1B.4—Reliability Criteria for System Planning

1. Scope

The design of PacifiCorp's electrical system is intended to meet the reliability performance requirements of all North American Electric Reliability Corporation (NERC), Western Electricity Coordinating Council (WECC), and PacifiCorp standards and criteria. This document discusses the specific standards and criteria, and how they apply to PacifiCorp's system.

2. References and Resource Documents

The latest revisions of the following industry documents in effect on the date of this document apply to the extent specified herein. The "TPL" and "FAC" documents listed below are included as attachments at the end of this document, as of this document's date of publication. Planners and other users can use the web links provided below to check for current versions of reference documents.

WECC Regional Performance Criterion, TPL-001-WECC-CRT-3, *Transmission System Planning Performance*, current version

NERC TPL Transmission System Planning Performance Requirements (TPL-001-4) current versions

NERC *System Operating Limits Methodology for the Planning Horizon* (FAC-010), current version

NERC *Facility Rating Methodology*,(FAC 008-3) Standard

ANSI / IEEE SA C57.92-1981, *IEEE Guide for Loading Mineral-Oil-Immersed Power Transformers up to and Including 100 MVA, with 55 Degrees C or 65 Degrees C Average Winding Rise*

ANSI / IEEE SA C57.115-1991, *IEEE Guide for Loading Mineral-Oil-Immersed Power Transformers Rated in Excess of 100 MVA (65 Degrees C Winding Rise)*

WECC and NERC Modeling, Data and Analysis (MOD) Standards

NERC Glossary of Terms, *Definition of Bulk Electric System*

WECC Glossary of Terms

The latest revisions of the following PacifiCorp documents in effect on the date of this document apply to the extent specified herein.

PacifiCorp Engineering Handbook 1B.3, Planning Standards for Transmission

Voltage PacifiCorp Engineering Handbook 1B.9, Substation Design Criteria

PacifiCorp's Open Access Transmission Tariff (OATT)

PacifiCorp's Network Diagram

NERC standards and WECC criteria apply to Bulk Electric System (BES) elements. PacifiCorp's BES is highlighted on the network diagram in blue except the BES that is part of a major WECC path which is highlighted in yellow.

3. Definitions

The NERC Reliability Standards' glossary provides the following definitions:

3.1. Bulk Electric System (BES) Transmission:

Unless modified by the lists shown below, the BES is all transmission elements operated at 100 kV or higher, and real power and reactive power resources connected at 100 kV or higher. This does not include facilities used in the local distribution of electric energy.

- Inclusions:
  1. Transformers with the primary terminal and at least one secondary terminal operated at 100 kV or higher unless excluded under exclusion #1 or #3 (below)
  2. Generating resource(s) with gross individual nameplate rating greater than 20 MVA or gross plant/facility aggregate nameplate rating greater than 75 MVA including the generator terminals through the high-side of the step-up transformer(s) connected at a voltage of 100 kV or above
  3. Blackstart resources identified in the transmission operator's restoration plan
  4. Dispersed power producing resources with aggregate capacity greater than 75 MVA (gross aggregate nameplate rating) utilizing a system designed primarily for aggregating capacity, connected at a common point at a voltage of 100 kV or above
  5. Static or dynamic devices (excluding generators) dedicated to supplying or absorbing reactive power that are connected at 100 kV or higher, or through a dedicated transformer with a high-side voltage of 100 kV or higher, or through a designated transformer
- Exclusions:
  1. Radial systems: A group of contiguous transmission elements that emanate from a single point of connection of 100 kV or higher and
     a. Only serve load. Or,
     b. Only include generation resources, not identified in inclusion I3, with an aggregate capacity less than or equal to 75 MVA (gross nameplate rating). Or,
     c. Where the radial system serves load and includes generation resources, not identified in inclusion I3, with an aggregate capacity of non-retail generation less than or equal to 75 MVA (gross nameplate rating).

