**Standard PRC-023-3 — Transmission Relay Loadability**

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**A. Introduction**

**1. Title: Transmission Relay Loadability**

**2. Number:** PRC-023-3

**3. Purpose:** Protective relay settings shall not limit transmission loadability; not interfere with

system operators’ ability to take remedial action to protect system reliability and; be set to

reliably detect all fault conditions and protect the electrical network from these faults.

**4. Applicability:**

**4.1. Functional Entity:**

**4.1.1** Transmission Owner with load-responsive phase protection systems as described in

PRC-023-3 - Attachment A, applied at the terminals of the circuits defined in 4.2.1

*(Circuits Subject to Requirements R1 – R5)*.

**4.1.2** Generator Owner with load-responsive phase protection systems as described in

PRC-023-3 - Attachment A, applied at the terminals of the circuits defined in 4.2.1

*(Circuits Subject to Requirements R1 – R5)*.

**4.1.3** Distribution Provider with load-responsive phase protection systems as described in

PRC-023-3 - Attachment A, applied at the terminals of the circuits defined in 4.2.1

*(Circuits Subject to Requirements R1 – R5)*, provided those circuits have bidirectional

flow capabilities.

**4.1.4** Planning Coordinator

**4.2. Circuits**:

**4.2.1 Circuits Subject to Requirements R1 – R5:**

**4.2.1.1** Transmission lines operated at 200 kV and above, except Elements that

connect the GSU transformer(s) to the Transmission system that are used

exclusively to export energy directly from a BES generating unit or

generating plant. Elements may also supply generating plant loads.

**4.2.1.2** Transmission lines operated at 100 kV to 200 kV selected by the Planning

Coordinator in accordance with Requirement R6.

**4.2.1.3** Transmission lines operated below 100 kV that are part of the BES and

selected by the Planning Coordinator in accordance with Requirement R6.

**4.2.1.4** Transformers with low voltage terminals connected at 200 kV and above.

**4.2.1.5** Transformers with low voltage terminals connected at 100 kV to 200 kV

selected by the Planning Coordinator in accordance with Requirement R6.

**4.2.1.6** Transformers with low voltage terminals connected below 100 kV that are

part of the BES and selected by the Planning Coordinator in accordance with

Requirement R6.

**4.2.2 Circuits Subject to Requirement R6:**

**4.2.2.1** Transmission lines operated at 100 kV to 200 kV and transformers with low

voltage terminals connected at 100 kV to 200 kV, except Elements that

connect the GSU transformer(s) to the Transmission system that are used

exclusively to export energy directly from a BES generating unit or

generating plant. Elements may also supply generating plant loads.

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**4.2.2.2** Transmission lines operated below 100 kV and transformers with low

voltage terminals connected below 100 kV that are part of the BES, except

Elements that connect the GSU transformer(s) to the Transmission system

that are used exclusively to export energy directly from a BES generating

unit or generating plant. Elements may also supply generating plant loads.

**5. Effective Dates:** See Implementation Plan.

**B. Requirements**

**R1.** Each Transmission Owner, Generator Owner, and Distribution Provider shall use any one of the

following criteria (Requirement R1, criteria 1 through 13) for any specific circuit terminal to

prevent its phase protective relay settings from limiting transmission system loadability while

maintaining reliable protection of the BES for all fault conditions. Each Transmission Owner,

Generator Owner, and Distribution Provider shall evaluate relay loadability at 0.85 per unit

voltage and a power factor angle of 30 degrees. *[Violation Risk Factor: High] [Time Horizon:*

*Long Term Planning].*

**Criteria**:

**1.** Set transmission line relays so they do not operate at or below 150% of the highest seasonal

Facility Rating of a circuit, for the available defined loading duration nearest 4 hours

(expressed in amperes).

**2.** Set transmission line relays so they do not operate at or below 115% of the highest seasonal

15-minute Facility Rating1 of a circuit (expressed in amperes).

**3.** Set transmission line relays so they do not operate at or below 115% of the maximum

theoretical power transfer capability (using a 90-degree angle between the sending-end and

receiving-end voltages and either reactance or complex impedance) of the circuit (expressed

in amperes) using one of the following to perform the power transfer calculation:

 An infinite source (zero source impedance) with a 1.00 per unit bus voltage at each end

of the line.

