AESO DER ROADMAP INTEGRATION PAPER

DER Ride-Through Performance Recommendations

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Introduction

As discussed in the *AESO Distributed Energy Resources (DER) Roadmap*[1], the growth of distributed energy resources (DERs) and their integration with the Alberta interconnected electric system (AIES) will drive significant changes for the AESO, distribution facility owners (DFOs), transmission facility owners (TFOs), market participants, and consumers in Alberta. As DER penetration continues to grow, the increasing complexity and scale of power systems in Alberta may present reliability challenges concerning AIES operations and coordination of planning between the distribution and transmission systems. A particular challenge concerns DER ride-through capability and ride-through performance.

DER frequency ride-through (FRT) and voltage ride-through (VRT) refer to the ability of DERs to withstand frequency and voltage disturbances within defined limits and continue operating according to predetermined specifications. Historically, the standards for FRT and VRT developed by the Institute of Electrical and Electronics Engineers (IEEE)[2] defined a relatively narrow normal operating range for frequency and voltage, beyond which DERs were required to trip. The requirements in these standards, which have historically been adopted by DFOs and DER manufacturers as distribution interconnection requirements, restricted DERs from riding through larger frequency-deviation and delayed voltage-recovery events. More recently, the increased level of DER penetration has given rise to concerns amongst electric system operators that large numbers of DERs could potentially trip in response to system disturbances, which could further deteriorate the performance of electric systems or potentially lead to unpredictable cascading events. With increasing amounts of DERs being added to the generation resource mix across North American electric systems, there is broad industry recognition that DER ride-through capability during abnormal operating conditions is an important interconnection requirement that should be reviewed and updated as needed to maintain system reliability during system disturbances.

Recently, the IEEE and Canadian Standards Association (CSA) have each published recommended standards for the interconnection of DERs, which: (i) contemplate new measures for DER-related FRT and VRT based on different scopes and electric system impacts[3]; and (ii) emphasize different levels of performance[4] depending on the level of DER penetration and type of DER technology ("industry standards"). The industry standards are not binding requirements unless adopted by an implementing agency (regulatory body, DFOs or TFOs). The voluntary nature of the industry standards has given rise to questions from Alberta's industry participants, particularly DFOs and TFOs, regarding which of the requirements set out in the industry standards should be selected and adopted for purposes of establishing DFOs' distribution system-level DER interconnection requirements in Alberta. This AESO DER Roadmap Integration Paper examines and recommends the adoption by DFOs of certain industry standards to ensure the continued reliability of the AIES. This paper sets out the AESO's recommendations only; should the AESO determine that AESO requirements are necessary in the future,

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[1] AESO Distributed Energy Resources (DER) Roadmap (June 2020), available on the AESO website

[2] IEEE Standard 1547-2003, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems

[3] The IEEE and CSA standards emphasize the impacts that DERs may have on the transmission system and distribution systems, respectively. See the section titled ***Overview of Industry Standards*** for further details.

[4] *I.e.*, "categories" or "grades", as further described in the section titled ***Overview of Industry Standards***.

these will be addressed through the applicable processes for developing ISO rules and Alberta reliability standards.

Background and Purpose

The AESO's legislative duties include directing the safe, reliable and economic operation of the AIES.[5] Given its central role in ensuring the reliability of the AIES, the AESO developed the *AESO DER Roadmap*, which is being advanced in collaboration with stakeholders, to explore and manage the challenges and opportunities associated with the transformation of the AIES.[6]

In July 2019, the AESO established the Technical Performance Exploration Group (TPEG)[7], consisting of technical experts from utilities across Alberta, including DFOs and TFOs, to exchange ideas, discuss DER-related topics, and proactively prepare for a future state with higher DER penetration and potentially rapid growth in DERs. The TPEG focuses on:

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

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).

This AESO DER Roadmap Integration Paper:

- provides an update to stakeholders, including DFOs, TFOs, DER owners, the Alberta Utilities Commission, and other interested parties, about the results of the TPEG's work;
- articulates the AESO's rationale for recommending the adoption of the relevant industry standards into DFOs' technical interconnection requirement documents; and
- sets out the AESO's recommended implementation approaches, developed in collaboration with the TPEG.

This document is also intended to assist interested parties in assessing the potential impacts that the AESO's recommendations may have on them, including current or planned projects, facilities, and services.

Overview of Industry Standards

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[5] Electric Utilities Act, section 17(h)

[6] AESO DER Roadmap, at PDF 5.

[7] The TPEG membership list is provided in Appendix A.

The following provides an overview of the industry standards regarding the interconnection of DERs.

IEEE Standard 1547-2018 - Performance Categories

IEEE Standard 1547-2018 – *Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces* (IEEE Standard 1547-2018) was published in April 2018. IEEE Standard 1547-2018 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”[8] (BPS) and present opportunities for maintaining or improving BPS reliability with increasing DERs penetration.

IEEE Standard 1547-2018 requires DERs to ride through abnormal operating conditions without tripping offline, with expanded mandatory tripping requirements to enhance the recovery of the BPS to normal operation. These expanded mandatory tripping requirements mean that a DER shall[9] not trip offline when voltage or frequency is within the predefined ride-through zone. IEEE Standard 1547-2018 provides three increasing levels (categories) of VRT and FRT capability to ensure DERs do not negatively impact electric system performance when a fault has occurred. These categories are defined[10] and explained[11] as follows:

Category I

Category I is based on essential BPS stability/reliability needs and reasonably attainable by all DER technologies that are in common usage today.

This is a level of compliance compatible with most—but not all—BPS needs, and therefore feasible for all DER technologies to achieve. However, Category I ride-through performance is not capable of achieving reliable operations under high levels of DER penetration[12]. Therefore, to avoid negatively impacting system reliability, only a limited number of DERs should be allowed under this category.

Category II

Category II covers all BPS stability/reliability needs and is coordinated with existing reliability standards to avoid tripping for a wider range of disturbances of concern to BPS stability.