     Note: A normally-open switching device between radial systems, as depicted on prints or one-line diagrams for example, does not affect this exclusion.
  2. A generating unit (or multiple generating units) on the customer's side of the retail meter that serves all or part of the retail load with electric energy if:
     a. The net capacity provided to the BES does not exceed 75 MVA

b. Standby, backup, and maintenance power services are provided to the generating unit (or multiple generating units) or to the retail load by a balancing authority, or provided pursuant to a binding obligation with a generator owner or generator operator, or under terms approved by the applicable regulatory authority

3. Local networks (LN): A group of contiguous transmission elements operated at or above 100 kV but less than 300 kV that distribute power to load rather than transfer bulk power across the interconnected system. LN's emanate from multiple points of connection at 100 kV or higher to improve the level of service to retail customer load and not to accom- modate bulk power transfer across the interconnected system. The LN is characterized by all of the following:

   a. Limits on connected generation: The LN and its underlying elements do not include generation resources identified in Inclusion I3 and do not have an aggregate capacity of non-retail generation greater than 75 MVA (gross nameplate rating),

   b. Power flows only into the LN and the LN does not transfer energy originating outside the LN for delivery through the LN,

   c. Not part of a flowgate or transfer path: The LN does not contain a monitored facility of a permanent flowgate in the Eastern Interconnection, a major transfer path within the Western Interconnection, or a comparable monitored facility in the ERCOT or Quebec Interconnections, and is not a monitored facility included in an Interconnection Reli- ability Operating Limit (IROL)

4. Reactive power devices owned and operated by the retail customer solely for its own use.

Note: Elements may be included or excluded on a case-by-case basis through the rules of procedure exception process.

Consequential load loss: All load that is no longer served by the transmission system as a result of transmission facilities being removed from service by a protection system operation designed to isolate the fault.

Non-consequential load loss: Non-interruptible load loss that does not include:

1. Consequential load loss,
2. The response of voltage sensitive load, or
3. Load that is disconnected from the system by end-user equipment.

Firm Transmission Service: Priority service offered to customers under a filed rate schedule that anticipates no planned interruptions.

Other terms used in this document:

3.2. Non-Bulk Electric System (Non-BES) Transmission

The electrical generation resources, transmission lines, interconnections with neighboring systems, and associated equipment, which are not included in the BES. This is the portion of the transmission system to which the NERC and WECC planning standards and criteria do not apply.

3.3. Distribution System

The distribution system is the final stage in the delivery of electricity to end users. The distribution system (up to and including 34.5 kV), is generally designed as a radial system, subject to loss of load any time the distribution line or transformer is lost. Some end users receive delivery at voltages other than distribution voltages.

4. BES Transmission, Non-BES Transmission and Distribution

4.1. BES Transmission Requirements

NERC TPL-001-4 Table 1, *Steady State & Stability Performance Planning Events*, provides performance standards required for the BES for a wide variety of conditions. The planning coordinator and the transmission planner are required to annually demonstrate, through a valid assessment, that its portion of the interconnected transmission system is planned such that facilities can be operated to supply projected customer demands and projected firm (non-recallable reserved) transmission services, at all demand levels over the range of forecast demand, under the contingency conditions defined in the appropriate category of NERC TPL-001-4 Table 1. Planning shall also be consistent with the current revision of PacifiCorp's Open Access Transmission Tariff, Attachment C, *Methodology to Assess Available Transfer Capability*.

Additional requirements are provided in NERC FAC-010 (including Section E), and, within the WECC region, criterion for acceptable impacts to systems owned and/or operated by other entities is provided in TPL-001-WECC-CRT-3. This regional performance criterion document also defines the voltage stability, post-transient voltage deviation, and other requirements applicable to transmission path rating studies.

System topologies and models used in planning studies and assessments shall be maintained in accordance with WECC and NERC MOD standards and requirements, and NERC FAC-008.

4.1.1. Category P0—No Contingency, with System Normal

As shown in the Category P0 portion of NERC TPL-001-4 Table 1, this category is system normal with no contingencies. All facilities must be within their applicable facility ratings and voltage limits. As noted in section 4.1.2 a, "applicable facility rating" refers to the applicable normal and emergency facility rating as determined and consistently applied by the facility owner, and may include emergency ratings applicable to short durations, as required, to permit operating steps necessary to maintain system control. For PacifiCorp, normal and emergency facility ratings are published in the weak link database for lines and transformers. Voltage limits are provided in Engineering Handbook 1B.3, Planning Standards for Transmission Voltage. For category P0, interruption of firm transmission service and non-consequential load loss is not allowed.

