GUIDE TO THE IEEE 1547-2018 STANDARD AND ITS IMPACTS ON COOPERATIVES

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NRECA
America's Electric Cooperatives

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This document is not sanctioned by, and does not carry the approval or endorsement of, the IEEE. The author does not represent the IEEE. A copy of IEEE 1547-2018 is available on IEEE's website at: https://standards.ieee.org/findstds/standard/1547-2018.html

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Scope of this Guide

In order to give cooperative engineers a starting point with the new IEEE 1547-2018 standard, NRECA commissioned the development of this "field guide." The intent of this guide is to:

1. Provide co-ops with a brief overview of the changes and new features of this standard compared to the original (both mandatory and optional).
2. Provide a guide to establishing settings for 1547-2018 compliant distributed energy resources (DERs) that most closely match those typically used in 1547-2003 compliant DERs (i.e., settings that most closely maintain a "business as usual" scenario).
3. Identify what settings or features are now mandatory and cannot be disabled.
4. Provide an idea of what the impact on a system may be if the new default settings are utilized.

This will not be an all-inclusive guide to, nor a replacement for, the standard, but instead it provides a means for assisting cooperatives in "getting off the ground" with 1547-2018 by relating it to the familiar 2003 standard.

Disclaimers

The information in this guide is intended to be a helpful and educational resource. ***This document is NOT intended to replace IEEE 1547-2018***. The information is not an exhaustive and complete examination of issues relating to IEEE 1547-2018. The guide contains information to help cooperatives understand the recent changes to IEEE standard 1547 and the potential implications for cooperatives. This document does not establish any requirements and is not a standard itself, and the reader must obtain a copy of 1547-2018 and rely on its wording and requirements for any interconnection policy decisions.

NRECA and the authors are not attempting to render specific legal or other professional advice in this guide. Electric cooperatives are: (1) independent entities; (2) governed by independent boards of directors; and (3) affected by different member, financial, legal, political, policy, operational, and other considerations. For these reasons, each electric cooperative should make its own business decisions on whether and how to use this information.

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1.0

Introduction

When IEEE 1547-2003 standard was written, distributed energy resources (DERs) were still relatively rare and sparsely deployed. They represented only a tiny fraction of the power generation capacity of the system then, so the effects of DERs were almost entirely local. As a result, the 2003 standard's philosophy centered largely around ensuring that DERs did not interfere with the normal operation of the distribution system's regulation and protection systems. By extension, this also meant that both worker and public safety were the top priority.

The 26-page 2003 standard had four main groups of requirements: General Requirements, Response to Abnormal System Conditions, Power Quality, and Islanding. Some of the requirements imposed by the 2003 standard were the following:

1. **Scope**[1]. The 2003 standard applied to DERs with an aggregate rating of 10 MVA or less, connected to distribution systems.

2. **Definitions**[2] Specifically:

    a. ***Electric Power System*** was abbreviated "EPS." The 2003 standard defines a **Local** EPS as an EPS contained entirely within a premise or group of premises, such as an industrial plant or commercial facility. An **Area** EPS is one that directly serves Local EPSs, generally understood to mean the distribution system. (The term "distribution" was avoided because that term had differing definitions for different system operators.) The 2003 standard did not specifically define any system above the Area EPS.

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[1] 2003 standard Clause 1, and particularly 1.3.

[2] 2003 standard Clause 3.1.

b. ***Cease to energize.*** The 2003 standard defined cease to energize as a cessation of energy outflow capability. It was silent on whether this implied open contacts or other electrical isolation, and did not *specifically* mention VAR flows.

c. ***Trip.*** The 2003 standard contains no definition for "trip," although the term is used in the standard in conjunction with under-frequency settings.

3. **Voltage Regulation**[3] DER was prohibited from regulating the voltage at their Point of Common Coupling (PCC). Traditionally, this has not been interpreted as disallowing fixed power factor control, because that mode is not voltage regulation *per se*.