Category II performance covers all BPS reliability needs and coordinates with the existing North American Electric Reliability Corporation Standard PRC-024-2 – *Generator Frequency and Voltage Protective Relay Settings*, developed to avoid adverse tripping of bulk system generators during system disturbances. Category II performance levels are attainable by inverter-based resources.

Category III

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

[9] For purposes of this AESO DER Roadmap Integration Paper, “shall” is used in the manner contemplated in the Industry Standards.

[10] IEEE Standard 1547-2018, at clause 1.4.

[11] Midcontinent Independent System Operator, MISO Guideline for IEEE, Std 1547-2018 Implementation, Recommendations on Requirements Impacting Transmission Systems (November 2019) [MISO Guideline].

[12] IEEE Standard 1547-2018 does not clearly define or prescribe levels of DER penetration.

Category III is based on both BPS stability/reliability and distribution system reliability/power quality needs and is coordinated with existing interconnection requirements for very high DER penetration.

Category III provides for the highest levels of disturbance ride-through capabilities, which are attainable by inverter-based resources where very high levels of DER penetration or high variability in output are expected, or where momentary cessation requirements are viewed as a desirable solution for coordinating with distribution system protection and safety. Category III provides for an enhanced level of robustness, where the operation of DERs under abnormal conditions is important to the reliable operation of the distribution system.

CSA C22.3 No. 9:20 – Performance Grades

CSA C22.3 No. 9:20, *Interconnection of distributed energy resources and electricity supply systems* (CSA C22.3 No. 9:20) was published in January 2020. CSA C22.3 No. 9:20 specifies the technical requirements for the interconnection of DERs and distribution systems up to voltage levels of 50 kV line-to-line at the point of common coupling. It is important to recognize that CSA C22.3 No. 9:20 does not address transmission system impacts or upgrades due to DER integration, however, these topics are fully contemplated in IEEE Standard 1547-2018.

CSA C22.3 No. 9:20 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. The applicable grades of capability are "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[13] is determined by the distribution wires owner. From the perspective of FRT and VRT performance requirements, the *baseline grade* defined in CSA is equivalent to "Category I" defined in IEEE Standard 1547-2018, and the *supplemental grade* defined in CSA is equivalent to the "Category II" defined in IEEE Standard 1547-2018. In CSA C22.3 No. 9:20, the default settings applicable to DERs for frequency tripping and ride-through and voltage tripping and ride-through are within the range of allowable settings defined in IEEE Standard 1547-2018, and *vice versa*.

State of DER Integration in Alberta

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

Integration Level by Technology Type

Understanding the types of DER technology and their current level of integration on the AIES is informative when determining appropriate technical capability standards and associated cost implications for market participants.

[13] In CSA C22.3 No. 9:20, "penetration level" (*e.g.*, "high" or "low") refers to the aggregate capacity of a DER connecting to a particular feeder or section of a distribution system. This CSA standard intentionally uses qualitative measures (*i.e.*, high/low DER penetration) instead of quantitative measures. Further, the distribution wires owner defines the aggregate capacity for each section of its distribution system, which in turn informs the assessment of whether the DER penetration level is either high or low.

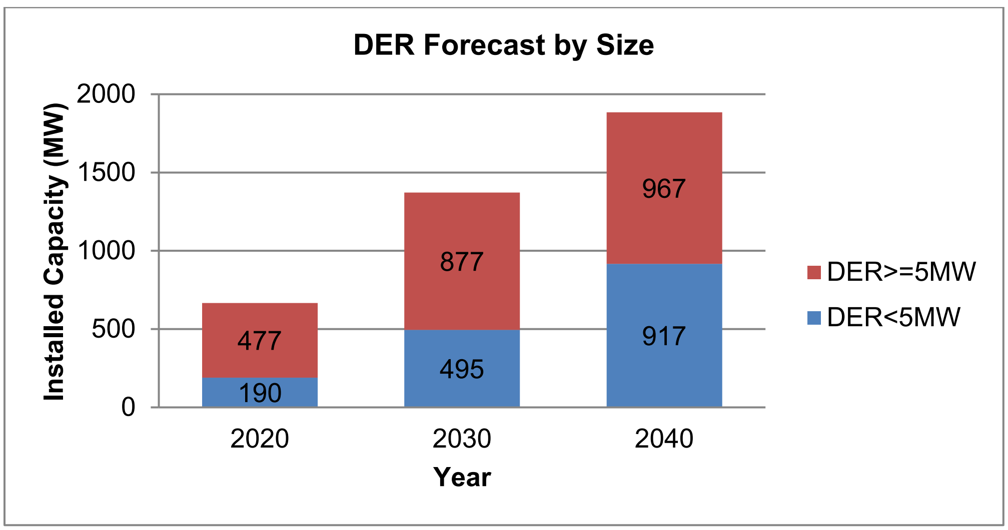
Generally, there are two distinct categories of DERs in Alberta, based on their technology types, which present distinctive dynamic behaviors and fault response characteristics under system abnormal conditions:

i) Machine-based DERs comprise synchronous and induction generators connected to a distribution system. The dynamic behavior of machine-based DERs is similar to conventional generating units. There is approximately 441 MW of machine-based DERs connected to the AIES as of January 2021, representing approximately 61% of total current DER capacity.

ii) Inverter-based DERs, which include distribution-connected energy storage technology, are integrated into power systems through fast-acting power electronics with specific control schemes. Inverters do not behave dynamically like synchronous or induction generators. The current installation capacity of inverter-based DERs connected to the AIES is about 283 MW, representing approximately 39% of the total current DER capacity.

Forecast data and DER projects in the AESO's Connection Project List provide additional information about the current and future state of DER integration in Alberta.

