AESO DISTRIBUTED ENERGY RESOURCES ROADMAP INTEGRATION PAPER

Distributed Energy Resources Primary Frequency Response Guideline

APRIL 2025

Contents

1. Introduction

As Alberta's power systems grow in complexity and scale, the generation mix and Alberta Interconnected Electric System (AIES) requirements are evolving along with the increased integration of distributed energy resources (DERs).

Challenges

- AIES frequency is prone to large disturbances (frequency deviation) due to its unique connection topology with the Western Electricity Coordinating Council (WECC).
- There is an emerging risk that the AIES may experience deviations due to over-frequency when it becomes an exporting system and is required to support connected large loads.
- The gradual displacement of traditional transmission-connected synchronous generators by inverter-based resources (IBRs) within both transmission and distribution networks has led to a notable reduction in synchronous inertia and **primary frequency response (PFR)** performance.

PFR represents a fundamental technical requirement necessary for ensuring the stability and reliability of power systems. This decline poses significant challenges to the operational resilience of Alberta's electric system.

Current State

- Transmission-connected resources, including IBRs, currently provide PFR through frequency-droop function to the AIES.
- Fast Frequency Response (FFR) services have been used since 2023 to enhance PFR capability during sudden supply losses.
- FFR is currently a service exclusively for under-frequency events.
- Distribution facility owners (DFOs) in Alberta currently do not require distributed energy resources (DERs) to enable frequency-droop function.
- Limited PFR is provided by machine-based DERs only through inertia response.

Opportunity

- PFR enhancement in the AIES by enabling frequency-droop function in DERs can theoretically decrease the required FFR capacity in under-frequency events and materially stabilize the system frequency in over-frequency events.
- As the AIES shifts toward exports to the Western Interconnection and anticipated large-load connections, the PFR from DERs could help stabilize the system frequency for over-frequency events resulting from the loss of exports or large loads.

The AESO believes it would be practical to share the responsibility for frequency response between transmission-connected resources and DERs. Enhancing PFR by enabling frequency-droop function in DERs is essential for supporting system frequency and maintaining the reliability of the AIES.

Guideline Overview

This *Distributed Energy Resources Primary Frequency Response Guideline* (Guideline) examines the PFR requirements outlined in the:

- Institute of Electrical and Electronic Engineers IEEE 1547-2018 – Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces (IEEE 1547-2018).
- Canadian Standards Association CSA C22.3 No 9:20 – Interconnection of distributed energy resources and electricity supply systems (CSA C22.3 No 9:20).

The AESO recommends IEEE 1547-2018 and CSA C22.3 NO 9:20 industry standards regarding PFR be referenced in each DFO's DER technical interconnection requirements for implementation.

This Guideline presents an overview of:

- Reliability challenges associated with increased penetration of DERs and IBRs into the AIES.
- The need and opportunity for DERs to provide PFR.
- Industry standards pertaining to the integration of DERs into the electric system.
- The AESO's rationale for recommending enabling frequency-droop function in DERs and the inclusion of IEEE 1547-2018 and CSA C22.3 No. 9:20 PFR requirements into DFO technical interconnection requirement documents.
- The applicability of this guideline and the recommended settings for implementation.

2. Background

In 2019, a Technical Performance Exploration Group (TPEG)[1] consisting of technical experts representing distribution and transmission facility owners from across Alberta was established to:

- Facilitate a common understanding of the overall impacts on the reliable operation and planning of the AIES due to DER integration.
- Develop consensus on the future state of DER technical performance.
- Propose recommendations to close any gaps identified between the current and desired future state of DER technical performance.
- Support the coordination of stakeholders' implementation of recommendations relating to the technical interconnection of DERs in Alberta.