4. **Response to Area EPS faults**[4] The 2003 standard required that a DER cease to energize the Area EPS if there is a fault on the circuit to which it is connected. The 2003 version did not specifically address open-phase conditions.

5. **Cease-to-Energize Pickup Thresholds and Clearing Times for Abnormal Voltages**[5] None of the thresholds or clearing times were adjustable (see the following table).

Voltage range (per unit of "base voltage"[6])	Clearing time (s)[7]
> 1.2	0.16
1.1-1.2	1
0.88-1.1	No requirement
0.5-0.88	2
< 0.5	0.16

6. **Pickups and Clearing Times for Abnormal Frequencies**[8] For small systems (<= 30 kW) both over- and under-frequency trip settings were very tight. For systems > 30 kW, there were two under-frequency trips allowed: one fixed at 57 Hz and tripping in 0.16 s, and the other adjustable over the ranges shown in the following table.

[3] 2003 standard, Clause 4.1.1.

[4] 2003 standard, Clause 4.2.1.

[5] 2003 standard, Table 1.

[6] The 2003 standard defined the "base voltages" according to the values listed in Table 1 of ANSI C84.1-1995.

[7] From Table 1 of IEEE 1547-2003. For DER rated at less than 30 kVA, the clearing times were to be interpreted as maximum clearing times. For larger systems, the clearing times given were default clearing times.

[8] 2003 standard, Table 2.

DER rating (kW)	Frequency range (Hz)	Clearing time(s)
≤ 30	> 60.5	0.16
	< 59.3	0.16
> 30	> 60.5	0.16
	< {57 – 59.8}	{0.16 – 300}
	< 57.0	0.16

In practice, the adjustable under-frequency trip was typically set to 0.16 s clearing time as well. The corresponding threshold was typically set to either 57 Hz (identical to the fixed under-frequency trip) or 59.3 Hz (identical to the settings for smaller systems). Higher under-frequency trips than 59.3 Hz were sometimes used for rotating DER. The 2003 standard also required that under-frequency trip[9] setpoints be coordinated with Area EPS operations.

7. **Power Quality** The 2003 standard provided basic power quality requirements by setting limits for DC current injection, harmonic current injection, and voltage flicker caused by the DER.

8. **Islanding** The 2003 standard covered only the prevention of unintentional islanding, and required that any island cease to be energized in either 2 s[10] or prior to the first reclose attempt by the Area EPS protection if it is shorter than 2 s[11].

9. **Communications** (called "monitoring")[12] Any DER unit larger than 250 kVA, or any aggregation of DER rated at more than 250 kVA at the PCC, was required to provide monitoring of the real and reactive power output of the DER, the voltage at the PCC, and the DER's connection status. The standard did not specify formats or protocols, nor to whom this information was to be provided.

[9] As noted earlier, this is the only place in the main-body text of the 2003 standard in which the term "trip" is used.

[10] 2003 standard, Clause 4.4.

[11] 2003 standard, Clause 4.2.2.

[12] 2003 standard, Clause 4.1.6.

2.0

A Stepping Stone: IEEE 1547A

The IEEE Standards Association and Standards Coordinating Committee 21[13] recognized in the early 2010s that a revision was needed to IEEE 1547-2003, but the DER deployment environment was changing much more quickly than the standards process could accommodate. Thus, as a stopgap measure, Amendment 1 to IEEE 1547-2003 was approved in May of 2014. The 1547A amendment allowed changes to the requirements in three sections of 1547-2003:

1. It removed the absolute prohibition on voltage regulation at the POI, and replaced it with an allowance for voltage regulation by a DER, if mutually approved by the DER and Area EPS operators.

2. It modified language in the section on Voltage and replaced the original table on over/under-voltage settings.

3. It also modified language in the section on Frequency and replaced the original table on over/under-frequency settings.

[13] IEEE SCC21 is the Standards Coordinating Committee on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage. It oversees the process of development of the IEEE 1547 family of standards, among others, and helps maintain coordination among standards development processes.