Figure 1: Forecast for DER Installed Capacity under Preliminary Results from the Reference Case in *AESO 2021 Long-term Outlook*



According to the preliminary results from the reference case in the *AESO 2021 Long-term Outlook* (LTO)[14], the total installed capacity of DERs (excluding biomass, gas cogeneration, hydro and other distribution-connected generation (DCG) types) will nearly triple the installed amount of year 2020 and reach 1,844 MW by year 2040. As shown in Figure 1, the integration of DERs equal to or greater than 5 MW is forecast to exceed the integration rate of DERs less than 5 MW initially; however, this initial difference is projected to diminish over time. The AESO's 2021 LTO preliminary results project that small-scale photovoltaic (PV) rooftop solar, an inverter-based resource in the under-5 MW category, will

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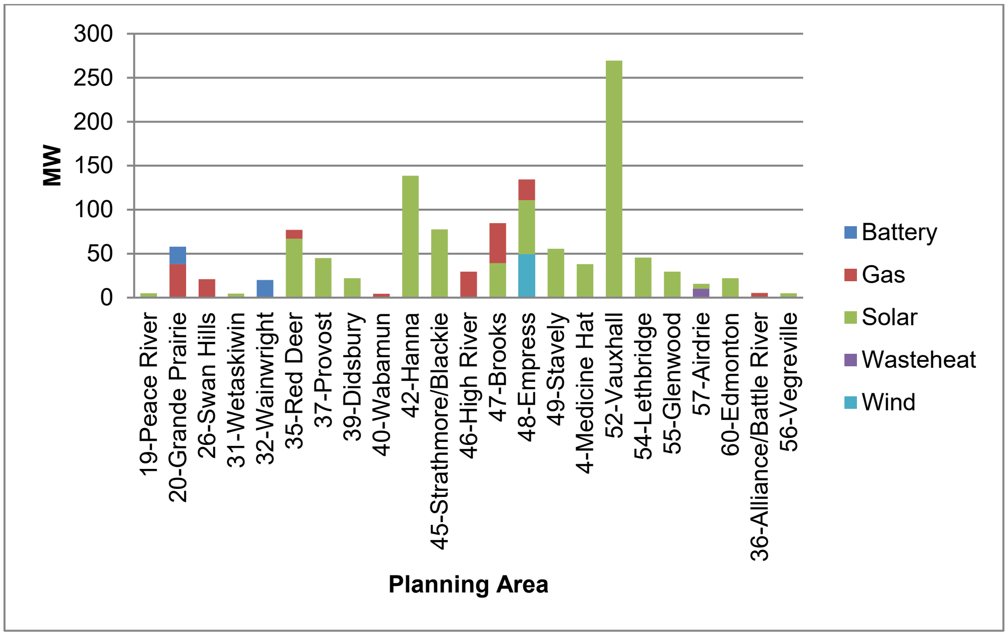
[14] Available on the AESO website at https://www.aeso.ca/assets/Uploads/Scenarios-Overview-for-Stakeholder-Insights-08Dec2021.pdf

increase significantly, reaching an installed capacity of 712 MW by 2040, and that gas DCG, a machine-based resource in the over-5 MW category, will reach to 531 MW by 2040.

The AESO Connection Project List[15] indicates that DER development across the AIES may not proceed uniformly, with different areas of the province potentially seeing differences in DER technology types and varying levels of DER integration. Solar PV projects constitute the predominant type of DER technology (for DERs equal to or greater than 5 MW) in the AESO Connection Project List. Figure 2 illustrates the installed capacity of DERs in Alberta organized by technology type and AESO planning area.[16]

Figure 2: DER Projects in AESO Connection Project List



Existing Technical Interconnection Requirements in Alberta

Each DFO in Alberta establishes technical interconnection requirements to satisfy their individual distribution reliability criteria. During Q1 2020, the TPEG identified that the majority of DFOs in Alberta do not have FRT or VRT requirements for DERs, and mandatory frequency and voltage tripping requirements vary greatly among the DFOs.[17]

The frequency of the AIES is prone to large disturbances due to its unique interconnection topology. At a high level, there are two scenarios that may potentially expose the AIES to large frequency deviations, not taking into account the availability of additional markets-related or operational measures to provide frequency support: i) AC interties tripping out-of-service under high import conditions; and ii) a large

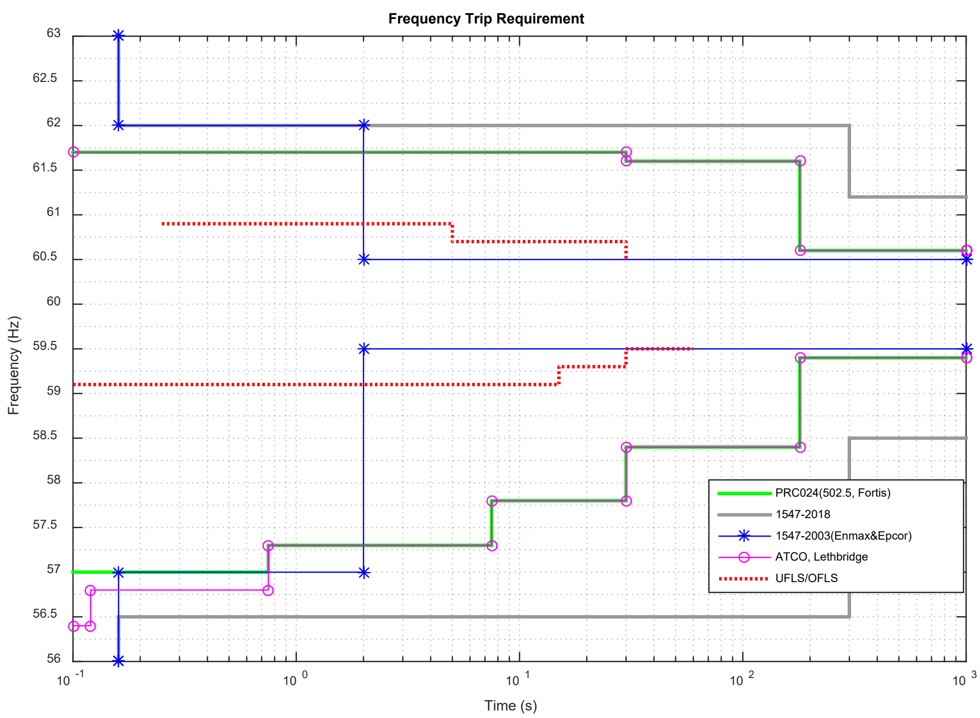
[15] Data revised based on April 2020 project list, available on the AESO website at https://www.aeso.ca/grid/projects/project-reports/