 An impedance at each end of the line, which reflects the actual system source impedance

with a 1.05 per unit voltage behind each source impedance.

**4.** Set transmission line relays on series compensated transmission lines so they do not operate

at or below the maximum power transfer capability of the line, determined as the greater of:

 115% of the highest emergency rating of the series capacitor.

 115% of the maximum power transfer capability of the circuit (expressed in amperes),

calculated in accordance with Requirement R1, criterion 3, using the full line inductive

reactance.

**5.** Set transmission line relays on weak source systems so they do not operate at or below 170%

of the maximum end-of-line three-phase fault magnitude (expressed in amperes).

**6.** Not used.

1 When a 15-minute rating has been calculated and published for use in real-time operations, the 15-minute rating

can be used to establish the loadability requirement for the protective relays.

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**7.** Set transmission line relays applied at the load center terminal, remote from generation

stations, so they do not operate at or below 115% of the maximum current flow from the load

to the generation source under any system configuration.

**8.** Set transmission line relays applied on the bulk system-end of transmission lines that serve

load remote to the system so they do not operate at or below 115% of the maximum current

flow from the system to the load under any system configuration.

**9.** Set transmission line relays applied on the load-end of transmission lines that serve load

remote to the bulk system so they do not operate at or below 115% of the maximum current

flow from the load to the system under any system configuration.

**10.** Set transformer fault protection relays and transmission line relays on transmission lines

terminated only with a transformer so that the relays do not operate at or below the greater of:

 150% of the applicable maximum transformer nameplate rating (expressed in amperes),

including the forced cooled ratings corresponding to all installed supplemental cooling

equipment.

 115% of the highest operator established emergency transformer rating.

**10.1** Set load-responsive transformer fault protection relays, if used, such that the

protection settings do not expose the transformer to a fault level and duration that

exceeds the transformer’s mechanical withstand capability2.

**11.** For transformer overload protection relays that do not comply with the loadability component

of Requirement R1, criterion 10 set the relays according to one of the following:

 Set the relays to allow the transformer to be operated at an overload level of at least

150% of the maximum applicable nameplate rating, or 115% of the highest operator

established emergency transformer rating, whichever is greater, for at least 15 minutes to

provide time for the operator to take controlled action to relieve the overload.

 Install supervision for the relays using either a top oil or simulated winding hot spot

temperature element set no less than 100° C for the top oil temperature or no less than

140° C for the winding hot spot temperature3.

**12.** When the desired transmission line capability is limited by the requirement to adequately

protect the transmission line, set the transmission line distance relays to a maximum of 125%

of the apparent impedance (at the impedance angle of the transmission line) subject to the

following constraints:

a. Set the maximum torque angle (MTA) to 90 degrees or the highest supported by the

manufacturer.

b. Evaluate the relay loadability in amperes at the relay trip point at 0.85 per unit voltage

and a power factor angle of 30 degrees.

c. Include a relay setting component of 87% of the current calculated in Requirement R1,

criterion 12 in the Facility Rating determination for the circuit.

2 As illustrated by the “dotted line” in IEEE C57.109-1993 - *IEEE Guide for Liquid-Immersed Transformer*

*Through-Fault-Current Duration,* Clause 4.4, Figure 4.

3 IEEE standard C57.91, Tables 7 and 8, specify that transformers are to be designed to withstand a winding hot spot

temperature of 180 degrees C, and Annex A cautions that bubble formation may occur above 140 degrees C.

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**13.** Where other situations present practical limitations on circuit capability, set the phase

protection relays so they do not operate at or below 115% of such limitations.

**R2.** Each Transmission Owner, Generator Owner, and Distribution Provider shall set its out-of-step

blocking elements to allow tripping of phase protective relays for faults that occur during the

loading conditions used to verify transmission line relay loadability per Requirement R1.

