FACILITY RATING METHODOLOGY

FOR

US ARMY CORPS OF ENGINEERS PROJECTS

WITHIN

BONNEVILLE POWER ADMINISTRATION'S SERVICE TERRITORY

AND

BUREAU OF RECLAMATION PROJECTS

WITHIN

BONNEVILLE POWER ADMINISTRATION'S SERVICE TERRITORY
WESTERN AREA POWER ADMINISTRATION SERVICE TERRITORY

1. SCOPE AND PURPOSE

This document describes the methodology used by the U.S. Army Corps of Engineers (USACE) and the Bureau of Reclamation (Reclamation) to rate their respective Bulk Electric System (BES) Facilities within the Federal Columbia River Power System. Both the USACE and Reclamation reserve the right to use other documented methodologies to rate their respective facilities in other areas of the United States. The methodology described herein covers Facilities solely and individually owned by the USACE and Reclamation. Neither the USACE nor Reclamation jointly owns any Facilities.

This Methodology is intended to provide documentation in compliance with NERC Reliability Standard FAC-008-1, approved by Federal Energy Regulatory Commission with an effective date of June 4, 2007. The rating methodology is based on industry standards as discussed below. These standards change from time to time and the rating methodology will be modified to keep pace with accepted industry practice.

The Facilities addressed in this document are comprised of various electrical equipment or Elements (defined term by NERC). Facilities may contain one or more Elements. A Facility Rating shall respect the most limiting applicable Equipment or Element Rating of the individual equipment that comprises the Facility. For the purposes of determining Generation Facility Ratings, the ratings include consideration of the following components: turbine, turbine shaft, generator mechanical components, and generator electrical components.

The scope of equipment or Elements addressed in this document includes the following:

- Generation Facilities (typical)
    - Turbine components and shaft(s)
    - Generator components
    - Medium voltage bus
    - Medium voltage generator breakers
    - Generator step-up transformers
- Transmission Facilities
    - Line conductors
    - System transformers
    - Shunt Reactors
    - High Voltage breakers
- Terminal Equipment
    - Disconnect switches
    - Switchyard conductors
    - Instrument transformers
    - Protective relaying

Neither the USACE nor Reclamation owns or operates series or shunt capacitors.

2. GENERATION FACILITIES

2.1 General Approach

By mutual understanding between the USACE, Reclamation, and the Bonneville Power Administration (BPA), the Facility Ratings for a Generation Facility are determined at the point of interconnection between the Generation Facility and the Transmission Owner, usually at the powerhouse end of the powerhouse line. Thus the Facility Rating for a Generation Facility is determined by reviewing the ratings of all equipment in the "water to wire" path for each generator. If more than one generator is normally connected to a single powerhouse line, the Facility Rating will be the sum of the individual unit ratings, subject to any limitations related to Elements common to the units.

Note that reservoir or river related issues may prevent the output of a powerhouse with several powerhouse lines from reaching the arithmetic sum of the associated Facility Ratings which are based on rated conditions for the equipment associated with each powerhouse line.

For the purposes of determining the Facility Rating, the following powerhouse equipment will be aggregated into one Facility:

- Turbine and turbine shaft and flanges
- Intermediate shaft and flanges (if applicable)
- Generator (mechanical and electrical components)
- Medium voltage segregated or isolated phase bus
- Generator breaker, and associated components
- Generator step up transformer, including bushings and current transformers

The ratings of the Elements below can impact the Generation Facility rating if they are located on the USACE/Reclamation side of the point of interconnection with the Transmission Owner. Since the rating methodology for this equipment is not related to the location of the equipment, the rating methodology discussion appears under headings other than Generation Facilities.

- High voltage bus
- Disconnect switches
- High Voltage breakers

The rating of the most limiting element between the turbine and the point of interconnection with BPA shall determine the Generation Facility rating. Where more than one turbine-generator is connected to a powerhouse line, the Facility Rating will be the lower of the sum of the individual unit ratings and the rating of the common equipment (transformer, high side disconnect switch, etc.)

The following conditions are assumed when determining the ratings for the various Elements in the Generation Facility:

- Turbine horsepower ratings shall be reported at rated head conditions for the turbine under evaluation. Typical ranges for head and other limitations on operation due to head changes will be documented, but the Facility Rating will assume rated conditions prevail.
- Generator ratings shall be reported at conditions of rated frequency, rated terminal voltage, rated power factor.

Generation Facility ratings are Continuous ratings only. There are no Emergency ratings for Generation Facilities. Time limitations on the Generator Facility Continuous ratings due to dependency on water supply (river flow and levels) will be noted in, but will not be used to adjust, the Facility Rating.