3.0

Major changes in IEEE 1547-2018

The 138-page IEEE 1547-2018 was developed in a very different DER deployment environment. Many are now seeing sufficient levels of DER deployed that the impacts on their systems are significant. As a result, the philosophy of the new standard is different as well: there is a pronounced shift toward ensuring Bulk Power System (BPS) dynamic and transient stability. Safety is still important, but it is now weighed against these other factors. Specifically, looking at the items described above from the 2003 standard:

1. **Scope** The 2018 standard still applies to DER connected to distribution, but the 10 MVA aggregate size limit has been removed.

2. **Definitions** Specifically:

   a. **Authority Governing Interconnect Requirements (AGIR):** The 2018 standard defines the AGIR as the agency that has authority for setting the requirements for interconnection to the Area EPS.

   b. The definitions for **EPS, Area EPS** and **Local EPS** are all essentially unchanged in the 2018 standard, but there is a new definition of the **Bulk EPS**, or BPS (Bulk Power System) which is essentially taken to be the transmission system and all generation connected to it.

   c. **Cease to Energize:** In the 2018 standard, the definition of "cease to energize" has been clarified with a note that "cease to energize" does **not** imply or require **open contacts** or other "air-gap" electrical isolation. This means that "cease to energize" can be achieved by any means that stops real power outflow from the DER, such as gate blocking in the case of an inverter, without opening any external breakers. Limitations have also been added with respect to reactive power flows that can take place while still meeting the definition of "cease to energize."

d. **Trip:** The 2018 standard does define "trip," but the definition may be different than some readers would intuitively expect because "trip" also does ***not necessarily*** imply any form of ***open contacts*** or other "air-gap" electrical isolation.

In the 2003 standard, after ceasing to energize, a DER was required to delay its return to service for up to five minutes. In the 2018 standard, a much faster return to service is allowed (and in some cases required). In some circumstances, however, the fast return to service is inhibited and that is what is defined as a "trip." With this definition, the term "trip" is always assumed to be preceded by a cease to energize — i.e., "cease to energize and trip."

3. **Voltage Regulation** The 2018 standard reverses the 2003 standard by requiring that all DERs have certain levels of voltage regulation capability.[14] DER is separated into two **Normal Operating Performance Categories**, designated A and B. DER in Category A shall have a set of voltage regulation capabilities that provide the minimum required level of Area EPS voltage regulation. DERs in Category B have an extended set of voltage capabilities designed to offset the impacts of high penetrations of DER, or DER with widely time-varying outputs.

   The standard defines a variety of voltage-regulating functions, such as volt-VAR and volt-watt functions, and requires that all DERs have the **capability** to perform these functions. **Use** and **settings** of these capabilities, however, is **at the discretion of the Area and/or BPS operators** (distribution co-ops or their generation and transmission company (G&T)) or the **AGIR**.

4. **Response to Area EPS faults**[15] The 2018 version discusses faults and open phases separately. For faults, the requirement is essentially the same as for the 2003 version, although the 2018 version adds specific language stating that a DER is not required to detect any fault that cannot be detected by the Area EPS protection.

   For open phases, the DER is required to detect an open phase at the "reference point of applicability" (typically either the PCC or the DER terminals, depending on the size of the system and other factors[16]) and cease to energize within 2 s. **There is no requirement in the standard that a DER be able to detect an open phase at any other location on the Area EPS.**

5. **Cease-to-Energize Pickup Thresholds and Clearing Times for Abnormal Voltages**[17] In order to keep DERs online during remote faults and other short-lived voltage excursions, in the 2018 standard, DERs can have much wider voltage cease-to-energize thresholds and longer clearing times than was allowed under the 2003 standard. DERs are separated into three A**bnormal Operating Performance Categories**, designated I, II and III:

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[14] 2018 standard, Clause 5.

[15] 2018 standard, Clause 6.2.

