HAWAIIAN ELECTRIC COMPANIES
GRID SUPPORT UTILITY-INTERACTIVE INVERTER STANDARDS
SOURCE REQUIREMENTS DOCUMENT
FOR CERTIFICATION WITH
UNDERWRITERS LABORATORIES 1741 SUPPLEMENT SA

Part I – General

Hawaiian Electric Companies'[1] Grid Support Utility-Interactive Inverter Standards set forth in either documents SRD-UL-1741-SA-V1.0, issued March 10, 2017 or SRD-UL-1741-SA-V1.1, updated September 26, 2017, shall serve as the Source Requirements Document[2] ("SRD") to be used with Underwriters Laboratories 1741 – Standard for Safety Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources, Supplement SA – Grid Support Utility-Interactive Inverters and Controllers ("UL 1741 Supplement SA") certification and sets forth the specific parameter settings to be used with the test methods of the UL 1741 Supplement SA.

This updated SRD-UL-1741-SA-V1.1 is intended to resolve any potential conflicts between the prior SRD-UL-1741-SA-V1.0, the Companies proposed revisions to Tariff Rule 14H, filed in Docket No. 2014-0192 – Instituting a Proceeding to Investigate Distributed Energy Resource Policies, and the pending update to the umbrella standard IEEE 1547.

The default settings provided herein are to be used for certification testing only. This SRD is not intended to provide the default settings and the functions to be activated for a Generating Facility interconnecting to the Company Electric Power System ("EPS"). Rule 14H shall be the controlling document for default function settings and activation states for a Generating Facility interconnecting with the Company EPS.

II.A. Definitions

For purposes of this SRD, the following terms and definitions apply. The Companies Rule 14H tariff should be consulted for terms not defined in this document.

1. Active Anti-Islanding Scheme - Equipment or control schemes installed with the Generating Facility that prevents the formation of an unintended island.

[1] Hawaiian Electric Company, Inc., Maui Electric Company, Limited, and Hawai'i Electric Light Company, Inc. are collectively referred to as the "Hawaiian Electric Companies" or "Companies".
[2] A Source Requirement Document or "SRD" is a document that includes the required operational functions and operating parameters, including limits and response times, for inverter testing. (See UL1741 SA, SA3.13)

2. Advanced Inverter (or Inverter) - Equivalent to "Grid Support Interactive Inverter" or "Grid Support Utility-Interactive Inverter" on the Unit Rating Label. (Referred to as "Advanced Inverter" in Rule 14H.)

3. Clearing Time - The time between the abnormal condition being applied and the Generating Facility ceasing to energize the utility distribution system.

4. Cease to Energize - Cessation of active current exchange related to the active power production of the Inverter with the EPS in not more than the maximum specified time. Cease to Energize does not imply galvanic separation or a Trip of the grid connected Utility-Interactive Inverter.

5. Continuous Operation - The Generating Facility operates indefinitely without tripping. Any functions that protect the Inverter from damage may operate as needed.

6. Converter – A device that accepts AC or DC power input and converts it to another form of AC or DC power. For purposes of this document and unless otherwise specified, AC output converters intended to directly supply power to loads are to be subjected to all of the requirements for Inverters.

7. Deadband - Signal domain interval or band where no action occurs.

8. Distribution System - All electrical wires, equipment, and other facilities at the distribution voltage levels (such as 25kV-HECO only, 12kV, or 4kV) owned or provided by the utility, through which the utility provides electrical service to its customers.

9. Electric Power System (EPS) - Equipment or facilities that deliver electric power to a load. The most common example of an EPS is the electric grid of the respective island utility (i.e. the utility's Distribution System, Subtransmission System, and/or Transmission System).

10. Emergency Conditions - Any situation that requires immediate action. Emergency conditions include, but are not limited to (a) system emergency or forced outage; (b) potential hazard to Company personnel or the general public; (c) hazardous condition relating to the Generating Facility; (d) generating facility interfering with the Company's equipment or equipment belonging to other customers (including non-utility generating equipment); (e) the Generating Facility's protective devices have been tampered with by the customer and/or owner and/or operator of the generating facility; or (f) there is a need for immediate action in response to a situation that has caused (or has the potential to cause) injury, loss of life or property damage. Pre-emergency conditions refer to the need for immediate action in response to a situation that has the potential to cause injury, loss of life, or property damage.

11. Generating Facility (or Generating Facilities) - Customer or utility-owned electrical power generation that is interconnected to the utility. This includes both generation and energy storage technologies.