*[Violation Risk Factor: High] [Time Horizon: Long Term Planning]*

**R3.** Each Transmission Owner, Generator Owner, and Distribution Provider that uses a circuit

capability with the practical limitations described in Requirement R1, criterion 7, 8, 9, 12, or 13

shall use the calculated circuit capability as the Facility Rating of the circuit and shall obtain the

agreement of the Planning Coordinator, Transmission Operator, and Reliability Coordinator with

the calculated circuit capability. *[Violation Risk Factor: Medium] [Time Horizon: Long Term*

*Planning]*

**R4.** Each Transmission Owner, Generator Owner, and Distribution Provider that chooses to use

Requirement R1 criterion 2 as the basis for verifying transmission line relay loadability shall

provide its Planning Coordinator, Transmission Operator, and Reliability Coordinator with an

updated list of circuits associated with those transmission line relays at least once each calendar

year, with no more than 15 months between reports. *[Violation Risk Factor: Lower] [Time*

*Horizon: Long Term Planning]*

**R5.** Each Transmission Owner, Generator Owner, and Distribution Provider that sets transmission

line relays according to Requirement R1 criterion 12 shall provide an updated list of the circuits

associated with those relays to its Regional Entity at least once each calendar year, with no more

than 15 months between reports, to allow the ERO to compile a list of all circuits that have

protective relay settings that limit circuit capability. *[Violation Risk Factor: Lower] [Time*

*Horizon: Long Term Planning]*

**R6.** Each Planning Coordinator shall conduct an assessment at least once each calendar year, with no

more than 15 months between assessments, by applying the criteria in PRC-023-3, Attachment B

to determine the circuits in its Planning Coordinator area for which Transmission Owners,

Generator Owners, and Distribution Providers must comply with Requirements R1 through R5.

The Planning Coordinator shall: *[Violation Risk Factor: High] [Time Horizon: Long Term*

*Planning]*

**6.1** Maintain a list of circuits subject to PRC-023-3 per application of Attachment B, including

identification of the first calendar year in which any criterion in PRC-023-3, Attachment B

applies.

**6.2** Provide the list of circuits to all Regional Entities, Reliability Coordinators, Transmission

Owners, Generator Owners, and Distribution Providers within its Planning Coordinator area

within 30 calendar days of the establishment of the initial list and within 30 calendar days of

any changes to that list.

**C. Measures**

**M1.** Each Transmission Owner, Generator Owner, and Distribution Provider shall have evidence

such as spreadsheets or summaries of calculations to show that each of its transmission relays is

set according to one of the criteria in Requirement R1, criterion 1 through 13 and shall have

evidence such as coordination curves or summaries of calculations that show that relays set per

criterion 10 do not expose the transformer to fault levels and durations beyond those indicated

in the standard. (R1)

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**M2.** Each Transmission Owner, Generator Owner, and Distribution Provider shall have evidence

such as spreadsheets or summaries of calculations to show that each of its out-of-step blocking

elements is set to allow tripping of phase protective relays for faults that occur during the

loading conditions used to verify transmission line relay loadability per Requirement R1. (R2)

**M3.** Each Transmission Owner, Generator Owner, and Distribution Provider with transmission

relays set according to Requirement R1, criterion 7, 8, 9, 12, or 13 shall have evidence such as

Facility Rating spreadsheets or Facility Rating database to show that it used the calculated

circuit capability as the Facility Rating of the circuit and evidence such as dated

correspondence that the resulting Facility Rating was agreed to by its associated Planning

Coordinator, Transmission Operator, and Reliability Coordinator. (R3)

**M4.** Each Transmission Owner, Generator Owner, or Distribution Provider that sets transmission

line relays according to Requirement R1, criterion 2 shall have evidence such as dated

correspondence to show that it provided its Planning Coordinator, Transmission Operator, and

Reliability Coordinator with an updated list of circuits associated with those transmission line

relays within the required timeframe. The updated list may either be a full list, a list of

incremental changes to the previous list, or a statement that there are no changes to the previous

list. (R4)

**M5.** Each Transmission Owner, Generator Owner, or Distribution Provider that sets transmission

line relays according to Requirement R1, criterion 12 shall have evidence such as dated

correspondence that it provided an updated list of the circuits associated with those relays to its

Regional Entity within the required timeframe. The updated list may either be a full list, a list

of incremental changes to the previous list, or a statement that there are no changes to the

previous list. (R5)

**M6.** Each Planning Coordinator shall have evidence such as power flow results, calculation

summaries, or study reports that it used the criteria established within PRC-023-3, Attachment

B to determine the circuits in its Planning Coordinator area for which applicable entities must

comply with the standard as described in Requirement R6. The Planning Coordinator shall have

a dated list of such circuits and shall have evidence such as dated correspondence that it

provided the list to the Regional Entities, Reliability Coordinators, Transmission Owners,

Generator Owners, and Distribution Providers within its Planning Coordinator area within the

required timeframe. (R6)

**D. Compliance**

**1. Compliance Monitoring Process**

**1.1. Compliance Enforcement Authority**

As defined in the NERC Rules of Procedure, “Compliance Enforcement Authority” means

NERC or the Regional Entity in their respective roles of monitoring and enforcing

compliance with the NERC Reliability Standards.