[16] For details on the definition of Reference Point of Applicability and how one determines where it is for a given system, see the 2018 standard, Clause 4.2.

[17] 2018 standard, Clause 6.4.

i. **Category I** is intended to meet minimum Bulk EPS reliability needs and to be achievable by all DER technologies, including rotating machines.

ii. **Category II** is designed to align with the requirements in NERC PRC-024-2[18].

iii. **Category III** is designed to meet the needs of low-inertia or highly-penetrated grids, and to align with California Rule 21[19], Hawaii Rule 14[20], and similar rules.

See the Appendix for details by the Abnormal Operating Performance Category.

In addition to differences in the allowable ranges of trip thresholds and times-to-trip, another major difference between the 2003 and 2018 standards is that the latter includes **mandatory operation** and **ride-through regions**. In the 2003 standard, there was no requirement that a DER operate at any voltage, so tripping was allowed at any voltage (i.e., if you wanted to ensure that a trip at 0.88 pu voltage occurred, you could set the voltage relay to 0.95 pu under the 2003 standard).

The 2018 standard specifically disallows voltage tripping within a continuous operating region.

It also requires DERs to ride through certain low-voltage conditions, with each Category having specific low-voltage ride-through (LVRT) requirements.

6. **Pickups and Clearing Times for Abnormal Frequencies**[21] Cease-to-energize thresholds and clearing times for abnormal frequencies are strongly impacted by the new standard's emphasis on Bulk EPS stability and reliability. They are much **wider and longer** than they were in the 2003 standard. As with voltage, there are new requirements that DERs ***not*** cease to energize in certain frequency ranges, but instead ride through a range of frequency excursions.[22] The frequency cease-to-energize thresholds, times, and ride-through requirements are the same for all three Categories.[23] In addition to the wider and longer cease-to-energize thresholds and times and the frequency ride-through requirements, the 2018 standard also imposes new **Rate of Change of Frequency (ROCOF)**[24] and **voltage phase angle change**[25] ride-through requirements.

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[18] See "Standard PRC-024-2, Generator Frequency and Voltage Protective Relay Settings", available at https://www.nerc.com/pa/Stand/Reliability%20Standards/PRC-024-2.pdf

[19] For more information, see http://www.cpuc.ca.gov/Rule21/.

[20] For more information, see https://www.hawaiianelectric.com/documents/billing_and_payment/rates/hawaiian_electric_rules/14.pdf.

[21] 2018 standard, Clause 6.5.

[22] 2018 standard, Clause 6.5.2.

[23] 2018 standard, Clause 6.5.2.3.1, Table 20. There is a small difference in the Category I requirement for active power output *capability* during a frequency deviation.

[24] 2018 standard, Clause 6.5.2.5.

[25] 2018 standard, Clause 6.5.2.6.

7. **Frequency Droop Functions**[26] The 2018 standard requires that DERs have the capability to increase output when frequency drops (if possible) and to decrease output when frequency increases in order to support the BPS. Frequency-droop operation is mandatory and default settings are included in the standard. Some adjustment is possible, but it is expected and recommended that the default values be used unless otherwise directed by the AGIR.

8. **Power quality**[27] In accordance with updates since 2003 to related standards such as IEEE 519 and 1453, the power quality requirements in 1547 have been updated, clarified, and expanded in the 2018 version. New guidance on interharmonic limits and on DER contributions to flicker and rapid voltage changes (RVCs) has been provided. The temporary overvoltage section is essentially similar to the 2003 requirements, but the transient overvoltage section is new and includes a transient overvoltage acceptance curve.[28]

9. **Islanding**[29]
   a. *Unintentional islanding.* The central requirement from the 2003 standard that unintentional islands be detected and de-energized within 2 s, or prior to the first reclose attempt by the Area EPS, is retained in the 2018 version. The method by which the DER may achieve this is not specified.
   b. *Intentional islanding.* The 2018 version includes an **all-new section on intentional islands.** The internal controls and dynamics of an intentional island are outside the scope of 1547, but the 2018 standard does establish limits on the impacts an intentional island can have on the Area EPS, and it also imposes requirements on DERs in an intentional island that includes Area EPS assets.

