Alberta Reliability Standard
Transmission Relay Loadability
PRC-023-AB-6

A. Introduction

1. Title: Transmission Relay Loadability

2. Number: PRC-023-AB-6

3. Purpose: Protective relay settings must not limit transmission loadability; not interfere with the real-time operating personnel's 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 Entities:

4.1.1 the **legal owner** of a **transmission facility** with load-responsive phase **protection systems** as described in PRC-023-AB-6 – Attachment A, applied at the terminals of the circuits defined in 4.2.1 *(Circuits Subject to Requirements R1 – R5)*.

4.1.2 the **legal owner** of a **generating unit** and the **legal owner** of an **aggregated generating facility** with load-responsive phase **protection systems** as described in PRC-023-AB-6 – Attachment A, applied at the terminals of the circuits defined in 4.2.1 *(Circuits Subject to Requirements R1 – R5)*.

4.1.3 the **ISO**.

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 **system elements** that are part of a **radial circuit**, including generator step-up transformer(s) and lines, that connect to the **transmission system** that are used exclusively to export energy directly from a **generating unit** or **aggregated generating facility** that is part of the **bulk electric system**. **System elements** may also supply **generating unit** loads or **aggregated generating facility** loads.

4.2.1.2 Transmission lines operated at 100 kV to 200 kV selected by the **ISO** in accordance with Requirement R6.

4.2.1.3 Transmission lines operated below 100 kV that are part of the **bulk electric system** and selected by the **ISO** 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 **ISO** in accordance with Requirement R6.

4.2.1.6 Transformers with low voltage terminals connected below 100 kV that are part of the **bulk electric system** and selected by the **ISO** 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 **system elements** that are part of a **radial circuit**, including generator step-up transformer(s) and lines, that connect to the **transmission system** that are used exclusively to export energy directly from a **generating unit** or **aggregated generating facility** that is part of the **bulk electric system**. **System elements** may also supply **generating unit** loads or **aggregated generating facility** loads.

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 **bulk electric system**, except **system elements** that are part of a **radial circuit**, including generator step-up transformers and lines, that connect to the **transmission system** that are used exclusively to export energy directly from a **generating unit** or **aggregated generating facility** that is part of the **bulk electric system**. **System elements** may also supply **generating unit** loads or **aggregated generating facility** loads.

5. Effective Date: January 1, 2028.

B. Requirements and Measures

R1. Each **legal owner** of a **transmission facility**, **legal owner** of a **generating unit**, and **legal owner** of an **aggregated generating facility** must 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 **bulk electric system** for all **fault** conditions. Each **legal owner** of a **transmission facility**, **legal owner** of a **generating unit**, and **legal owner** of an **aggregated generating facility** must evaluate relay loadability at 0.85 per unit voltage and a **power factor** angle of 30 degrees. *[Alberta Risk Rating: 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 10-minute **facility rating**[1] 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

[1] When a 10-minute rating has been calculated and published for use in real-time operations, the 10-minute rating can be used to establish the loadability requirement for the protective relays.

voltages and either reactance or complex impedance) of the circuit (expressed in amperes) using one of the following to perform the power transfer calculation:

a. An infinite source (zero source impedance) with a 1.00 per unit bus voltage at each end of the line.

b. 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:

a. 115% of the highest **emergency rating** of the series capacitor.

b. 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. Reserved for future use.

7. Set transmission line relays applied at the load center terminal, remote from **generating unit** or **aggregated generating facility**, 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 electric 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 electric 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:

a. 150% of the applicable maximum transformer **equipment rating** (expressed in amperes), including the forced cooled ratings corresponding to all installed supplemental cooling equipment.

b. 115% of the highest operator established transformer **emergency 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 capability[2].

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:

a. Set the relays to allow the transformer to be operated at an overload level of at least 150% of the maximum applicable **equipment rating**, or 115% of the highest **operator** established transformer **emergency rating**, whichever is greater, for at least 30 minutes to provide time for the operator to take controlled action to relieve the overload.

[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.

b. 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 temperature[3].

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.

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.

M1. Each **legal owner** of a **transmission facility, legal owner** of a **generating unit**, and **legal owner** of an **aggregated generating facility** must 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 must 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.

R2. [Reserved for future use.]

M2. [Reserved for future use.]

R3. Each **legal owner** of a **transmission facility, legal owner** of a **generating unit**, and **legal owner** of an **aggregated generating facility** that uses a circuit capability with the practical limitations described in Requirement R1, criterion 7, 8, 9, 12, or 13 must use the calculated circuit capability as the **facility rating** of the circuit and must obtain the agreement of the **ISO** with the calculated circuit capability. *[Alberta Risk Rating: Medium] [Time Horizon: Long Term Planning]*

M3. Each **legal owner** of a **transmission facility, legal owner** of a **generating unit**, and **legal owner** of an **aggregated generating facility** with transmission relays set according to Requirement R1, criterion 7, 8, 9, 12, or 13 must 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 the **ISO**.