4.1.2. Category P1—System Normal with Single Contingency Resulting in the Loss of a Single Element (generator, line, transformer, shunt device, or single pole of a DC line)

Category P1 shall include N-1 contingencies of a single generator, transmission line, transformer or shunt device. The loss of a single pole of a DC line is not applicable to PacifiCorp's system. Loss of "non-consequential load" is not permitted as noted in Table 1 for Category P2 and footnote 12. Interruption of firm transmission service is not allowed as noted in Table 1 for Category P2 and footnote 9.

4.1.3. Category P2—System Normal with Single Contingency Including opening of line w/o a fault, and bus or breaker fault

Category P2 shall include all applicable contingencies including bus section fault, breaker internal faults (non bus-tie and bus-tie breaker), and opening of a networked line section at one end without a fault such that the line is possibly serving load radial from a single source point. Internal breaker faults create a system fault that must be cleared by protection on both sides of the breaker.

Loss of "non-consequential load" is permitted for some events as noted in Table 1 for Category P2 and footnote 12. Interruption of firm transmission service is allowed for some events as noted in Table 1 for Category P2 and footnote 9.

4.1.4. Category P3—Multiple Contingencies Involving loss of generator(s)

Category P3 addresses N-1-1 contingencies. It is defined as loss of a generator as the first N-1, followed by the second N-1 involving a generator, transmission line, transformer or shunt device. The loss of a single pole of a DC line is not applicable to PacifiCorp's system.

Loss of "non-consequential load" is permitted for some events as noted in Table 1 for Category P3 and footnote 12. Interruption of firm transmission service is allowed for some events as noted in Table 1 for Category P3 and footnote 9.

4.1.5. Category P4—Multiple Contingencies Involving Fault Plus Stuck Breaker

Category P4 addresses fault with delayed clearing. Fault on a generator, transmission line, transformer, shunt device or bus section with delayed clearing due to stuck breaker (non- bus-tie breaker). This category also includes loss of multiple elements caused by a stuck bus-tie breaker attempting to clear a fault on the associated bus.

Loss of "non-consequential load" is permitted for some events as noted in Table 1 for Category P4. Interruption of firm transmission service is allowed for some events as noted in Table 1 for Category P4 and footnote 9.

4.1.6. Category P5—Multiple Contingencies Involving Fault Plus Relay Failure to Operate

Category P5 addresses fault with delayed clearing. Fault on a generator, transmission line, transformer, shunt device or bus section with delayed clearing due to non-redundant relay failure.

Loss of "non-consequential load" is permitted for some events as noted in Table 1 for Category P5 (HV BES only). Interruption of Firm Transmission Service is allowed for some events as noted in Table 1 for Category P5 and footnote 9.

4.1.7. Category P6—Multiple Contingencies Not Involving Loss of Generators Category

P6 addresses N-1-1 contingencies. It is defined as N-1-1 contingency combinations involving a transmission line, transformer or shunt device. The loss of a single pole of a DC line is not applicable to PacifiCorp's system.

Loss of "non-consequential load" is permitted for this category. Interruption of Firm Transmission Service is also allowed.

4.1.8. Category P7—Multiple Contingencies Involving Loss of Two Adjacent Lines on a Common Structure or Loss of a Bipolar DC Line

Category P7 addresses N-2 contingencies on any two adjacent (vertically or horizontally) circuits on a common structure. The loss of a bipolar DC line is not applicable to PacifiCorp's system.

Loss of "non-consequential load" is permitted for this category. Interruption of firm transmission service is also allowed.

4.2. Transmission System in a Radial Configuration

Transmission systems operated in a radial configuration are generally designed to provide service to a customer sector where the cost of service is minimized, rather than receiving the improved reliability that a looped configuration would provide.