10. **Communications and Monitoring** The 2018 standard has a much higher emphasis on communications requirements and interoperability; in fact, “Interoperability” is now in the title of the standard. The standard sets required communication capabilities for the DER at its interface to the Area EPS communications network; the DER’s internal communications and the Area EPS communications network are both out of scope of 1547. The 2018 standard provides a basic information model, in that it lists parameters that the DER must be able to provide to the utility and the protocols the DER must be capable of supporting.

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[26] 2018 standard, Clause 6.5.2.7.

[27] 2018 standard, Clause 7.

[28] 2018 standard, Clause 7.4.2, Figure 3.

[29] 2018 standard, Clause 8.

4.0

Authority Governing Interconnection Requirements (AGIR)

One concept that was introduced in the 2018 standard is the concept of the **Authority Governing Interconnection Requirements** (AGIR). The AGIR is exactly what its name implies: it is the person or group that has the authority to set the interconnection requirements used in a particular system. For a co-op, at least some portion of this responsibility will likely rest with the cooperative's governing board, but the AGIR authority may be shared among more than one organization — for example, requirements for certain functions with particular impacts on BPS stability may be set by a G&T provider or an Independent System Operator (ISO), while local requirements could be set by an organization governing the local utility (the Area EPS).

Many of the functions of the AGIR are legal or policy-oriented in nature, and those considerations are outside of the scope of 1547 and this document. However, the standard does specifically delegate to the AGIR the decision regarding whether Categories A/B or Categories I/II/III will be required of DERs in a specific system. Annex B of the 2018 standard discusses this delegation, how it was envisioned by the writers of 1547 that the process would work, and the various technical considerations that should be factored in when making this determination.

In general, standards are not retroactive and there is no indication that this one will be. For contractual reasons, standards usually cannot be retroactive. Bear in mind, however, that the reason for many new requirements in this standard is security of the BES. If the NERC or AGIR feel that there is enough non-compliant legacy equipment in service that the stability or security of the system might be compromised, it is conceivable that they may require some level of compatibility with IEEE 1547-2018. Again, there is no indication at this time that this is under consideration.

5.0

Approximation of IEEE 1547-2003 Voltage and Frequency Relay Settings

This section discusses options that Area EPS operators have for setting voltage and frequency trip functions in a manner that is fully 1547-2018 compliant, but that also most closely approximates the values in 1547-2003.

Table 1 lists the pickup (threshold) settings for the over/under-voltage and over/under-frequency trip[30] functions. The 1547-2018 values in the table are within the ranges allowed by 1547-2018 and that most closely approximate the values set by 1547-2003.

Table 2 lists the clearing time values for the over/under-voltage and over/under-frequency trip functions. Again, the 1547-2018 values given are those that most closely match those from 1547-2003.

Note that the voltage thresholds in Table 1are identical all the way across; in other words, the voltage trip settings that were allowed in 1547-2003 are all still allowed in 1547-2018 for Categories I, II, and III. Further, the minimum allowed trip times for the under-voltage trip functions are longer only for Category III as shown in Table 2.

Table 1 and 2 are provided on the following page.

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[30] "Trip functions" is the term used for these functions in 1547-2018, even though the term "trip" has been defined only in terms of an inhibition of return to service.