[16] Available on the AESO website at https://www.aeso.ca/grid/projects/project-reports/

[17] This reflects DFO data available to the AESO as at Q1 2020.

generating unit tripping while the AIES is islanded. It is important for DERs to ride through these frequency events and remain online to assist in recovering system frequency. Figure 3 illustrates the frequency tripping requirements currently used by DFOs in Alberta, compared with the requirements specified in IEEE Standard 1547-2018. The figure shows that the ranges for frequency trip currently adopted by Alberta DFOs are considerably narrower than the range required in IEEE Standard 1547-2018. Significantly, some DERs' under-frequency tripping thresholds (shown as a solid blue line in Figure 3) are based on IEEE Standard 1547-2003[18] and are less stringent than the settings of the system under-frequency load shed (UFLS) (shown as a dashed red line in Figure 3). UFLS is a critical safety net designed to avoid the risk of frequency collapse and stabilize the balance between generation and load following a transitory supply shortfall. This means that an extreme frequency event could result in DERs tripping before the UFLS program is activated, which could unexpectedly exacerbate the under-frequency condition.

Figure 3: Comparison of DER Frequency Tripping Requirements

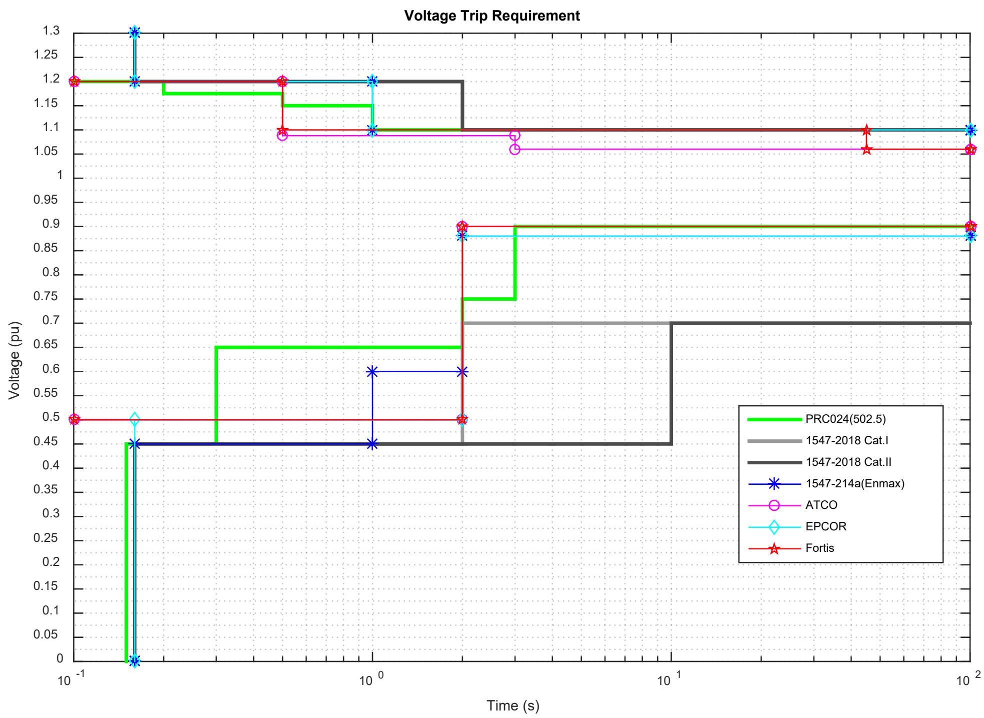


The DFOs' existing DER mandatory voltage-tripping requirements vary based on a number of factors, including different distribution protection relay settings and local voltage control schemes. Figure 4 shows the voltage tripping requirements for Alberta DFOs. For comparison purposes, Figure 4 also includes the requirements from Category I and Category II in IEEE Standard 1547-2018, and the voltage tripping

[18] The predecessor to IEEE Standard 1547-2018.

requirements that apply to transmission-connected generators as described in Section 502.5 of the ISO rules, *Generating Unit Technical Requirements.*

Figure 4: Comparison of DER Voltage Tripping Requirements



Jurisdictional Review

The AESO conducted a jurisdictional review to examine the current state of implementation of IEEE Standard 1547-2018 in different regions across North America. Several independent system operators (ISOs) and regional transmission organizations (RTOs) in Canada and the United States, with functionalities similar to the AESO, were selected for this jurisdictional review. ISOs and RTOs are responsible for managing the transmission grid in different geographic regions of the United States and these regions may encompass multiple states. Some ISOs and RTOs have issued guidelines and recommendations regarding the interconnection of DERs to the distribution system that may be superseded by a requirement established by some other relevant authority, referred to as an Authority Governing Interconnection Requirements (AGIR). IEEE Standard 1547-2018 introduces the concept of an AGIR and defines it as follows:

> **Authority Governing Interconnection Requirements (AGIR)**: A cognizant and responsible entity that defines, codifies, communicates, administers, and enforces the policies and procedures for allowing electrical interconnection of DER to the area Electric Power System (EPS). This may be a regulatory agency, public utility commission, municipality, cooperative board of directors, etc. The degree of AGIR

involvement will vary in scope of application and level of enforcement across jurisdictional boundaries. This authority may be delegated by the cognizant and responsible entity to the Area EPS operator or bulk power system operator.[19]

As part of the AESO's jurisdictional review, the AESO examined publicly available materials and engaged directly with various ISOs and RTOs. These findings are discussed below and a comparison of selected focus areas from each jurisdiction is outlined in Table 11 under Appendix B – *Jurisdictional Review Summary*. The AESO's findings are categorized as follows:

- Applicability of the requirement or guideline recommendation
- FRT performance requirement
- Frequency regulation - droop requirement
- VRT performance requirement
- Rate of change of frequency (ROCOF) ride-through performance
- Inertial response

Notably, the characteristics of the various jurisdictions' power systems may differ, and the penetration levels and growth rates vary substantially depending on the regions. Therefore, reliability needs may differ from region to region. The AESO's jurisdictional review provides a summary for information and reference purposes only; it is not exhaustive and is not determinative of the industry standards that should apply in Alberta.