The TPEG provided direction on the AESO's *Alberta Distributed Energy Resources Roadmap* (Roadmap), published in 2022, which outlines a future with greater integration of DERs and IBRs into the AIES. While the TPEG was disbanded in 2022 following the release of the Roadmap, the Roadmap continues to guide and support DER integration activities, including the development and publication of a series of documents called "AESO Roadmap Integration Papers":

- DERs Anti-Islanding Screening and Study Guideline [Updated: December 8, 2023]
- DERs Commissioning and Testing Recommendations [Posted: August 17, 2022]
- DERs Effective Grounding [Posted: March 31, 2022]
- DERs Ride-Through Performance Recommendations [Updated: June 2, 2022]

This Guideline is the latest addition to the series of AESO Roadmap Integration Papers. It provides an update on the AESO's preparation for a future state characterized by a higher penetration of DERs on the AIES and addresses the need for primary frequency response from DERs.

[1] The TPEG 2022 membership list is provided in **Error! Reference source not found.**.

3. State of DER Integration in Alberta

The following provides information on the current installed capacity of DERs in Alberta.

The total installed capacity of DERs in Alberta, as of October 2024, is 2,100 MW. This includes microgenerators (Microgen) and non-microgenerators (non-Microgen). Microgen constitutes 310 MW (17 per cent) of the total DER capacity, while non-Microgen makes up 1,790 MW (83 per cent). The Alberta Interconnected Load (AIL) as of 2024 is 7,697 MW (calculated at 90 percentile). This indicates that the DER's penetration in the AIES is considerably high.

Of the total DER capacity of 2,100 MW, 1,637 MW is from non-Microgen equal to or greater than 5 MW. This represents 77 per cent of the total DER capacity in Alberta. The following sections will concentrate on non-Microgen DERs.

3.1 Integration Level by Technology Type

Generally, there are two distinct categories of DERs in Alberta, based on their technology types, which present distinctive dynamic behaviours and fault response characteristics under abnormal system conditions:

i) Machine-based DERs, which comprise of synchronous and induction generators connected to a distribution system.

   – There are approximately 608 MW of machine-based DERs connected to the AIES as of October 2024, representing approximately 34 per cent of total current non-Microgen DER capacity.

ii) Inverter-based DERs, which include wind, solar and distribution-connected energy storage technology, are integrated into power systems through fast-acting power electronics with specific control schemes.

   – The installed capacity of inverter-based DERs connected to the AIES is about 1,182 MW as of October 2024, representing approximately 66 per cent of the total current non-Microgen DER capacity.

   – Of the inverter-based DERs, battery energy storage installed capacity is 180 MW as of October 2024.

The *AESO's 2024 Long-Term Outlook* (2024 LTO) shows that DER capacity in the AIES will continue to increase.

➡ ***The DER penetration increase in the AIES is faster than anticipated.***

3.2 State of Existing DFOs' DER Technical Interconnection Requirements in Alberta

Each DFO in Alberta establishes technical interconnection requirements for DERs in their service area to satisfy their individual distribution reliability criteria.

Tables 1 and 2 show the AESO's recommended frequency ride-through (FRT) and mandatory frequency tripping settings to be applied to DERs based on CSA C22.3 NO. 9.20 and IEEE 1547-2018, which are also contained in the AESO's DERs Ride-Through Performance Recommendations.

DFOs have adopted frequency ride-through functions and settings to DERs in the AIES as recommended by AESO's Integration Paper, DER Ride-Through Performance Recommendations.

TABLE 1: Frequency Ride-Through (FRT) Capability for DERs Connected to the AIES

Frequency range (Hz)	Minimum ride-through time(s) (design criteria)
f > 62.0	N/A
61.2 < f ≤ 62.0	299
58.8 < f ≤ 61.2	Infinite*
57.0 < f ≤ 58.8	299
f ≤ 57.0	N/A

** Applicable only for a per-unit ratio of voltage/frequency limit of V/f ≤ 1.1.*

TABLE 2: Mandatory Frequency Tripping Requirement for DERs Connected to the AIES

Trip function	Default settings	
	Frequency (Hz)	Clearing time(s)
OF2	62.0	0.16
OF1	61.2	300.0
UF1	58.5	300.0
UF2	56.5	0.16

Table 3 shows the AESO's recommended parameters for frequency-droop functions to be applied to inverter-based DERs based on IEEE Standard 1547-2018, which are also contained in the AESO's *DERs Ride-Through Performance Recommendations*. The AESO did not recommend machine-based DERs to adopt these parameters. However, it remained a consideration.