**1.2. Data Retention**

The Transmission Owner, Generator Owner, Distribution Provider and Planning

Coordinator shall keep data or evidence to show compliance as identified below unless

directed by its Compliance Enforcement Authority to retain specific evidence for a longer

period of time as part of an investigation:

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The Transmission Owner, Generator Owner, and Distribution Provider shall each retain

documentation to demonstrate compliance with Requirements R1 through R5 for three

calendar years.

The Planning Coordinator shall retain documentation of the most recent review process

required in Requirement R6. The Planning Coordinator shall retain the most recent list of

circuits in its Planning Coordinator area for which applicable entities must comply with the

standard, as determined per Requirement R6.

If a Transmission Owner, Generator Owner, Distribution Provider, or Planning Coordinator

is found non-compliant, it shall keep information related to the non-compliance until found

compliant or for the time specified above, whichever is longer.

The Compliance Enforcement Authority shall keep the last audit record and all requested

and submitted subsequent audit records.

**1.3. Compliance Monitoring and Assessment Processes**

 Compliance Audit

 Self-Certification

 Spot Checking

 Compliance Violation Investigation

 Self-Reporting

 Complaint

**1.4. Additional Compliance Information**

None.

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**2. Violation Severity Levels:**

**Requirement Lower Moderate High Severe**

**R1** N/A N/A N/A

The responsible entity did not use

any one of the following criteria

(Requirement R1 criterion 1

through 13) for any specific circuit

terminal to prevent its phase

protective relay settings from

limiting transmission system

loadability while maintaining

reliable protection of the BES for

all fault conditions.

OR

The responsible entity did not

evaluate relay loadability at 0.85

per unit voltage and a power factor

angle of 30 degrees.

**R2** N/A N/A N/A

The responsible entity failed to

ensure that its out-of-step blocking

elements allowed tripping of phase

protective relays for faults that

occur during the loading

conditions used to verify

transmission line relay loadability

per Requirement R1.

**R3** N/A N/A N/A

The responsible entity that uses a

circuit capability with the practical

limitations described in

Requirement R1 criterion 7, 8, 9,

12, or 13 did not use the calculated

circuit capability as the Facility

Rating of the circuit.

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**Requirement Lower Moderate High Severe**

OR

The responsible entity did not

obtain the agreement of the

Planning Coordinator,

Transmission Operator, and

Reliability Coordinator with the

calculated circuit capability.

**R4** N/A N/A N/A

The responsible entity did not

provide its Planning Coordinator,

Transmission Operator, and

Reliability Coordinator with an

updated list of circuits that have

transmission line relays set

according to the criteria

established in Requirement R1

criterion 2 at least once each

calendar year, with no more than

15 months between reports.

**R5** N/A N/A N/A

The responsible entity did not

provide its Regional Entity, with

an updated list of circuits that have

transmission line relays set

according to the criteria

established in Requirement R1

criterion 12 at least once each

calendar year, with no more than

15 months between reports.

**R6** N/A

The Planning Coordinator used the

criteria established within

Attachment B to determine the

circuits in its Planning Coordinator

area for which applicable entities

must comply with the standard and

met parts 6.1 and 6.2, but more

The Planning Coordinator used the

criteria established within

Attachment B to determine the

circuits in its Planning Coordinator

area for which applicable entities

must comply with the standard and

met parts 6.1 and 6.2, but 24

The Planning Coordinator failed to

use the criteria established within

Attachment B to determine the

circuits in its Planning Coordinator

area for which applicable entities

must comply with the standard.

**Standard PRC-023-3 — Transmission Relay Loadability**

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**Requirement Lower Moderate High Severe**

than 15 months and less than 24

months lapsed between

assessments.