2.2 Turbine Ratings

The horsepower rating of the turbine has a direct bearing on the maximum real power rating of the generator, as the latter can be no larger than the former. Confirmation of the turbine horsepower rating can be accomplished by the methods described below.

2.2.1 Original Design Rating

If there have been no changes to the original design rating of the turbine due to unit ratings increase due to uprate work or unit ratings decrease due to mechanical degradation or failure, the original nameplate horsepower of the turbine can be assumed to be applicable. The conditions for which the horsepower rating is valid, including rated head, must be included in the turbine rating.

2.2.2 Changed Design Rating

In the event that the original design rating has been changed or the turbine has been replaced, the new rating shall be documented by engineering analysis and organizational approval of the new rating based on technical review and acceptance of the uprate study, or by field tests of the up-rated unit in accordance with applicable ASME standards.

2.3 Generator Ratings

Generator ratings are determined in accordance with the applicable version of ANSI/IEEE C50.12, Standard for Salient Pole Synchronous Generators and Generator/Motors for Hydraulic Turbine Applications. The version of C50.12 that applies to a particular generator is that which was in effect when the generator was specified and manufactured. For generators manufactured prior to 1982, a continuous overload capability of 115% of the nameplate MVA rating was required to be incorporated into the machine design. Generators built after 1982 do not have a continuous overload capability beyond the nameplate MVA rating.

2.3.1 Original Design Rating

If there have been no changes to the original design rating of the generator, the rating can be determined by applying the overload capability (if applicable) of the machine to the nameplate data for MVA, at rated voltage, frequency, and power factor.

2.3.2 Changed Design Rating

In cases where the generator design rating has been increased, the new rating shall be supported by engineering analysis of the generator components including, but not limited to, the following:

- Generator mechanical components - shaft, rotor (spider, rim, and poles), stator frame, sole plates, air coolers, thrust and guide bearings, etc.
- Generator electrical components – stator winding, circuit rings, main leads, field winding, field leads, exciter, collector rings, current transformers, etc.

The new generator rating should be subject to organizational approval of the new rating based on a technical review and acceptance of an uprate study, or by field tests of the up-rated unit in accordance with applicable IEEE standards.

Note that a new stator winding with higher MVA rating does not constitute an uprate of the whole generator. Until all the other components of the generator (and turbine) are studied and confirmed to be capable of operation at the increased stator winding rating, the generator rating remains unchanged from the original design.

In those cases where the generator rating has been decreased from nameplate ratings, due to compromised operation (cooling problems, stator coil cut-out, etc), the reduced rating shall be reported as the generator rating.

2.4 Medium Voltage Bus

The required ratings of medium-voltage bus are identified when the equipment specifications are prepared. The continuous current rating of medium voltage (typically segregated or isolated phase) bus is required to be equal to or greater than the value specified in the equipment specifications. The current rating specified is based on the requirements of the connected generator(s). The ampacity ratings are required to be determined in accordance with the requirements of:

- ANSI/IEEE C37.23, IEEE Guide for Metal Enclosed Bus and Calculating Losses in Isolated Phase Bus Duct.

The Normal Rating for medium voltage bus is rated as shown on the manufacturer's nameplate. Neither USACE nor Reclamation establish Emergency Ratings for medium voltage bus so no Emergency Ratings are provided.

2.5 Generator Breakers and Associated Components

The required ratings of generator circuit breakers are identified when the equipment specifications are prepared. The continuous current ratings are chosen to meet or exceed the connected generator current ratings. The following standards are referenced in breaker procurement and testing specifications:

- IEEE C37.04, IEEE Standard Rating Structure for AC High Voltage Circuit Breakers
- ANSI C37.06, AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis- Preferred Ratings and Related Required Capabilities.
- IEEE C37.09, IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
- IEEE C37.013, IEEE Standard for AC High-Voltage Generator Circuit Breakers Rated on a Symmetrical Current Basis

The Normal Rating for generator circuit breakers is rated as shown on the manufacturer's nameplate. The USACE and Reclamation do not establish emergency ratings for generator circuit breakers, therefore Emergency Ratings are not provided.

Current transformers and breaker disconnecting switches procured with and as part of the generator breaker assembly have the same continuous current rating as the circuit breaker. In cases where the circuit breaker has been replaced but the original current transformers or disconnecting switches are retained, the rating for the circuit breaker Element will be the lowest of the ratings for the breaker, current transformers, and the disconnect switches.