Table 1. Voltage and Frequency Pickups (Thresholds):
Values from IEEE 1547-2003, and the Values from IEEE 1547-2018 that Most Closely Approximate Them

	2003	2018-I	2018-II	2018-III
Voltage thresholds				
OV2 (p.u.)	1.2	1.2‡	1.2‡	1.2‡
OV1 (p.u.)	1.1	1.1‡	1.1‡	1.1‡
UV1 (p.u.)	0.88	0.88	0.88	0.88‡
UV2 (p.u.)	0.5	0.5	0.5	0.5‡
Frequency thresholds				
OF2 (Hz)	n/a	61.8[31]	61.8	61.8
OF1 (Hz)	60.5	61	61	61
UF1 (Hz)	59.3	59	59	59
UF2 (Hz)	n/a	57	57	57

‡Denotes a default value

Table 2. Clearing Time Settings:
Values from IEEE 1547-2003, and the Values from IEEE 1547-2018 that Most Closely Approximate Them (all times given in seconds)

	2003	2018-I	2018-II	2018-III
Voltage clearing times (s)				
OV2	0.16	0.16‡	0.16‡	0.16‡
OV1	1	1	1	1
UV1	2	2‡	2	21
UV2	0.16	0.16‡	0.16‡	2‡
Frequency clearing times (s)				
OF2	n/a	0.16‡	0.16‡	0.16‡
OF1	0.16	180	180	180
UF1	0.16	180	180	180
UF2	n/a	0.16	0.16‡	0.16‡

‡Denotes a default value

For the frequency trip functions, the situation is significantly different. First, for most DER installations under 1547-2003, there was only one over-frequency and one under-frequency threshold. These thresholds were set fairly close to the nominal frequency value (i.e., “tight” frequency thresholds), and their maximum clearing times were 0.16 s, with many examples of DER units tripping more quickly than the maximum time as was allowed under the 2003 standard.

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[31] 2018 standard Table 18.

In 1547-2018, there are now two over-frequency and two under-frequency thresholds. In order to ensure that DERs do not compromise BPS stability by tripping prematurely, even the most restrictive frequency relay settings are far wider than they were under 1547-2003, and the corresponding clearing times are longer. The frequency trip function settings must also be coordinated with the frequency ride-through requirements,[32] meaning that there are now significant constraints on the ability to set the frequency trip functions with "tight" thresholds.

Also, as noted earlier, it is important to remember that under 1547-2018, the requirements for what a DER must do when it is *inside* the trip thresholds (i.e., not in a trip condition) have changed relative to the 2003 standard. In 1547-2003, there was no requirement to operate under any condition, meaning that a DER was allowed to cease to energize at any value inside the stated thresholds. If, for example, a system operator wanted to change the 59.3 Hz under-frequency setting to 59.9 Hz and reduce the time to trip from 0.16 s to zero, that was permitted under 1547-2003. That is no longer the case under 1547-2018, because there are mandatory regions of operation and minimum ride-through requirements.

Finally, it should also be noted that the 2018 standard includes new requirements that DERs ride through certain ranges of rate of change of frequency (ROCOF)[33] and for certain magnitudes of voltage phase angle changes.[34] These requirements have been set as they are in the standard to address bulk system stability concerns and cannot be changed, so they are not described further here. The frequency droop functions are also mandatory[35] and cannot be disabled. Some adjustment of this particular function is possible, but it is recommended that the default settings be used unless otherwise directed by the respective AGIR.

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[32] 2018 standard, Clause 6.5.2.

[33] 2018 standard, Clause 6.5.2.5.

[34] 2018 standard, Clause 6.5.2.6.

[35] 2018 standard; see Table 22, page 59.

6.0

Default Settings in IEEE 1547-2018

Some co-ops may wish to use the new default settings under the new standard, and in general a DER would be installed using the default values, unless the installer is instructed by the AGIR to do otherwise. Table 3 gives the **default "must-trip" values** for the over/undervoltage and over/underfrequency trip functions. Table 4 provides the clearing times corresponding to each of the thresholds in Table 3 (See the following page for Tables 3 and 4.) The overvoltage thresholds are the same for all three Categories in the 2018 standard as they were in the 2003 standard, but the clearing times are longer. For undervoltage, Category I changes are relatively small; the undervoltage thresholds are lower, but the clearing times are the same as they were in the 2003 standard. For Categories II and III, the clearing times are significantly longer than they were in the 2003 standard. For the frequency trip functions, the changes in default values from the 2003 to the 2018 version are much more significant and "permissive" in the sense that the DER is required to stay on for much longer.