12. Grid Support Utility-Interactive Inverter/Controller (GSUII) or Grid Support Utility Inverter/Controller (GSUI) - An Inverter or Converter intended for use in parallel with an electric utility that is a certified as a Utility Interactive inverter that is additionally evaluated for specific grid support functions different from those defined in IEEE 1547-2003 and IEEE 1547.1-2005. The Inverter may have utility specific interconnection settings that allow them to provide grid support functionality such as voltage and frequency regulation functions and voltage and frequency ride through as well as other mandatory and/or optional requirements and tests specified in UL 1741 Supplement SA and IEEE Std 1547.

13. Interconnection Facilities - The electrical wires, switches and related equipment that are required in addition to the facilities required to provide electric service to a customer to allow interconnection. Interconnection Facilities may be located on either side of the Point of Interconnection as appropriate to their purpose and design. Interconnection Facilities may be integral to a Generating Facility or provided separately.

14. Inverter System - A machine, device, or system that changes direct-current power to alternating-current power.

15. Mandatory Operation - The Inverter shall continue to import or export active current and exchange reactive current with Electric Power System as prescribed, notwithstanding disturbances of the Electric Power System voltage or frequency having magnitude and duration severity within defined limits.

16. Momentary Cessation - Temporarily Cease to Energize in response to an Electric Power System voltage or frequency disturbance, with the capability of immediate restore output of operation when the Electric Power System voltage and frequency return to within defined ranges.

17. Nameplate Rated Active Power - The maximum active power the inverter can provide continuously, depending on technical capability or control software settings.

18. Network System - An electrical system in which two or more utility feeder sources are electrically tied together on the primary or secondary voltage level to form one power source for one or more customers. The Network System is designed to provide higher reliability for customers connected to it.

19. Open Loop Response Time – See also, Response Time.

20. Point of Common Coupling (PCC) – See also, Point of Interconnection.

21. Parallel Operation - The operation of a distributed Generating Facility, while interconnected, such that customer load can be fed by the Generating Facility and Company system simultaneously.

22. Permissive Operation - In response to an abnormal excursion, the Generating Facility is allowed, but not required, to operate at any current level.

23. Point of Interconnection (POI) - The point at which the Utility or EPS and the customer interface occurs. Equivalent to Service Point as specified in the National Electric Code and the National Electric Safety Code.

24. P_predisturbance (P_{pre}) – Is the active power output level of the Inverter immediately prior to the disturbance, in p.u. of the Inverter rating.

25. P_rated (P_{rated}) – Is the rated active power, in p.u. of the Inverter rating (i.e., 1.0 p.u.).

26. Response Time - The time duration between a control signal input step change (reference value or system quantity) and the point in time when the output moves 90% of the way to its final value, (before any overshoot). For example, in volt-watt mode, the Response Time is the time from a change in voltage till the corresponding change in Inverter output power moves 90% of the way to the new value.

27. Return to Service – The criteria required for and behavior of the Inverter as it re-energizes the EPS following an abnormal excursion resulting in a Trip, Cease to Energize, or Momentary Cessation operation.

28. Ride-Through - The ability to withstand voltage or frequency excursions outside defined limits without tripping or malfunctioning. While the Inverter is in Ride-Through state, the SRD may require particular action such as Momentary Cessation or Mandatory Operation.

29. Rule 14H - Refers to the Hawaiian Electric Companies Tariff Rule 14, Paragraph H – Interconnection of Distributed Generating Facilities with the Company's Distribution System.

30. Settling Time – See also, Response Time.

31. Subtransmission System - All electrical wires, equipment, and other facilities at the sub-transmission voltage levels (such as 46kV, 35kV, or 23kV) owned or provided by the utility, through which the utility provides electrical service to its customers.

32. Transmission System - All electrical wires, equipment, and other facilities at the transmission voltage levels (such as 138kV or 69kV) owned or provided by the utility, through which the utility provides electrical service to its customers.

33. Trip - Cessation of energization or disconnection from the Transmission, Sub-transmission and Distribution System, without immediate return to service. Following a Trip, the Inverter must delay re-energizing until the EPS have returned to normal operating conditions for not less than the minimum specified time in the Return to Service criteria as defined by the SRD.

34. Unintended Islanding - Islanding is a condition in which one or more Generating Facilities deliver power to a utility customer or customers using a portion of the utility's Distribution System that is electrically isolated from the remainder of the utility's Distribution System in a manner that is not intended. Unintended Islanding may occur following an unanticipated loss of connection of a portion of the utility Distribution System.