R4. Each **legal owner** of a **transmission facility, legal owner** of a **generating unit**, and **legal owner** of an **aggregated generating facility** that chooses to use Requirement R1 criterion 2 as the basis for verifying transmission line relay loadability must provide the **ISO** 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. *[Alberta Risk Rating: Lower] [Time Horizon: Long Term Planning]*

[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.

M4. Each **legal owner** of a **transmission facility, legal owner** of a **generating unit**, and **legal owner** of an **aggregated generating facility** that sets transmission line relays according to Requirement R1, criterion 2 must have evidence such as dated correspondence to show that it provided the **ISO** 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.

R5. Each **legal owner** of a **transmission facility, legal owner** of a **generating unit**, and **legal owner** of an **aggregated generating facility** that sets transmission line relays according to Requirement R1 criterion 12 must provide an updated list of the circuits associated with those relays to the **ISO** at least once each calendar year, with no more than 15 **months** between reports, to allow the **ISO** to compile a list of all circuits that have protective relay settings that limit circuit capability. *[Alberta Risk Rating*: *Lower]* [*Time Horizon: Long Term Planning]*.

M5. Each **legal owner** of a **transmission facility, legal owner** of a **generating unit**, and **legal owner** of an **aggregated generating facility** that sets transmission line relays according to Requirement R1, criterion 12 must have evidence such as dated correspondence that it provided an updated list of the circuits associated with those relays to the **ISO** 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.

R6. The **ISO** must conduct an assessment at least once each calendar year, with no more than 15 **months** between assessments, by applying the criteria in PRC-023-AB-6, Attachment B to determine the circuits in its planning area for which **legal owners** of a **transmission facility, legal owners** of a **generating unit**, and **legal owners** of an **aggregated generating facility** must comply with Requirements R1 through R5. The **ISO** must: *[Alberta Risk Rating: High] [Time Horizon: Long Term Planning]*

- **6.1** Maintain a list of circuits subject to PRC-023-AB-6 per application of Attachment B, including identification of the first calendar year in which any criterion in PRC-023-AB-6, Attachment B applies.
- **6.2** Provide the list of circuits to all **legal owners** of **transmission facilities, legal owners** of **generating units**, and **legal owners** of **aggregated generating facilities** within its planning area within 30 **days** of the establishment of the initial list and within 30 **days** of any changes to that list.

M6. The **ISO** must have evidence such as power flow results, calculation summaries, or study reports that it used the criteria established within PRC-023-AB-6, Attachment B to determine the circuits in its planning area for which applicable entities must comply with the standard as described in Requirement R6. The **ISO** must have a dated list of such circuits and must have evidence such as dated correspondence that it provided the list to **legal owners** of a **transmission facility, legal owners** of a **generating unit**, and **legal owners** of an **aggregated generating facility** within its area within the required timeframe.

C. Compliance

[Intentionally left blank.]

D. Regional Variances

None.

Alberta Reliability Standard
Transmission Relay Loadability
PRC-023-AB-6

E. Associated Documents

- AESO Information Document, #2012-004RS, *PRC-023 Transmission Protection Relay Loadability* and any amendments made from time to time.

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.

NERC Reliability Standard PRC-023-6 Technical Rationale.

Version History

Version	Effective Date	Description of Change
AB-6	2028-01-01	Revised based on the NERC PRC-023-6, as approved by FERC in Docket No. RD23-5-000.
AB-4	2020-07-01	Revised based on the NERC PRC-023-4, as approved by FERC in Docket No. RM15-13-000
AB-2	2014-04-01	Initial release.

Alberta Reliability Standard
Transmission Relay Loadability
PRC-023-AB-6

Attachment A

A1. This **reliability standard** includes any protective functions which could trip with or without time delay, on load current, including:

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:

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 current-based, communication-assisted schemes (i.e., pilot wire, phase comparison, and line current differential) where the scheme is capable of tripping for loss of communications.

A2. The following **protection systems** are excluded from requirements of this **reliability 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. [Reserved for future use.]

2.4. [Reserved for future use.]

2.5. Relay elements used only for **remedial action schemes**.

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.

Alberta Reliability Standard
Transmission Relay Loadability
PRC-023-AB-6

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 major transfer path within the **western interconnection** that has been included to address reliability concerns for loading of that circuit, as confirmed by the **ISO**.

B2. The circuit is selected by the **ISO** based on **planning assessments** of the **near-term transmission planning horizon** that identify instances of instability, **cascading**, or uncontrolled separation, that adversely impact the **reliability** of the **bulk electric system** for planning events.

B3. [Intentionally left blank]

B4. The circuit is identified through the following sequence of power flow analyses[4] performed by the **ISO** 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 real time operating personnel 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 **legal owner** of the facility, against a threshold based on the **facility rating** assigned for that circuit and used in the power flow case by the **ISO**.

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**.

   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

[4] Past analyses may be used to support the **planning assessment** if no material changes to the system have occurred since the last **planning assessment**.

must comply with the **reliability 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 **ISO** based on technical studies or assessments, other than those specified in criteria B1 through B4, in consultation with the **legal owner** of the facility.

B6. The circuit is mutually agreed upon for inclusion by the **ISO** and the **legal owner** of the facility.