IESO

Ontario's Independent Electricity System Operator (IESO) currently requires compliance with the Category III requirements for VRT set out in IEEE Standard 1547-2018. This is part of an interim requirement[20] for DERs that receive IESO support and plan to install new, inverter-based equipment. Frequency disturbance ride-through is required to be consistent with the off-nominal frequency curve in IESO Market Rules, Chapter 4, Appendix 4.2.2[21], which is less stringent than the requirement in IEEE Standard 1547-2018. It also requires that frequency-watt control be set to 4% droop and adjustable between 3% and 5% as part of the interim requirement. The interim requirement does not contemplate ROCOF and inertial response.

MISO

The Midcontinent Independent System Operator (MISO) does not have jurisdiction over the interconnection of DERs, which falls under the jurisdiction of the relevant distribution provider and, as applicable, the state public utility commission or electric cooperative governing board.[22] MISO has

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[19] IEEE Standard 1547-2018, available on the IEEE website at https://standards.ieee.org/standard/1547-2018.html

[20] The report of IESO Interim Requirements for the Application of IEEE 1547-2018, which can be obtained by contacting gridinnovationfund@ieso.ca. Detailed request information is available at https://www.ieso.ca/en/Get-Involved/Funding-Programs/Grid-Innovation-Fund/Open-Intake-Call-for-Proposals

[21] Available on the IESO website at http://www.ieso.ca/sector-participants/market-operations/-/media/304fbd51fad3492dad10bcc7c25ce34d.ashx

[22] The content in this subsection is informed by the MISO Guideline.

prepared a reliability guideline[23] for distribution-connected generation and storage resources. Adoption of the MISO guideline is encouraged and includes the following recommendations:

- For VRT performance, MISO's recommendations depend on the type of DER technology. For machine-based DERs, MISO strongly recommends performance capability consistent with Category I in IEEE Standard 1547-2018 as a minimum. For inverter-based DERs, MISO recommends performance capability consistent with Category III (with amended updates) or Category II in IEEE Standard 1547-2018.
- MISO strongly recommends that DERs of any type be capable of the unified frequency ride-through requirements specified in IEEE Standard 1547-2018, with no exceptions to these minimum requirements.
- MISO strongly recommends that inverter-based generation and energy storage assigned to abnormal Categories II or III use the default settings with no exceptions.
- MISO strongly recommends following the ROCOF ride-through performance in Clause 6.5.2.5 of IEEE Standard 1547-2018.
- MISO does not provide any recommendations for inertial response, more commonly known as a special form of fast frequency response.

ERCOT

On August 11, 2020, the Electric Reliability Council of Texas' (ERCOT's) Technical Advisory Committee (TAC) approved Nodal Operating Guide Revision Request (NOGRR) 212, related to the document NPRR1016, *Clarify Requirements for Distribution Generation Resources (DGRs) and Distribution Energy Storage Resources (DESRs)*[24]. This document establishes the multiple reliability requirements, including FRT and VRT requirements, applicable to DGRs and DESTs participating in the ERCOT market.

The FRT requirements are equivalent to those in IEEE Standard 1547-2018. The VRT requirements apply to DGRs utilizing either synchronous or inverter-based generators and are equivalent to Category I and Category III in IEEE Standard 1547-2018, respectively.

PJM

PJM Interconnection LLC (PJM) provides a ride-through guideline document[25] that is applicable only to DCG. DCG installed after January 1, 2022, should have the capability to ride through abnormal frequency and voltage events in accordance with Category II or Category III of IEEE Standard 1547-2018, as specified by the electric distribution company. However, an exception is available for generators utilizing technologies that are unable to satisfy the Category II or Category III performance criteria. These generators are required to satisfy the ride-through requirements specified by the electric distribution company. Inverter-based technology is capable of meeting Category II and Category III performance requirements. Generators that are designed and configured to effectively ride through abnormal low

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[23] MISO Guideline, available on the MISO website at https://cdn.misoenergy.org/MISO%20Guideline%20for%20IEEE%20Std%201547388042.pdf.

[24] Available on the ERCOT website at http://www.ercot.com/mktrules/issues/NOGRR212

[25] Available on the PJM website at https://www.pjm.com/-/media/planning/plan-standards/pjm-guideline-for-ride-through-performance.ashx?la=en

voltage conditions according to the voltages and durations indicated in the guideline document provide adequate ride-through for BPS stability and reliability needs in PJM.

ISO-NE

ISO New England Inc. (ISO-NE) is working with the Massachusetts Technical Standards Review Group (TSRG) on full implementation of IEEE Standard 1547-2018. A Source Requirement Document (SRD)[26] was developed as an interim solution for inverter-based solar PV projects. According to the SRD, all applicable inverter-based applications shall:

- be certified per the requirements of UL 1741 SA as a grid support utility interactive inverter
- have the voltage and frequency trip settings specified in the SRD
- have the abnormal performance capabilities (ride-through) specified in the SRD
- comply with other grid support utility interactive inverter functions statuses

CAISO

According to a report from California Distributed Generation Statistics, the California Public Utilities Commission (CPUC) has stated that there is 8,739 MW of DERs installed on the California grid.[27] California's Electric Tariff Rule 21 (Rule 21) is a tariff that describes the interconnection, operating and metering requirements that must be satisfied for generation facilities to be connected to a utility's distribution system.[28] The CPUC approved set of utility distributed generation interconnection requirements specifies advanced features for inverter-based DERs, which are expected to provide enhanced network support through a range of autonomous functions. Rule 21 governs all net energy metering facilities, "Non-Export" facilities, and qualifying facilities intending to sell power at avoided cost to the host utility. Rule 21 does not apply to the interconnection of generating or storage facilities intending to participate in wholesale markets overseen by the Federal Energy Regulatory Commission.[29] Notably, the Category III abnormal performance capability defined under IEEE standard 1547-2018 was developed based on Rule 21. In 2013, the CPUC created the Smart Inverter Working Group to develop a structured approach to mitigate the impact of increased DER penetration. The Smart Inverter Working Group is currently engaged in efforts to update Rule 21 to reflect the requirements in IEEE 1547-2018.