35. Utility-grade Protective Equipment - Protective equipment that meets requirements defined by:
    a. ANSI/IEEE C37.90-1989 IEEE Standards for Relays and Relay Systems Associated with Electric Power Apparatus
    b. IEEE C37.90.1 IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems
    c. IEEE C37.90.2 IEEE Trial-Use Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers

36. Utility-Interactive Inverter - An Inverter or Inverter System intended for use in parallel with the electric utility grid to supply common loads, which may from time to time, deliver power to the electric utility. Equipment for general utility interactive applications is in compliance with the applicable parts of IEEE 1547-2003 and IEEE 1547.1-2005.

Part II. - Inverter Generating Facility Design And Operating Requirements

The Inverter shall not cause the service voltage at other customers Point of Common Coupling to go outside the requirements of ANSI C84.1-2016, Range A (IEEE 1547-4.1.1).

All Inverter(s) shall be allowed to be configured as specified by the Company using the other values specified in the adjustable ranges, as described herein. The characteristics are allowed to be adjusted remotely as specified by the Company in accordance with Rule 14H (Remote Configurability). Until such time that the Company establishes detailed technical requirements for Remote Configurability, the Inverter(s) are permitted to be activated/deactivated or change Inverter settings locally.

II.A Reactive Power Capabilities

The Inverter shall provide reactive power capability to actively and continuously operate based upon the kVA nameplate rating of the Inverter, not actual output. Reactive power must be continuously available per the following when active power is greater than or equal to the minimum steady state power capability, or 5% of rated active power, P_{rated}, (kW) of the Inverter, whichever is greater. For operation at active power output greater than or equal to 5% and less than 20% of rated active power, the Inverter shall be capable of exchanging reactive power which is linearly proportional to the active power from zero to the minimum reactive power value (kvar) provided in Table 1. Reactive power capability at active power output greater than or equal to 20% of active power nameplate rating shall be greater than or equal to the minimum reactive power value, and shall not constrain the delivery of reactive power up to the capability specified in Table 1. In other words, reactive power output shall be prioritized above active power output. The Inverter shall reduce active power output to provide the required reactive power when required:

Aggregate Generating Facility Size	Minimum Reactive Power Injection Capability as % of Nameplate Apparent Power (kVA) Rating	Minimum Reactive Power Absorption Capability as % of Nameplate Apparent Power (kVA) Rating
Greater than 15kW	53	53
Less than or equal to 15kW	44	44

Table 1: Minimum reactive power requirements by Generating Facility size

The Inverter may produce active power up to the kVA rating provided that the Inverter remains capable at all times to absorb or inject reactive power, to the full extent of the reactive power capability ranges defined above, as demanded by the reactive power control mode and corresponding settings established by the EPS operator.[3]

[3] The Inverter may need to reduce active power in order to meet the demanded reactive power in order to respect its apparent power limits.

Figure 1A and 1B below are illustrative of the operating range for less than or equal to 15kW Generating Facilities, and greater than 15kW Generating Facilities.

S_{rated} is the maximum apparent power the Inverter can provide continuously, P is the instantaneous active power output of the Inverter, and Q is the instantaneous reactive power output of the Inverter.