As noted previously, DER are also required to ride-through ROCOF and voltage phase angle changes in order to support BPS stability. These ride-through functions cannot be disabled or field-adjusted. The frequency droop functions are also mandatory[36] and cannot be disabled. The AGIR may select parameter values for the droop function in such a way as to tailor its response, but in most cases, it is expected and recommended that the droop function default values[37] will be used as-is. With regard to the voltage functions described in Section 7 of this document,[38] by default, DER will be in the fixed power factor mode operating at unity power factor.

[36] 2018 standard; see Table 22, page 59.

[37] 2018 standard; see Table 24, page 60.

[38] Clause 5 of the 2018 standard.

Table 3. Default Values for Voltage and Frequency Trip Thresholds from 1547-2003, and for Categories I, II, and III in 1547-2018

	2003[39]	2018-I[40]	2018-II[41]	2018-III[42]
Voltage thresholds				
OV2 (p.u.)	1.2	1.2	1.2	1.2
OV1 (p.u.)	1.1	1.1	1.1	1.1
UV1 (p.u.)	0.88	0.7	0.7	0.88
UV2 (p.u.)	0.5	0.45	0.45	0.5
Frequency thresholds				
OF2 (Hz)	n/a	62	62	62
OF1 (Hz)	60.5	61	61	61
UF1 (Hz)	59.3	58.5	58.5	58.5
UF2 (Hz)	n/a	56.5	56.5	56.5

Table 4. Default Values for Voltage and Frequency Trip Functions from 1547-2003, and for Categories I, II and III in 1547-2018

	2003[39]	2018-I[40]	2018-II[41]	2018-III[42]
Voltage clearing times (s)				
OV2	0.16	0.16	0.16	0.16
OV1	1	2	2	13
UV1	2	2	10	21
UV2	0.16	0.16	0.16	2
Frequency clearing times (s)				
OF2	n/a	0.16	0.16	0.16
OF1	0.16	300	300	300
UF1	0.16	300	300	300
UF2	n/a	0.16	0.16	0.16

[39] 2003 standard, Table 1 (page 8) for voltage values and Table 2 (page 9) for frequency values.

[40] 2018 standard, Table 11 page 45.

[41] 2018 standard, Table 12 page 45.

[42] 2018 standard, Table 13 page 46.

7.0

Voltage and Frequency Regulation Functions

IEEE 1547-2018 requires that DERs have specified capabilities for voltage-dependent reactive power control[43] and voltage-dependent active (real) power control.[44] As noted in the previous section, the default setting will be for the DER to operate in the fixed power factor mode at unity power factor.

The requirements for these control functions, the specific mathematical functions that have to be implemented, and parameters and allowed ranges are all described in detail in Clause 5. It is important to understand that while all DER must have the ***capability*** to implement these functions, whether or not any of these functions are required to be ***activated*** in any specific deployment is up to the discretion of the Area EPS operator.

DERs can operate in a **watt-priority mode** or a **VAR-priority mode**. The difference between these two modes lies in how the DER responds when it reaches its output limits. At that point, the DER must curtail either its real or reactive power output to maintain within the device's limits. If the DER is in watt-priority mode, VAR output is curtailed; in VAR-priority mode, watt output is curtailed.

The volt-VAR function can be a more optimal way of correcting voltage problems on a circuit hosting DER, and is presently the subject of much research and discussion. With properly-selected parameter values, under volt-VAR control the DER can provide needed VAR support for either high or low voltages as needed, but still maintain maximum real power output when the voltage is near nominal.

The new standard also contains a requirement that DERs **adjust their real power** output **during frequency excursions** according to a frequency-power droop characteristic. This requirement is part of

[43] IEEE 1547-2018 clause 5.3.