TABLE 3: Parameters of Frequency-Droop (Frequency/Power) for DERs

Parameter	Default settings
db_{OF}, db_{UF} (Hz)	0.036
k_{OF}, k_{UF}	0.05
$T_{response}$ (s)	5

4. The Need for DER Primary Frequency Response

The generation mix and the needs of the AIES are continually changing in conjunction with increased penetration of DERs.

The frequency of the AIES is prone to large disturbances (frequency deviations) due to its unique interconnection topology with the WECC. Discounting the availability of additional markets-related/operational measures to provide frequency support, at a high level, there are four scenarios that may potentially expose the AIES to large frequency deviations:

- Alternating Current (AC) interties tripping out of service under high import conditions
- Alternating Current (AC) interties tripping out of service under high export conditions
- Large generating unit tripping while the AIES is islanded
- Large load tripping while the AIES is islanded

PFR is a fundamental technical requirement in power systems that impacts the stability and reliability of the AIES. PFR primarily includes inertia response, frequency-droop response from generators, and FFR from ancillary service in the AIES. As more IBRs replace traditional transmission-connected synchronous generators in both transmission and distribution networks, PFR performance in Alberta's electric system continues to decline.

The AESO has observed poor system frequency response in real-time, leading to growing reliability concerns, as outlined in the *AESO 2023 Reliability Requirements Roadmap*. Presently, transmission-connected resources, including IBRs, have frequency-droop function enabled to provide PFR to the AIES. To address this issue further, the AESO introduced Fast Frequency Response (FFR) service in 2023 to enhance PFR capability within the AIES during sudden supply losses (under-frequency events). Currently, FFR is exclusively a service for under-frequency events. There is also an emerging risk that the AIES may experience over-frequency deviations when the AIES becomes an exporting system and when it is required to support the connection of large loads.

The frequency droop function installation recommendation for inverter-based DERs was laid out in the AESO's *DER Ride-Through Performance Recommendations*, updated on June 2, 2022. There was no recommendation on frequency-droop function for machine-based DERs.

Enabling frequency droop function of DERs can theoretically decrease the required FFR capacity in the under-frequency events and materially stabilize the system frequency in the over-frequency events.

The AESO is recommending that the DERs adopt and enable the frequency-droop functions to provide primary frequency response similar to transmission-connected resources. The frequency-droop response from the DERs can theoretically reduce the required volume of FFR in under-frequency events. The frequency-droop response may not be very effective for under-frequency events because most renewable energy based DERs operate at their maximum capacity, leaving no extra capacity to respond to under-frequency events. The most benefit of frequency-droop response from DERs is realized during over-frequency events. As the AIES shifts toward exports to the Western Interconnection and anticipated connected large loads, the frequency droop response from DERs will be very effective in stabilizing the system frequency from over-frequency events resulting from loss of exports or large loads.

5. Overview of Industry Standards

The following sections provide an overview of industry standards regarding the interconnection of DERs. PFR requirements are derived from these industry standards. Industry standards emphasize that DERs are expected to perform under both normal operating conditions and abnormal network conditions, where PFR service is required.

5.1 IEEE Standard 1547-2018 – Normal and Abnormal Operating Performance

IEEE Standard 1547-2018, published in April 2018:

- Compared to the previous 2003 version, this standard significantly enhances and expands the required levels of performance and functional capability for DERs connecting specifically to primary and secondary distribution systems.
  - These new capabilities align with the needs of the bulk power system[2] (BPS) and present opportunities for maintaining or improving BPS reliability with increasing DER penetration.
- Requires DERs to ride through abnormal operating conditions without tripping offline to enhance the recovery of the BPS to normal operation.

[2] As contemplated in IEEE Standard 1547-2018.