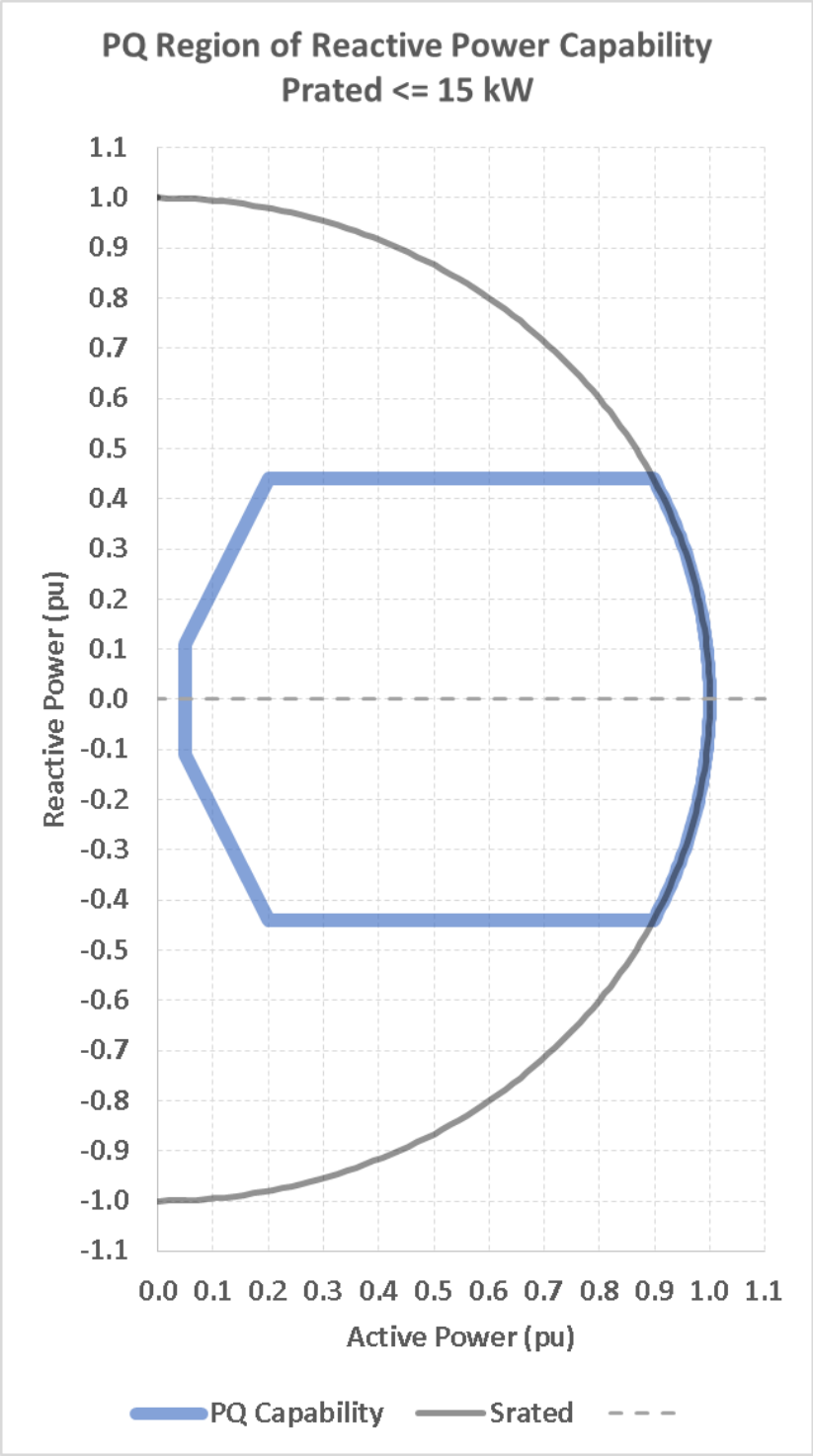

Figure 1A: Minimum reactive power operating range for Generating Facilities less than or equal to 15 kW