Considerations and situations that can determine the need for a system upgrade from a radial configuration to a looped configuration include, but are not limited to:

1. Customers willing to fund the conversion to increase reliability
2. Significantly increasing load
3. Effects of a large-scale outage
4. Expected outage exposure, in load amount and hours at risk
5. Estimated time to repair an outage
6. Prevention of thermal overload or low-voltage situations
7. Projected future system performance
8. Economics

The benefits of converting a long-distance radial system to a looped system may not justify the expense to the ratepayer. In such situations, state utility commissions may provide advice as to how to proceed, and how, and when, to fund the expansion.

4.3. Non-BES Transmission System

This section applies to the non-BES transmission system. As a minimum, PacifiCorp's internal design and operating standards (Engineering Handbooks 1B.3 and 1B.9) apply to all PacifiCorp facilities.

Additionally, PacifiCorp generally aims to apply the planning guidelines within this document (Section 4.1) to the planning and construction of new facilities (subject to economics and other factors which may include expected outage exposure, typical times to repair outage, MW at risk, annual hours of exposure, etc.).

4.4. Distribution System

The distribution system, generally designed as a radial system, is subject to loss of load any time the distribution line or transformer is de-energized. Underground distribution systems in high-density load centers (such as downtown Portland and downtown Salt Lake City) are designed with redundancy to operate without sustained loss of load following the loss of a line or transformer. Any construction required to reduce load-loss exposure must be within a cost range justified by the amount of exposure reduction. Factors included in the reliability criteria planning for PacifiCorp's distribution system are contained in Engineering Handbook Document 1E.3.1.

5. Power Transformer Loading Criteria

The goal of power transformer loading criteria is to define planning and design criteria, which provides loading limits for transformers in transmission and distribution substations under typical summer and winter conditions. Questions concerning specific guidelines for existing transformers and their auxiliary equipment should be referred to substation engineering and area planning.

5.1. Background

The nameplate rating of a transformer is the load that the transformer is designed to carry continuously in an average ambient temperature of 30°C and a maximum ambient of 40°C. Under these loading conditions the insulation in a given transformer is expected to degrade at a rate which is considered normal.

At ambient temperatures above or below these values, a transformer is designed to carry loads less or greater, respectively, than its nameplate rating, while still providing normal life.

Additionally, transformers are designed to carry greater loads for short periods of time, when compared to their capacity under continuous loading conditions. This is due to the thermal lag in the heating of the transformer core and oil. It is desirable to incorporate these thermal characteristics into transformer loading guidelines for planning, budgeting, design and operational purposes.

5.2. Loading Guidelines

Information used to determine the loading guidelines in Table 2 comes from:

ANSI/IEEE C57.92, IEEE Guide for Loading Mineral-Oil-Immersed Power Transformers up to and including 100 MVA, with 55 Degrees C. or 65 Degrees C. Average Winding Rise; and

IEEE C57.115, IEEE Guide for Loading Mineral-Oil-Immersed Power Transformers Rated in Excess of 100 MVA (65 Degrees C. Winding Rise).

These standards give conservative recommendations for loading substation transformers under various conditions with no loss of life expectancy. They also give recommendations for loading transformers under emergency conditions if a moderate loss of life expectancy is to be permitted to avoid curtailment of service; however, neither the guidelines given in this document nor the generic emergency ratings in the appendix consider use of loss of life expectancy in determining the given ratings.

The company does not plan to overload any substation transformers, where overload is defined as the loading of a transformer beyond the recommendations given in Table 2 below. This provides for no loss of life expectancy above what is considered normal aging of a transformer. Table 3 and Table 4 provide emergency recommendations for transmission and substation transformers.

Table 1—Substation Transformer Loading Guidelines

Criteria	**Value**	
Average ambient temperature	Winter: 10°C	
	Summer: 30°C	
Equivalent continuous preload	100% of top nameplate	
Peak load duration	8 hours[a]	
Transformer Cooling Class	**Highest Nameplate Rating[b c]**	
	Winter	**Summer [d e]**
ONAN	130%	105%
ONAN/ONAF	125%	105%
ONAN/ONAF/ONAF, OFAF, or ONAN/ODAF/ODAF	120%	105%

a) Duration of time in 24-hour period that transformer is expected to be loaded above equivalent preload, which in this case is 100% of top nameplate.

b) Recognizing the capabilities of 65° degree transformer insulation, for 55/65° rise transformers, the 65° nameplate rating is used.

c) Allowable loading generally limited to available mobile transformer ratings at distribution substations.

d) For bulk electric system transformers, 100% rating will be used.

e) On a case-by-case basis, the maximum loading may be decreased below 105%, based on known transformer characteristics such as poor heat run tests, known core degradation, or environmental criteria.

