of the conductor.

4.5.8. Bus Duct

4.5.8.1. Normal

The normal rating shall be the rating supplied by the manufacturer through correspondence or by duct nameplate.

4.5.8.2. Emergency

The emergency rating of bus duct is equal to the normal rating.

4.5.9. Wavetraps

4.5.9.1. Normal Rating

The normal rating shall be the rating supplied by the manufacturer or obtained from manufacturer specifications such as the nameplate rating in accordance with ANSI Standard C93.3.

4.5.9.2. Emergency Rating

The emergency rating shall be in accordance with ANSI Standard C93.3.

4.5.9.3. Ambient Temperature Adjusted Operational Ratings

Ambient adjusted wavetrap ratings are made available for use in the near-term operation of the system when appropriate. The wavetrap ratings are calculated in 10 degree F increments from 100 degrees F down to 0 degrees F. The 100 degrees F rating is equal to the Normal Rating. For ambient temperatures less than 100 degrees F the wavetrap normal rating is adjusted based on ANSI Standard 93.3-1981.

4.5.10. Fuses

There are presently no fuses utilized as part of the series circuit on the MidAmerican 100 kV and above system; however, if a fuse were to be installed as part of the series circuit, MidAmerican would base the normal and emergency rating upon information provided by the equipment manufacturer and applicable industry standards.

4.5.11. Potential Devices

There are presently no potential devices utilized as part of the series circuit on the MidAmerican 100 kV and above system; however, if a potential device were to be installed as part of the series circuit, MidAmerican would base the normal and emergency rating upon information provided by the equipment manufacturer and applicable industry standards.

4.6. Relay Protective Devices

4.6.1. Relay Settings

Protective relay settings are considered in establishing facility normal and emergency ratings. For facilities subject to NERC Standard PRC-023, Criteria 1 of the standard is applied to ensure adequate margin.

For facilities not subject to PRC-023, the relay load limit calculation used are as follows. When load encroachment is used, the relay load limit is calculated using the load encroachment formula.

Non-PRC-023 Relay Load Calculation:

$$RLL_{MVA @ 90\%V} = \frac{90\% * kV^2}{Z_p * \frac{PT_{ratio}}{CT_{ratio}} * \cos(\theta_{relay} - 25.84)}$$

Non-PRC-023 Relay Load Calculation with Load Encroachment:

$$RLL_{MVA@90\%V} = \frac{90\% * kV^2}{Z_{LE} * \frac{PT_{ratio}}{CT_{ratio}}}$$

4.6.1.1. Relay & Secondary Circuit Thermal Limits

MidAmerican's substation design recommended practice RP 330-300 specifies 12 AWG and 10 AWG for control leads and current transformer secondary leads. The smaller of these conductors is rated for 20 Amps. Digital relays are typically rated for 10 Amps or more. To observe this 10 Amp limit, current transformer ratings are limited to thermal factors no greater than twice the tapped winding. In this manner, secondary currents will not exceed 10 Amps unless specifically reviewed and determined capable of higher secondary currents.

5. <u>REFERENCES</u>

- [1] General Cable Technologies Corporation, "TransPower ACSS A Proven Concept for a Composite Aluminum-Steel Conductor for Overhead Transmission Lines", (2001): p. 6.
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- [10] ANSI Standard for Electric Connectors for Use Between Aluminum to Aluminum or Aluminum to Copper Bare Overhead Conductors, C119.4-2003.
- [11] IEEE Standard 738-2006 Standard for Calculating the Current-Temperature of Bare Overhead Conductors.
- [12] IEEE C57.91 Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators
- [13] NERC Standard PRC-023-2 Transmission Relay Loadability
- [14] MidAmerican Energy Substation Engineering Recommended Practice RP 330-300, Control Cable Wire Types and Applications

6. <u>REVISION HISTORY</u>

- 1. Version 1.0 issued on 6/15/2007
- 2. Version 1.1 revised to remove specific Generator and Generator Step-Up rating references
- 3. Version 2.0 issued on 7/5/2007. Revisions to remove system planning criteria such that the document focuses only on facility ratings.
- 4. Version 2.1 expanded assumptions section 3.5 for clarification.
- 5. Version 2.2 expanded to provide winter season rating assumptions in Section 3.7.1 and to provide information concerning NEMA to ANSI switch rating conversions in Section 3.9.8.
- 6. Version 2.3 issued on 6/1/2009. Additional clarification that ambient adjusted ratings are only for use in the near-term operation of the transmission system.
- 7. Version 2.4 issued on 3/12/2010. Minor revisions to reflect MidAmerican participation in MISO model building processes and other minor clarifications.
- 8. Version 2.5 issued on 9/15/2010. Minor revisions to include series compensation.
- 9. Version 2.6 issued on 3/2/2011. Additional clarifications regarding calculation of ratings for segmentally owned lines, and maximum conductor operating temperature and resulting line conductor sag clearances. Additional section describing fuses and potential devices under Terminal Equipment category.
- 10. Version 2.7 issued on 4/15/2011. Minor revision to description of most limiting element in Section 3.2.
- 11. Version 3.0 issued on 11/19/2013. Revision to include ambient adjusted normal ratings for breaker, current transformers, switches, and wavetraps. Removed rerate references. Minor reorganization. Added Table of Contents. Added clarification in current transformer and relaying sections.
- 12. Version 3.1 issued on 3/5/2014. Added relay limit calculations for non-PRC-023 subject lines. Removed timelines in 1.3 due to removal of R4 and R5. Added field inspection to hierarchy. Clarified transformer emergency description. Added condenser bushing wording to tubular bus.
- 13. Version 3.2 issued 4/8/2014. Clarified scope of transformer rating and clarified that Current Transformer section does not apply to transformer CTs as they are included in the transformer equipment rating. Revised ring bus and breaker-and-a-half procedures to extend only to the next adjacent line or transformer terminal.
- 14. Complete document review 12/27/2015
- 15. Version 3.3 issued 5/24/2016. Added bus duct equipment under section 4.
- 16. Version 3.4 issued 2/20/2017. Removed section 1.3 to pursuant to retirement of requirements R4 and R5. Clarified cable rating as either transmission conductor or terminal equipment.