2.6 Generator Step-up Transformers

The required ratings of generator step-up transformers are identified when the equipment specifications are prepared. The transformer ratings are chosen to meet or exceed the ratings of the connected generators, with due consideration of connected station service loads. The ratings are required to be in accordance with the provisions of:

- IEEE C57.12.00, IEEE General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
- IEEE C57.91, IEEE Guide for Loading Mineral-Oil Immersed Transformers
- IEEE C57.116 Guide for Transformers Directly Connected to Generators
- IEEE C57.13, IEEE Standard Requirements for Instrument Transformers

- IEEE C57.19.00, IEEE Standard General Requirements and Test Procedures for Power Apparatus Bushings

- IEEE C57.9.01, IEEE Standard Performance Characteristics and Dimensions for Outdoor Apparatus Bushings

The Normal Rating for the generator step-up transformer is as shown on the manufacturer's nameplate. The ratings of all accessory devices, such as bushings and current transformers, which can affect the transformer rating, are reviewed to ensure consistency with the transformer rating. Neither USACE nor Reclamation establish Emergency Ratings for generator step-up transformers so no Emergency Ratings are provided.

3. TRANSMISSION FACILITIES

3.1 Transmission Line Conductor

Normal and Emergency Rating Criteria

The required ratings of transmission line conductors are identified when the equipment and material specifications are prepared. Required ratings are developed in coordination with power marketing agencies or local utilities based on the location of the project. Normal Ratings for overhead transmission conductors are determined using the rating methodology described below. Neither USACE nor Reclamation establish ratings above Normal for these conductors therefore no Emergency Ratings are provided.

The ampacity rating of bare overhead conductors is:

- Based on the steady state load current carrying capacity of the conductor.

- A continuous thermal rating based on a maximum rated conductor temperature. This rating serves as the "normal" or "full time" continuous rating for the line section it is in. There is no continuous "emergency" rating with a higher temperature rise associated with it for USACE or Reclamation Transmission lines.

Industry Standards

Bare overhead transmission conductor ratings are consistent with and use the methodology described in the IEEE Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors (IEEE Standard 738).

Input Criteria Assumptions

Ampacities for most transmission line conductors are based on single conductors in free air, emissivity factor of 0.5 for aluminum, and a percent conductivity based on the

International Annealed Copper Standard (IACS) conductivity. An assumed wind speed of 2 ft/sec is used. The relative sun exposure is determined based on project location and calculations for solar heat gain are performed using appropriate inputs. Maximum conductor temperatures and ambient temperatures assumed for calculating continuous current rating determination are coordinated with values used by the Transmission Owner with whose system the transmission lines connect. Maximum conductor temperatures range from 50ºC to 100ºC, and assumed maximum ambient temperatures range from 30ºC to 40ºC or higher.

3.2 System Transformers

The required ratings of system transformers are identified when the equipment specifications are prepared. Required ratings are developed in coordination with power marketing agencies or local utilities based on the location of the project. The ratings are required to be in accordance with the provisions of:

- IEEE C57.12.00, IEEE General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
- IEEE C57.91, IEEE Guide for Loading Mineral-Oil Immersed Transformers
- IEEE C57.13, IEEE Standard Requirements for Instrument Transformers
- IEEE C57.19.00, IEEE Standard General Requirements and Test Procedures for Power Apparatus Bushings
- IEEE C57.19.01, IEEE Standard Performance Characteristics and Dimensions for Outdoor Apparatus Bushings

The Normal Rating for system transformer is rated as shown on the manufacturer's nameplate. The ratings of all accessory devices, such as bushings and current transformers, which can affect the transformer rating, are reviewed to ensure consistency with the transformer rating. Neither USACE nor Reclamation establish Emergency Ratings for system transformers so no Emergency Ratings are provided.

3.3 Shunt Reactors

The required ratings of shunt reactors are identified when the equipment specifications are prepared. Required ratings are developed in coordination with power marketing agencies or local utilities based on the location of the project. The ratings are required to be in accordance with the provisions of:

- IEEE C57.21, IEEE Standard Requirements, Terminology, and Test Code for Shunt Reactors Rated over 500KVA
- IEEE C57.13, IEEE Standard Requirements for Instrument Transformers

- IEEE C57.19.00, IEEE Standard General Requirements and Test Procedures for Power Apparatus Bushings

- IEEE C57.19.01, IEEE Standard Performance Characteristics and Dimensions for Outdoor Apparatus Bushings

The Normal Rating for a shunt reactor is rated as shown on the manufacturer's nameplate. The ratings of all accessory devices, such as bushings and current transformers, which can affect the reactor rating, are reviewed to ensure consistency with the reactor rating. Neither USACE nor Reclamation establish Emergency Ratings for shunt reactors so no Emergency Ratings are provided.