Criteria for Selection of Applicable Abnormal Performance Categories

Some DER technology types are unable to satisfy all of the ride-through capability requirements to support system reliability. Accordingly, the specifications for DERs in both the IEEE and CSA standards

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[26] Available on the ISO-NE website at https://www.iso-ne.com/static-assets/documents/2018/02/a2_implementation_of_revised_ieee_standard_1547_iso_source_document.pdf

[27] CPUC, Document No. 10007451-HOU-R-03-F, Customer Distributed Energy Resources Grid Integration Study, DER Grid Impacts Analysis, In Compliance with Public Utilities Code 913.6 (February 1, 2020)

[28] Available on the CPUC website at https://www.cpuc.ca.gov/General.aspx?id=3962

[29] Available on the CPUC website at https://www.cpuc.ca.gov/Rule21/

include performance capability categories (or grades) and ranges of allowable functional settings that provide flexibility in alignment with specific system needs. For purposes of assigning the applicable performance categories for abnormal operating conditions, the TEPG considered the recommended criteria from the industry standards as set out below.

IEEE Standard: Performance Category Selection

The following is an excerpt of questions recommended by IEEE Standard 1547-2018 to be taken into consideration when assigning performance categories to DER types:

- Is it impractical for the given DER type to be designed to meet Category II or III performance?
- Is there a societal benefit provided by the DER type that offsets the potential adverse impact on system security due to reduced capability?
- Is the projected penetration of all DER types allowed to interconnect with Category I performance relatively small compared to the total load level in the region?

> Bulk electrical system reliability impacts are related to the total amount of DER in a relatively large region, and penetration levels at individual distribution systems or circuits are not of particular relevance.

If the answer to each of the previous is 'yes,' then assignment of performance Category I to the particular DER type grouping is appropriate from the standpoint of *bulk power system* reliability. In all other cases, the AGIR should assign performance Category II or Category III, but may also consider the overall benefit to impact ratios.[30]

CSA Standard: Recommendation for Performance Grade Selection

The CSA standard summarizes the recommendations for performance grade selection, as shown in Table 1. The recommended performance grade is based on the level of DER penetration and the DER technology type at the particular point of common coupling corresponding to the interconnection between the DER and the distribution system.[31]

Table 1: Recommended Criteria from CSA standard[32]

DER type	Penetration level	Interconnection grade capabilities
Inverter interfaced generators, doubly fed induction generators and new technologies	Low	Baseline
	High	Supplemental
Synchronous generators	Any	Baseline
Induction generators	Any	Baseline

[30] IEEE Standard 1547-2018, B.4.3.3 Assignment of abnormal performance categories, at clause 6.

[31] CSA C22.3 No. 9:20 (7.2.3.1 Grades of DER system interconnection capabilities)

[32] CSA C22.3 NO. 9.20, Table 3 Recommended criteria to determine DER system interconnection grade capabilities

AESO Approach for Recommending Adoption of Industry Standards, and TPEG Feedback

Given the evaluation criteria recommended by the industry standards, the AESO and TPEG recognized the importance of establishing an approach for determining which industry standards to recommend for adoption in Alberta to ensure the continued safe, reliable and economic operation of the AIES. In addition to ensuring system reliability, the selection of relevant industry standards also considered reasonable options to facilitate cost-effective integration of DERs into the AIES, including recommending the application of lower categories of abnormal operating performance for certain DERs, as appropriate.

In collaboration with the TPEG, the AESO has developed, a criteria matrix, shown in Table 2, for purposes of assigning applicable categories of performance under abnormal operating conditions. Table 2 reflects both the AESO's assessment of key performance criteria for the AIES and findings from the AESO's jurisdictional review.

Table 2: Criteria for Selection of Applicable Performance Categories

Performance category selection criteria	DER technology type	
	Inverter-based	Machine-based
Technology type	Power electronic interfaced	Rotating machine: synchronous and induction generator
Current penetration (installed capacities)	Low penetration	Dominant technology
Expected future regional penetration (installed capacities)	Dominant technology with increasing integration rate. Varied regional penetration levels.	Not clear at this time. Forecast data will be available in 2021.
Technology limitations in compliance with Category II	Not expected, as DFOs require new inverter to be certified per the requirements of UL 1741 SA	No certification requirement in place. There are technical difficulties and potential compliance issues in compliance with Category II or III.
Benefit and cost if lowered to Category I	No further benefit identified by TPEG	There will be cost saving to DER customers identified by TPEG
Recommendation from IEEE standard	Category II or III	Category I
Recommendation from CSA standard	Supplemental Grade (equivalent to Category II)	Baseline Grade (equivalent to Category I)

Performance category selection criteria	DER technology type	
	Inverter-based	Machine-based
Jurisdictional Review	The majority of ISOs/RTOs listed in the jurisdictional review adopted or recommended the adoption of Category II or III	The majority of ISOs/RTOs listed in the jurisdictional review adopted or recommended the adoption of Category I; or to be specified by DFOs

In addition to applying the criteria in Table 2, the TPEG also held in-depth technical discussions and reached agreement on the following relevant considerations, representing areas that could potentially be impacted by new requirements for FRT and VRT in a variety of circumstances:

- **Local protection coordination**: DFOs and TFOs shall ensure the parameter settings at upstream protective devices be coordinated and match with the proposed DER ride-through and mandatory tripping requirements.
- **General reclosing coordination:** DFOs and TFOs shall ensure that upstream automatic reclosing onto a circuit that remains energized by a DER does not result in exposure to unacceptable stresses or disturbances due to differences in instantaneous voltage, phase angle, or frequency between the separated systems at the instant of the reclosure.
- **Risk of unintentional islanding with DERs that ride through disturbances:** The ride-through requirements shall not be falsely inhibited by any methods or design features utilized to detect unintentional islanding when an actual unintentional island condition does not exist.[33] Conversely, non-compliance with ride-through requirements shall not be justified by the false detection of an unintentional island that does not actually exist.[34,35]
- **Alignment with existing off-frequency requirement:** The DER FRT requirement shall be aligned with previously-specified off-frequency requirements. The frequency requirement in IEEE Standard 1547-2018 is more stringent than the existing requirement assigned for transmission connected generators[36], and transmission equipment (*e.g.*, HVDC and SVC). Enabling the recommended DER frequency requirement will enhance the ability of the AIES to withstand frequency volatility.

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[33] IEEE Standard 1547-2018, 6.1 Introduction, at clause 6.

[34] IEEE Standard 1547-2018, 8.1.1 Unintentional islanding General, at clause 8.

[35] Presently another TPEG work stream, "DER Anti-islanding Screening and Study Guideline", is engaged in a coordinated effort to examine a proposed screening method to identify the potential sustained islands of distribution or part of the transmission system before conducting a detailed study, to effectively reduce the risk of the interference between ride-through and anti-islanding.

[36] Division 502 of the ISO rules, *Technical Requirements*, available on the AESO website.

- **ROCOF ride-through:** Unexpected DER tripping due to ROCOF may impact reliable operation of the AIES, especially when the AIES experiences rapid frequency change, usually in the event of separation from the WECC or the loss of a large generating unit while the AIES is operating as an island. There are no mandatory requirements for ROCOF ride-through in Alberta. DFOs may set ROCOF as an alternative to a direct transfer trip (DTT), which would require the incurrence of costs. The DER facility may also set ROCOF as a passive method for islanding detection. It is recommended that the AESO work to ensure as much consistency as possible among Alberta's DFOs and TFOs in terms of establishing a coordinated ROCOF approach as one of the protection measures while not jeopardizing system reliability. The AESO plans in the future to perform ROCOF-related studies in conjunction with other studies pertaining to frequency-related products and technical requirements.

The following AESO recommendations regarding minimum ride-through capability, mandatory tripping requirements, and frequency regulation were proposed and accepted unanimously by TPEG. These recommendations were made through a comprehensive evaluation of the available information[37] and provide uniform technical minimum requirements and performance capabilities to reliably integrate DERs into the AIES.

AESO-recommended DER Response to Abnormal Voltage Conditions

The AESO recommends that inverter-based DERs incorporate default settings corresponding with the "supplemental grade" defined in CSA C22.3 NO. 9.20 as the minimum requirements for voltage tripping and VRT during abnormal voltage conditions, as described in Table 3 and Table 4. These CSA requirements are equivalent to the requirements assigned by IEEE Standard 1547-2018 Category II.

Table 3: Mandatory Voltage Tripping Requirements for Inverter-based DERs

	Default settings	
Trip function	Voltage (% of nominal voltage)	Clearing time (s)
OV2	120	0.16
OV1	110	2.0
UV1	88	10.0
UV2	45	0.16

[37] The AESO may revisit its proposed recommendations if new information becomes available in the future as the proliferation of DERs continues across North America.

Table 4: VRT Capability for Inverter-based DERs

Voltage range (% of nominal voltage)	Minimum ride-through time (s) (design criteria)	Maximum response time (s) (design criteria)	Response
V > 120	N/A*	0.16	Cease to energize
117.5 < V ≤ 120	0.2	N/A	Mandatory operation
115 < V ≤ 117.5	0.5	N/A	Mandatory operation
110 < V ≤ 115	1	N/A	Mandatory operation
88 ≤ V ≤ 110	Infinite	N/A	Continuous operation
65 ≤ V < 88	Linear slope of 8.7s/1p.u. voltage starting at 3s@0.65p.u.: $T_{VTR} = 3 + \frac{8.7s}{1\text{p.u.}}(V - 0.6.5p.u.)$	N/A	Mandatory operation
45 ≤ V < 65	0.32	N/A	Mandatory operation
30 ≤ V < 45	0.16	N/A	Mandatory operation
V < 30	N/A*	0.16	Cease to energize

** Cessation of current of DER in not more than the maximum specified time and with no intentional delay. This does not necessarily imply disconnection, isolation, or a trip of the DER.*

The AESO recommends that machine-based DERs incorporate default settings corresponding with the "baseline grade" defined in CSA C22.3 NO. 9.20 as the minimum requirements for voltage tripping and VRT during abnormal conditions, as described in Table 5 and Table 6. These CSA requirements are equivalent to the requirements assigned by IEEE Standard 1547-2018 Category I.

Table 5: Mandatory Voltage Tripping Requirements for Machine-based DERs

	Default settings	
Trip function	Voltage (% of nominal voltage)	Clearing time (s)
OV2	120	0.16
OV1	110	2.0
UV1	88	2.0
UV2	45	0.16

Table 6: VRT Capability for Machine-based DERs

Voltage range (% of nominal voltage)	Minimum ride-through time (s) (design criteria)	Maximum response time (s) (design criteria)	Response
V > 120	N/A*	0.16	Cease to energize
117.5 < V ≤ 120	0.2	N/A	Mandatory operation
115 < V ≤ 117.5	0.5	N/A	Mandatory operation
110 < V ≤ 115	1	N/A	Mandatory operation
88 ≤ V ≤ 110	Infinite	N/A	Continuous operation
70 ≤ V < 88	Linear slope of 4s/1p.u. voltage starting at 0.7s@0.7p.u.: $T_{VTR} = 0.7s + \frac{4s}{1\text{p.u.}}(V - 0.7p.u.)$	N/A	Mandatory operation
50 ≤ V < 70	0.16	N/A	Mandatory operation
V < 50	N/A*	0.16	Cease to energize

** Cessation of current of DER in not more than the maximum specified time and with no intentional delay. This does not necessarily imply disconnection, isolation, or a trip of the DER.*

AESO-recommended DER Response to Abnormal Frequency Conditions

The AESO recommends that all DERs on the AIES incorporate the uniform settings for mandatory frequency tripping and FRT from CSA C22.3 NO. 9.20 as the uniform requirement as described in Table 7 and Table 8, which are equivalent to the requirements in IEEE Standard 1547-2018.