Table 2—30-Minute Emergency Transmission Transformer (with Low-Side Voltages Greater than or Equal to 230 kV) Guidelines[a]

Criteria	**Value**	
Average ambient temperature	Summer: 30 °C	
Equivalent continuous preload	70% of top nameplate	
Peak load duration	30 minutes	
	Highest Nameplate Rating	
Transformer Cooling Class	**Summer**	
	Load	**Temp °C**
ONAN/ONAF/ONAF, OFAF, or ONAF/ODAF/ODAF	150%	156

a The 30-minute transmission transformer emergency loading rating percentage and maximum hot-spot guideline were adopted based on allowable ratings in ANSI/IEEE C57.92-1981 and extended to all PacifiCorp power transformers rated above 100 MVA and with low-side voltages greater than or equal to 230 kV.

Table 3—Generic Short-Time Emergency Ratings for Substation Transformers[a]

Assumptions
Average ambient temperature: 0 °C Winter, 30 °C Summer
Equivalent continuous preload: 90% of top nameplate
Transformer just meets ANSI loading capability standards

Transformer Type		Winter		Summer	
		Load[b]	Temp °C[c]	Load[b]	Temp °C[c]
ONAN-cooled					
65°-rise[d] transformers					
	1-hour peak duration	200%	151°	153%	142°
	2-hour peak duration	177%	145°	134%	134°
	4-hour peak duration	156%	137°	120%	128°
55°-rise transformers					
	1-hour peak duration	200%	121°	156%	122°
	2-hour peak duration	189%	126°	138%	116°
	4-hour peak duration	166%	119°	122%	110°
ONAN/ONAF-cooled					
65°-rise[d] transformers					
	1-hour peak duration	179%	151°	143%	143°
	2-hour peak duration	159%	144°	128%	136°
	4-hour peak duration	144%	136°	116%	128°
55°-rise transformers					
	1-hour peak duration	189%	132°	146%	124°
	2-hour peak duration	169%	126°	129%	117°
	4-hour peak duration	152%	118°	118%	111°
ONAN/ONAF/ONAF, OFAF, or ONAF/ODAF/ODAF-cooled					
65°-rise[d] transformers					
	1-hour peak duration	152%	151°	130%	144°
	2-hour peak duration	141%	143°	120%	136°
	4-hour peak duration	132%	133°	112%	127°
55°-rise transformers					
	1-hour peak duration	160%	132°	132%	125°
	2-hour peak duration	147%	125°	122%	117°
	4-hour peak duration	138%	113°	113%	110°

a) The short-time emergency loading rating percentages and maximum hot-spot temperature for the emergency ratings were adopted from ANSI/IEEE C57.92-1981 and extended to all PacifiCorp power transformers rated above 100 MVA.

b) Transformer loading capability in percent of highest nameplate rating.

c) Allowable maximum hot-spot indication. Do not exceed this value, regardless of transformer loading. d)Includes 55/65°-rise transformers.

d)Includes 55/65°-rise transformers.

NOTE 1: Ampacity limitations of protective devices and other devices in the circuit should be considered. If the problem encountered has no clear-cut, short-term solution, contact area engineering, standards engineering, and/or operating resource personnel to assist in resolution.

NOTE 2: The one-hour peak duration loading levels shall only be used if the manufacturer transformer test report indicates that short-term operation at the temperature indicated in the table will not excessively damage the transformer. If data is available, a transformer heat run model may be developed. In addition, the thermal protection shall be verified as set to allow the hot spot temperature estimated in the table.

6. Issuing Department

The transmission planning department of PacifiCorp authored this publication; engineering publications department of PacifiCorp published this document.

This material specification shall be used and duplicated only in support of PacifiCorp projects.

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