OR

The Planning Coordinator used the

criteria established within

Attachment B at least once each

calendar year, with no more than

15 months between assessments to

determine the circuits in its

Planning Coordinator area for

which applicable entities must

comply with the standard and met

6.1 and 6.2 but failed to include

the calendar year in which any

criterion in Attachment B first

applies.

OR

The Planning Coordinator used the

criteria established within

Attachment B at least once each

calendar year, with no more than

15 months between assessments to

determine the circuits in its

Planning Coordinator area for

which applicable entities must

comply with the standard and met

6.1 and 6.2 but provided the list of

circuits to the Reliability

Coordinators, Transmission

Owners, Generator Owners, and

Distribution Providers within its

Planning Coordinator area

between 31 days and 45 days after

the list was established or updated.

months or more lapsed between

assessments.

OR

The Planning Coordinator used the

criteria established within

Attachment B at least once each

calendar year, with no more than

15 months between assessments to

determine the circuits in its

Planning Coordinator area for

which applicable entities must

comply with the standard and met

6.1 and 6.2 but provided the list of

circuits to the Reliability

Coordinators, Transmission

Owners, Generator Owners, and

Distribution Providers within its

Planning Coordinator area

between 46 days and 60 days after

list was established or updated.

(part 6.2)

OR

The Planning Coordinator used the

criteria established within

Attachment B, at least once each

calendar year, with no more than

15 months between assessments to

determine the circuits in its

Planning Coordinator area for

which applicable entities must

comply with the standard but

failed to meet parts 6.1 and 6.2.

OR

The Planning Coordinator used the

criteria established within

Attachment B at least once each

calendar year, with no more than

15 months between assessments to

determine the circuits in its

Planning Coordinator area for

which applicable entities must

comply with the standard but

failed to maintain the list of

circuits determined according to

the process described in

Requirement R6. (part 6.1)

OR

The Planning Coordinator used the

criteria established within

Attachment B at least once each

calendar year, with no more than

15 months between assessments to

determine the circuits in its

Planning Coordinator area for

which applicable entities must

comply with the standard and met

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**Requirement Lower Moderate High Severe**

(part 6.2) 6.1 but failed to provide the list of

circuits to the Reliability

Coordinators, Transmission

Owners, Generator Owners, and

Distribution Providers within its

Planning Coordinator area or

provided the list more than 60 days

after the list was established or

updated. (part 6.2)

OR

The Planning Coordinator failed to

determine the circuits in its

Planning Coordinator area for

which applicable entities must

comply with the standard.

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**E. Regional Differences**

None.

**F. Supplemental Technical Reference Document**

**1.** The following document is an explanatory supplement to the standard. It provides the technical

rationale underlying the requirements in this standard. The reference document contains

methodology examples for illustration purposes it does not preclude other technically comparable

methodologies.

“Determination and Application of Practical Relaying Loadability Ratings,” Version 1.0, June

2008, prepared by the System Protection and Control Task Force of the NERC Planning

Committee, available at:

http://www.nerc.com/fileUploads/File/Standards/Relay\_Loadability\_Reference\_Doc\_Clean\_Fina

l\_2008July3.pdf

**Version History**

**Version Date Action Change**

**Tracking**

1 February 12,

2008

Approved by Board of Trustees New

1 March 19, 2008 Corrected typo in last sentence of Severe

VSL for Requirement 3 — “then” should be

“than.”

Errata

1 March 18, 2010 Approved by FERC

1 Filed for

approval April

19, 2010

Changed VRF for R3 from Medium to

High; changed VSLs for R1, R2, R3 to

binary Severe to comply with Order 733

Revision

2 March 10, 2011

approved by

Board of

Trustees

Revised to address initial set of directives

from Order 733

Revision (Project

2010-13)

2 March 15, 2012 FERC order issued approving PRC-023-2

(approval becomes effective May 7, 2012)

3 November 7,

2013

Adopted by NERC Board of Trustees Supplemental SAR

to Clarify

applicability for

consistency with

PRC-025-1 and

other minor

corrections.