[44] IEEE 1547-2018 clause 5.4.

the abnormal operating conditions requirements and is described in detail in Clause 6.5.2.7. That Clause specifies the mathematical function that is to be implemented and the ranges and default values of parameters, and Annex H provides graphical examples of the droop functions. Note that this function is not optional; it is **mandatory** and **cannot be turned off.** The AGIR may select parameter values for the function that tailor the response of this function to the needs of a particular system, but it is expected and recommended that in most cases the default values for the frequency droop function[45] will be used.

[45] 2018 standard; see Table 24, page 60.

APPENDIX

Summary Comparison of Voltage Setpoints for Abnormal Operating Conditions

Legend: Matches Pickup for Given Category; Matches Time for Given Category

Category I

Condition	Clause	1547-2003		Closest to 1547-2003		New Default	
Voltage Trip		Pickup	Time	Pickup	Time	Pickup	Time
OV2	6.4	1.2 p.u.	0.16 s	1.20 p.u.	0.16 s	1.20 p.u.	0.16 s
OV1	6.4	1.1 p.u.	1.00 s	1.10 p.u.	1.0 s	1.10 p.u.	2.0 s
UV1	6.4	0.88 p.u.	2.00 s	0.88 p.u.	2.0 s	0.70 p.u.	2.0 s
UV2	6.4	0.5 p.u.	0.16 s	0.50 p.u.	0.16 s	0.45 p.u.	0.16 s

Category II

Condition	Clause	1547-2003		Closest to 1547-2003		New Default	
Voltage Trip		Pickup	Time	Pickup	Time	Pickup	Time
OV2	6.4	1.2 p.u.	0.16 s	1.2 p.u.	0.16 s	1.2 p.u.	0.16 s
OV1	6.4	1.1 p.u.	1.00 s	1.1 p.u.	1.0 s	1.1 p.u.	2.0 s
UV1	6.4	0.88 p.u.	2.00 s	0.88 p.u.	2.0 s	0.7 p.u.	10.0 s
UV2	6.4	0.5 p.u.	0.16 s	0.5 p.u.	0.16 s	0.45 p.u.	0.16 s

Category III

Condition	Clause	1547-2003		Closest to 1547-2003		New Default	
Voltage Trip		Pickup	Time	Pickup	Time	Pickup	Time
OV2	6.4	1.2 p.u.	0.16 s	1.20 p.u.	0.16 s	1.20 p.u.	0.16 s
OV1	6.4	1.1 p.u.	1.00 s	1.10 p.u.	1.0 s	1.10 p.u.	13.0 s
UV1	6.4	0.88 p.u.	2.00 s	0.88 p.u.	21.0 s	0.88 p.u.	21.0 s
UV2	6.4	0.5 p.u.	0.16 s	0.50 p.u.	2.0 s	0.50 p.u.	2.0 s

Based on Tables 11, 12 & 13 of IEEE 1547-2018 for Voltage Disturbance Trip Requirements.

Summary Comparison of Frequency Setpoints for Abnormal Operating Conditions

Category I, II, and III

	Condition	Clause		1547-2003			Closest to 1547-2003			New Default	
Frequency Trip											
	OF2	6.5		n/a	n/a		61.8 Hz	0.16 s		62.0 Hz	0.16 s
	OF1	6.5		60.5	0.16 s		61.0 Hz	180.0 s		61.2 Hz	300.0 s
*	**UF1**	6.5		59.3	0.16 s		59.0 Hz	180.0 s		58.5 Hz	300.0 s
	UF2	6.5		n/a	n/a		57.0 Hz	0.16 s		56.5 Hz	0.16 s

Based on Table 18 of IEEE 1547-2018 for Frequency Disturbance Trip Requirements.
* IEEE 1547-2003 allowed adjustable frequency values down to 57.0 Hz for up to 300 s in systems >30 kW, but in practice the expanded range was rarely used.