3.4 High Voltage Breakers

The required ratings of high voltage breakers are identified when the equipment specifications are prepared. Required ratings are developed in coordination with power marketing agencies or local utilities based on the location of the project. The following standards are referenced in breaker procurement and testing specifications and address current ratings:

- IEEE C37.04, IEEE Standard Rating Structure for AC High Voltage Circuit Breakers

- ANSI C37.06, AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis- Preferred Ratings and Related Required Capabilities.

- IEEE C37.09, IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

- IEEE C57.19.00, IEEE Standard General Requirements and Test Procedures for Power Apparatus Bushings

- IEEE C57.19.01, IEEE Standard Performance Characteristics and Dimensions for Outdoor Apparatus Bushings

The Normal Rating for transmission circuit breakers are rated as shown on the manufacturer's nameplate. The USACE and Reclamation do not establish emergency ratings for transmission circuit breakers, therefore Emergency Ratings are not provided.

Current transformers procured with and as part of the transmission breaker assembly are usually rated the same as the circuit breaker. If the current transformer continuous current rating is below that of the breaker, the lower rating will be used when determining the Normal Rating.

4. TERMINAL EQUIPMENT

4.1 Disconnect Switches

The required ratings of high voltage disconnect switches are identified when the equipment specifications are prepared. Required ratings are developed in coordination with power marketing agencies or local utilities based on the location of the project. The following Standards are used to determine the ratings of High-Voltage switches:

- IEEE C37.30, Standard Requirements for High-Voltage Switches
- ANSI C37.32, American National Standard for High-Voltage Switches, Bus Supports, and Accessories, Schedule of Preferred Ratings, Construction Guidelines, and Specifications
- IEEE C37.37, Standard Loading Guide for AC High-Voltage Switches (in excess of 1000 volts).

The Normal Rating for disconnect switches are rated as shown on the manufacturer's nameplate. The USACE and Reclamation do not establish emergency ratings for disconnect switches, therefore Emergency Ratings are not provided.

4.2 Switchyard Conductors and Bus

The required ratings of high voltage switchyard conductor and bus are identified when the equipment specifications are prepared. Required ratings are developed in coordination with power marketing agencies or local utilities based on the location of the project. The following Standards are used to determine the ratings of switchyard conductors (and bus):

- IEEE Standard 605, IEEE Guide for Design of Substation Rigid-Bus Structures
- IEEE Standard 738, IEEE Standard for Calculating the Current-Temperature of Bare overhead Conductors

Ampacities for most conductors used in outdoor substations are based on single bus conductors in free air, emissivity factors of 0.35 for copper and 0.5 for aluminum, and a percent conductivity based on the International Annealed Copper Standard (IACS) conductivity. An assumed wind speed of 2 ft/sec is assumed for both rigid and flexible conductors. The relative sun exposure is determined for each location and an ampacity between those listed in the standards for Full and No sun is determined.

For new installations, the conductor sizes will normally be determined with conductor ampacities for a 30º C temperature rise above 40º C ambient. The 50º C rise over 40º C ambient ampacity will normally be used for existing switchyards, to determine if existing conductors should be replaced with higher ampacity conductors.

The ampacity of conductors and associated connectors are rated at or above the switches and equipment to which they are connected. The USACE and Reclamation do not establish emergency ratings for switchyard conductors, therefore Emergency Ratings are not provided.

4.3 Instrument Transformers

The required ratings of instrument transformers are identified when the equipment specifications are prepared. Required ratings are developed in coordination with power marketing agencies or local utilities based on the location of the project. Free standing and bushing current transformers, potential or voltage transformers, are rated according to:

- IEEE C57.13, Standard Requirements for Instrument Transformers.

The Normal Ratings for instrument transformers are as shown on the manufacturer's nameplate. The USACE and Reclamation do not establish emergency ratings for instrument transformers, therefore Emergency Ratings are not provided.

4.4 Protective Relaying

The required ratings of protective relaying are identified when the equipment specifications are prepared. Required ratings and settings are developed in coordination with power marketing agencies or local utilities based on the location of the project. The ratings of protective and other relays associated with power system equipment are determined in accordance with:

- IEEE C37.90, IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus

The design philosophy for both the USACE and Reclamation is such that the continuous current rating of devices connected to the secondary of any current transformers must not limit rating of the associated Element or Facility. Neither the USACE nor Reclamation has applications where protective relays are sensitive to system loading within Normal or Emergency ratings.