Table 7: Mandatory frequency tripping requirement for DERs connected to AIES

	Default settings	
Trip function	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 8: FRT capability for DERs connected to 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.*

AESO-recommended DER Frequency Regulation Capability

The AESO recommends that inverter-based DERs shall have the functional capability to meet the frequency-droop (frequency/power) requirements defined in IEEE Standard 1547-2018, as described in Table 9. The AESO may, upon further assessment in the future, determine whether this function needs to be enabled.

Table 9: Parameters of Frequency-Droop (Frequency/Power) for Inverter-based DER

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

AESO's Proposed Implementation Approach for Alberta

The AESO recommends that the relevant industry standards, discussed throughout this document, be adopted and incorporated into each DFOs' technical interconnection agreements as soon as practicable, but no later than December 31 2021. The recommended industry standards discussed in the previous section provide clarity, predictability, and consistency for DER developers planning to integrate DERs into the AIES.

Further, the AESO recognizes that DER development across the AIES may not proceed uniformly, with different areas of the province potentially seeing differences in DER technology types and varying levels of DER integration. As a result, individual DFOs may choose to adopt, following prior consultation with the AESO, more stringent requirements than the AESO's recommended minimum industry standards for VRT and tripping, as appropriate for each DFO's local conditions. Doing so provides DFOs flexibility to manage DER-related requirements based on the local conditions within their respective service areas.

The AESO recommends that DFOs exempt existing DERs already connected to the AIES from complying with the recommended industry standards, given the expected cost associated with retrofitting the DERs to meet the relevant industry standards. However, the AESO recommends that DFOs require existing AIES-connected DERs that undergo modification (*e.g.*, replacing the protective relays, resizing, and equipment upgrades) to comply with the relevant industry standards.

The AESO recommends that DFOs apply the recommended industry standards to all new DER projects connected to the AIES on December 31, 2021 or by the time the DFOs' revised technical interconnection agreements are published, whichever occurs first.

For DER projects that are currently in the process of being interconnected, whether through the AESO Connection Process or the DFOs' respective interconnection processes, the AESO encourages DFOs to work with DER proponents to implement the relevant industry standards if practical to do so.

The AESO strongly recommends the implementation of the recommended industry standards as soon as possible in order to minimize the impacts that historical DER ride-through and trip settings may have on system performance following large disturbances, and to ensure that newly-connected DERs have the capability and appropriate settings to meet the functional specifications.

Other Recommendations under Consideration

The AESO will continue to lead the TPEG as it explores the need to recommend adoption of further requirements defined in IEEE 1547-2018 for purposes of maintaining system reliability.

In addition to the decisions relating to the assignment of performance capability categories for abnormal operating conditions, the specification of regional settings for any active power-related functions should be coordinated with the AESO. Such functions include frequency regulation (also referred to as frequency droop or frequency-watt), ROCOF ride-through, return-to-service after trip, and voltage support (*e.g.*, voltage-active power method). These functions and capabilities will limit unexpected or significant changes in output from DERs and reduce adverse impacts to system reliability that may otherwise occur due to the aggregate effect of increasing numbers of DERs. To prepare for higher DER penetration in the future and avoid unnecessary expensive retrofits, the AESO will assess whether to recommend that DFOs adopt requirements pertaining to these functions and capabilities, including the provision for adjustable settings. The AESO may, upon further assessment in the future and as conditions dictate, recommend that DFOs require these functions be enabled.

Appendix A: TPEG Membership

Table 10: Table of TPEG Members

TPEG Member
AESO
Altalink
ATCO
City of Lethbridge
City of Medicine Hat
City of Red Deer
ENMAX Power
EPCOR
FortisAlberta

Appendix B: Jurisdictional Review Summary

Table 11: Comparison of Implementing IEEE Standard 1547-2018 from ISOs/RTOs Survey

Jurisdiction	FRT Performance		Freq. Droop		VRT Performance		ROCOF - RT		Inertia response	Applicability/Notes
	IB DER*	MB DER	IB DER	MB DER	IB DER	MB DER	IB DER	MB DER	IB DER	
IESO	Market Rules (less stringent)	N/A	4% droop, adjustable [3% ,5%].	N/A	Cat. III	N/A	N/A	N/A	N/A	All IESO funded DER pilot projects (through the Grid Innovation Fund)
MISO	Cat. I, II and III	Cat. I, II and III	5% droop	N/A	Cat. III with amended or Cat. II	Cat. I	Yes Clause 6.5.2.5	Yes Clause 6.5.2.5	No	Guideline with recommendation
ERCOT	Cat. I, II and III	Cat. I, II and III	N/A	N/A	Cat. III Cat. II	Cat. I	No	No	N/A	Market participants complying with Nodal Operating Guide
PJM	Cat. I, II and III	Cat. I, II and III	N/A	N/A	Cat. II or Cat. III	Specified by DFOs	N/A	N/A	N/A	Guideline document
ISO-NE	ISO-SRD (Identical)	NPCC-PRC-006	Yes (not enabled)	No	Cat. II	No	No	No	No	Interim solution for solar PV projects
CA Rule 21	Cat. III	N/A	5%,	N/A	Cat. III	N/A	No	N/A	No	Facilities not participating in wholesale markets

***Note:** IB = inverter-based; MB = machine-based

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