**Standard PRC-023-3 — Transmission Relay Loadability**

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**PRC-023-3 — Attachment A**

**1.** This standard includes any protective functions which could trip with or without time delay, on load

current, including but not limited to:

**1.1.** Phase distance.

**1.2.** Out-of-step tripping.

**1.3.** Switch-on-to-fault.

**1.4.** Overcurrent relays.

**1.5.** Communications aided protection schemes including but not limited to:

**1.5.1** Permissive overreach transfer trip (POTT).

**1.5.2** Permissive under-reach transfer trip (PUTT).

**1.5.3** Directional comparison blocking (DCB).

**1.5.4** Directional comparison unblocking (DCUB).

**1.6.** Phase overcurrent supervisory elements (i.e., phase fault detectors) associated with currentbased,

communication-assisted schemes (i.e., pilot wire, phase comparison, and line current

differential) where the scheme is capable of tripping for loss of communications.

**2.** The following protection systems are excluded from requirements of this standard:

**2.1.** Relay elements that are only enabled when other relays or associated systems fail. For example:

 Overcurrent elements that are only enabled during loss of potential conditions.

 Elements that are only enabled during a loss of communications except as noted in section

1.6.

**2.2.** Protection systems intended for the detection of ground fault conditions.

**2.3.** Protection systems intended for protection during stable power swings.

**2.4.** Not used.

**2.5.** Relay elements used only for Special Protection Systems applied and approved in accordance

with NERC Reliability Standards PRC-012 through PRC-017 or their successors.

**2.6.** Protection systems that are designed only to respond in time periods which allow 15 minutes or

greater to respond to overload conditions.

**2.7.** Thermal emulation relays which are used in conjunction with dynamic Facility Ratings.

**2.8.** Relay elements associated with dc lines.

**2.9.** Relay elements associated with dc converter transformers.

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**PRC-023-3 — Attachment B**

**Circuits to Evaluate**

 Transmission lines operated at 100 kV to 200 kV and transformers with low voltage terminals

connected at 100 kV to 200 kV.

 Transmission lines operated below 100 kV and transformers with low voltage terminals

connected below 100 kV that are part of the Bulk Electric System.

**Criteria**

If any of the following criteria apply to a circuit, the applicable entity must comply with the standard for

that circuit.

**B1.** The circuit is a monitored Facility of a permanent flowgate in the Eastern Interconnection, a

major transfer path within the Western Interconnection as defined by the Regional Entity, or a

comparable monitored Facility in the Québec Interconnection, that has been included to address

reliability concerns for loading of that circuit, as confirmed by the applicable Planning

Coordinator.

**B2.** The circuit is a monitored Facility of an Interconnection Reliability Operating Limit (IROL),

where the IROL was determined in the planning horizon pursuant to FAC-010.

**B3.** The circuit forms a path (as agreed to by the Generator Operator and the transmission entity) to

supply off-site power to a nuclear plant as established in the Nuclear Plant Interface

Requirements (NPIRs) pursuant to NUC-001.

**B4.** The circuit is identified through the following sequence of power flow analyses4 performed by the

Planning Coordinator for the one-to-five-year planning horizon:

a. Simulate double contingency combinations selected by engineering judgment, without

manual system adjustments in between the two contingencies (reflects a situation where a

System Operator may not have time between the two contingencies to make appropriate

system adjustments).

b. For circuits operated between 100 kV and 200 kV evaluate the post-contingency loading, in

consultation with the Facility owner, against a threshold based on the Facility Rating assigned

for that circuit and used in the power flow case by the Planning Coordinator.

c. When more than one Facility Rating for that circuit is available in the power flow case, the

threshold for selection will be based on the Facility Rating for the loading duration nearest

four hours.

d. The threshold for selection of the circuit will vary based on the loading duration assumed in

the development of the Facility Rating.

4 Past analyses may be used to support the assessment if no material changes to the system have occurred since the

last assessment

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i. If the Facility Rating is based on a loading duration of up to and including four hours,

the circuit must comply with the standard if the loading exceeds 115% of the Facility

Rating.

ii. If the Facility Rating is based on a loading duration greater than four and up to and

including eight hours, the circuit must comply with the standard if the loading

exceeds 120% of the Facility Rating.

iii. If the Facility Rating is based on a loading duration of greater than eight hours, the

circuit must comply with the standard if the loading exceeds 130% of the Facility

Rating.

e. Radially operated circuits serving only load are excluded.

**B5.** The circuit is selected by the Planning Coordinator based on technical studies or assessments,

other than those specified in criteria B1 through B4, in consultation with the Facility owner.

**B6.** The circuit is mutually agreed upon for inclusion by the Planning Coordinator and the Facility

owner.