- This means that a DER shall[3] not trip offline when voltage or frequency is within the predefined ride-through zone.
- This provides three categories of increasing levels of disturbance ride-through (voltage ride-through [VRT] and frequency ride-through [FRT]) capability to ensure DERs do not negatively impact electric system performance when a fault has occurred. These categories—Category I, Category II and Category III—are defined[4] and explained[5] in the AESO's *DER Ride-Through Performance Recommendations*[6].

- Defines two separate normal operating performance categories (Category A and Category B) related to reactive power capability and voltage control.

5.2 CSA C22.3 No. 9:20 – Normal and Abnormal Operating Performance

CSA C22.3 No. 9:20, published in January 2020:

- Specifies the technical requirements for the connection of DERs and distribution systems up to voltage levels of 50 kV line-to-line at the point of common coupling.
- Requires that the distribution wires owner for a particular point of common coupling associated with the connection between a DER and the distribution system specify the applicable grade of DER system interconnection capability.
- Defines applicable grades of capability as "baseline" or "supplemental," based on the assessed level of DER penetration (i.e., baseline for "low" penetration levels, and supplemental for "high" penetration levels) and the type of DER technology (i.e., inverter-based, synchronous, or induction)—penetration level[7] is determined by the distribution wires owner:
  - The baseline grade is equivalent to "Category I," and the supplemental grade is equivalent to "Category II" defined in IEEE Standard 1547-2018, from the perspective of disturbance ride-through (FRT and VRT) performance requirements.
  - The baseline grade is equivalent to Category A, and the supplemental grade is equivalent to Category B defined in IEEE Standard 1547-2018, from the perspective of reactive power capability and voltage control.

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[3] For purposes of this AESO DER Roadmap Integration Paper, "shall" is used in the manner contemplated in the Industry Standards.
[4] IEEE Standard 1547-2018, at clause 1.4.
[5] Midcontinent Independent System Operator, MISO Guideline for IEEE, Std 1547-2018 Implementation, Recommendations on Requirements Impacting Transmission Systems (November 2019) [MISO Guideline].
[6] IEEE Standard 1547-2018 does not clearly define or prescribe levels of DER penetration.
[7] In CSA C22.3 No. 9:20, penetration level (e.g., high or low) indicates the total capacity of DERs connected to a specific feeder or section of a distribution system. The standard uses qualitative terms instead of numerical metrics, and the distribution wires owner defines the aggregate capacity for each section of its distribution system, which helps assess whether the DER penetration is considered high or low.

- Therefore, merged the grading of DERs in terms of reactive power capability and voltage control, and disturbance ride-through capability in IEEE Standard 1547-2018 into baseline or supplemental grades.

5.3 IEEE Standard 1547-2018 – Control Functions

Beyond their required performance under normal operating conditions, DERs are expected to withstand voltage and frequency variations during abnormal operating conditions in the bulk power system. While in the ride-through mode, certain DER control functions could be enabled to help restore the bulk power system back to normal operating conditions.

During abnormal operating conditions, one of the control functions outlined in the standard is frequency-droop (frequency-power), which borders on frequency response. When there are temporary disturbances in frequency that push system frequency outside of the adjustable deadband but still within the trip settings, the DER adjusts its active power output from the pre-disturbance levels, according to the droop.

According to the standard, the droop shall be adjusted between three per cent and seven per cent and set at five per cent, and the frequency dead-band shall be adjustable between zero and 100 mHz and set to 36 mHz.

The active power output shall be as defined by the following equation, until frequency returns to within the deadband:

$$P_{\square}(f) = \begin{Bmatrix} max\{Ppre - \dfrac{f-(60+dbOF)}{60 \times kOF}; Pmin\} & f > 60 + db_{OF} \\ min\{Ppre + \dfrac{(60-dbUF)-f}{60 \times kUF}; Pavl\} & f < 60 - db_{UF} \end{Bmatrix}$$

where

P(f) is the active power output in p.u. of the DER nameplate active power rating as a function of the disturbed system frequency in Hz

f is the disturbed frequency or applicable frequency in Hz

P_{avl} is the available active power in p.u. of the DER rating

P_{pre} is the pre-disturbance active power output, defined by the active power output at the point of time the frequency exceeds the deadband in p.u. of the DER rating

P_{min} is the minimum active power output due to DER prime mover constraints, in p.u. of the DER active power rating in kW

db_{OF} is the single-sided deadband value for high-frequency, in Hz

db_{UF} is the single-sided deadband value for low-frequency, in Hz

k_{OF} is the per-unit frequency change corresponding to 1 per-unit power output change (frequency droop) and is a constant droop for over-frequency events

k_{UF} is the per-unit frequency change corresponding to 1 per-unit power output change (frequency droop) and is a constant droop for under-frequency events

The standard requires that the DER response shall conform to the prioritization of DER responses specified in clause 4.7. This is ensured by testing the DERs to IEEE 1547.1-2020 – IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces (IEEE 1547.1-2020) "Test standard." The DER returns to its pre-disturbance operating mode after responding to the disturbance, which could be one of these mutually exclusive modes: constant power factor mode, voltage reactive power mode, active power reactive power mode, and constant reactive power mode.

5.4 CSA C22.3 No. 9:20 – Control Functions

CSA C22.3 No. 9:20 tailors the IEEE 1547-2018 in the control functions requirements for DER, except that it does not provide prioritization of DER responses. However, testing the DERs to industry-recommended standards IEEE 1547.1-2020 demonstrates compliance with the requirements of 4.7 (priority of responses) in IEEE 1547-2018.

6. Recommendation

Based on the review of the industry standards and the peculiar nature of AIES reliability challenges discussed throughout this document and the feedback received from DFOs, the AESO makes the following recommendations to all DFOs:

- The applicability of this guideline is to new DER equal to or larger than five MW with an In-Service Date later than December 31, 2025, and existing DER equal to or larger than five MW that applies for a project change later than December 31, 2025.
- Enable the frequency-droop function of applicable DERs.
- Apply Table 3 settings to frequency-droop function of applicable DERs including both machine-based DERs and inverter-based DERs.
- No active power headroom or foot room is required for frequency-droop response by DERs.
- Incorporate the recommended frequency-droop response requirements above into each DFO's technical interconnection requirements in reference to IEEE 1547-2018 and CSA C22.3 No. 9:20 industry standards.

The AESO also provides the following guidance to DFOs in the implementation of this guideline:

- The DFOs have the discretion to make exemptions from this recommendation for qualified DERs.
- DFOs have the option to include primary frequency response (including inertia response, frequency-droop response, and FFR response) impact assessments on the distribution networks, such as distribution voltage, among others, in their DER interconnection technical requirements.
- If a DFO includes PFR in their DER interconnection technical requirements, it is recommended that the DFO follow IEEE Standard 1547-2018, which demands that the DER response shall conform to the prioritization of DER responses specified in clause 4.7.
  - This is ensured by testing the DERs to IEEE 1547.1-2020 – IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces (IEEE 1547.1-2020) "Test standard" or other equivalent test standards such as UL1741SB.
- If a DFO enables a frequency-droop function for applicable DERs, the DFO is required to submit model updates to the AESO for the DERs per Section 503.21 of ISO Rules.

DFOs are in a crucial role in the implementation of this AESO guideline to improve the primary frequency response in the AIES.

Appendix A: Technical Performance Exploration Group Membership

Company
AESO
AltaLink
ATCO
City of Lethbridge
City of Medicine Hat
City of Red Deer
ENMAX Corporation
ENMAX Power
EPCOR
FortisAlberta

Note: The TPEG's scope of work excludes matters relating to policy and the regulatory framework in Alberta, the electricity market impact of DERs, and various other technical aspects related to DER integration and operation, including modelling, forecasting, and DER management systems (DERMS).

Appendix B: Revision History Table

Table 4 Revision History

Version	Release Date	Change Notes
V1	2025-04-30	Initial publication

Alberta Electric System Operator

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