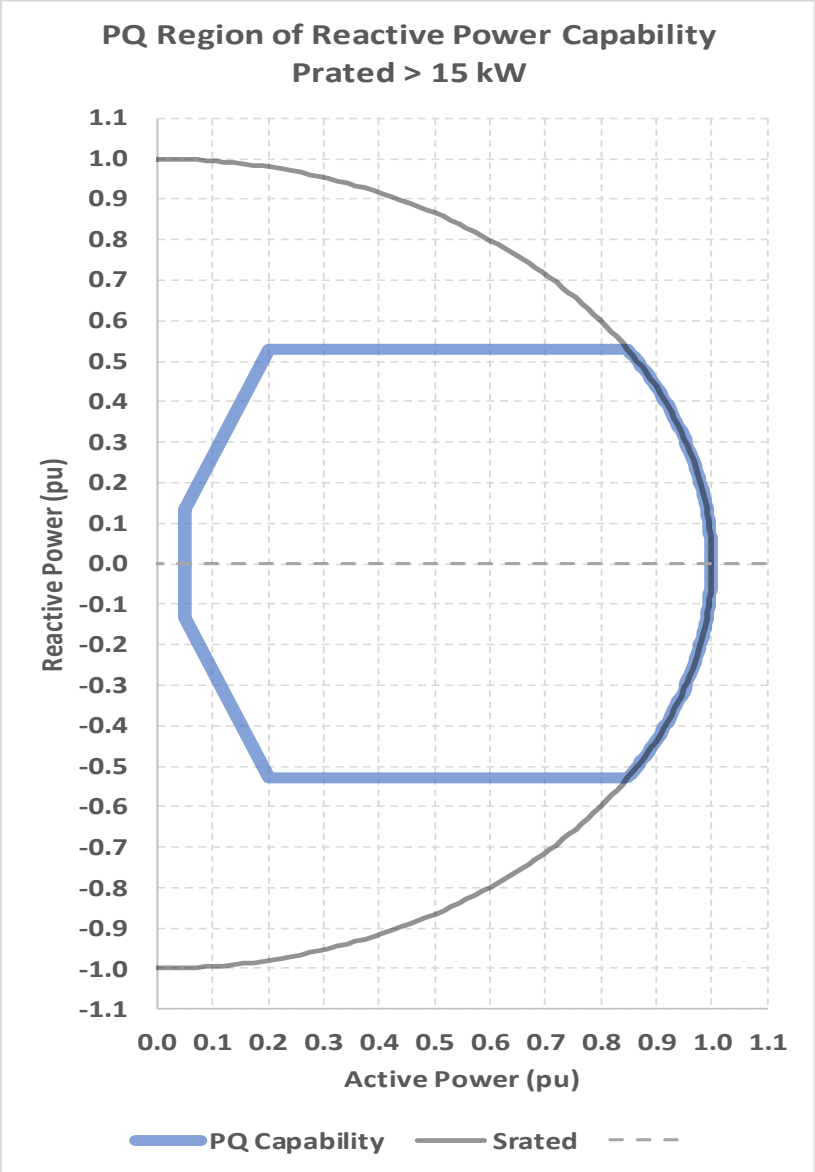

Figure 1B: Minimum reactive power operating range for Generating Facilities greater than 15 kW

Notes:
1. **Figure 1A and 1B does not illustrate four quadrant operation for energy storage systems.**
2. **Figure 1A and 1B illustration assumes $P_{rated} = 1.0 * S_{rated}$. It is possible for $P_{rated} \leq S_{rated}$.**

The Inverter shall have the capability of performing two different modes of reactive power functions:

1. Fixed Power Factor (FPF) mode with reactive power priority
2. Voltage-reactive power (VV) mode with reactive power priority

The reactive power functions, above, shall not be activated simultaneously; however, each shall be capable of being activated independently or in combination with Volt-Watt (VW) (See Section II.B).

II.A.1 Fixed Power Factor - Adjustable Constant Power Factor Mode (FPF) – UL1741 SA12

When operating in Fixed Power Factor (FPF) mode, and consistent with Section II.A (Reactive Power Capabilities), the Inverter shall operate at the default Power Factor setting at rated output or a Company specified power factor in accordance with the following requirements:

a. Default power factor setting: -0.95 absorbing (underexcited)

b. Aggregate Generating Facility is greater than 15 kW: Adjustable range 1.0 +/- 0.15 (0.85 absorbing (underexcited) to 0.85 injecting (overexcited) down to 20% rated power.

c. Aggregate Generating Facility is less than or equal to 15 kW: Adjustable range 1.0 +/- 0.10 (0.90 absorbing (underexcited) to 0.90 injecting(overexcited) down to 20% rated power.

d. The maximum Response Time to maintain constant power factor shall be 10 seconds or less with no intentional delay.

When in Fixed Power Factor (FPF) mode, the Inverter shall reduce active power if needed to maintain the specified power factor, i.e. power factor takes priority over active power production.

II.A.2 Volt-var (VV) – UL1741 SA13

When operating in this Volt-var (VV) mode, and consistent with Section II.A (Reactive Power Capabilities), the Inverter shall provide reactive power output as a function of voltage as an illustrative example in Figure 2 and the default values in Table 2.[4] The Inverter shall have minimum and maximum adjustable ranges per Table 2.

Volt-var Parameters	**Default Value**	**Minimum Adjustable Range**	**Maximum Adjustable Range**
V_{Ref}	Nominal Voltage (V_N) (e.g. 120 volts)	0.95 of V_N	1.05 of V_N
V_2	V_{Ref} – 0.03 of V_N	V_{Ref} – 0.03 of V_N	V_{Ref}
Q_2	0	100% of nameplate reactive power capability, absorption(1)	100% of nameplate reactive power capability, injection(1)
V_3	V_{Ref} + 0.03 of V_N	V_{Ref}	V_{Ref} + 0.03 of V_N
Q_3	0	100% of nameplate reactive power capability, absorption(1)	100% of nameplate reactive power capability, injection(1)
V_1	V_{Ref} – 0.06 of V_N	0.82 of V_N	V2 – 0.02 of V_N
Q_1	44% of nameplate apparent power	0	100% of nameplate reactive capability, injection(1)
V_4	V_{Ref} + 0.06 of V_N	V_3 + 0.02 of V_N	1.18 of V_N
Q_4	44% of nameplate apparent power	100% of nameplate reactive capability, absorption(1)	0
Response Time	10 seconds	1 second	90 seconds

[4] Note: An adjustable or non-adjustable Response Time implementation may be used until the publication by IEEE of the related Voltage-reactive power (Volt-var) modifications to P1547, or upon mutual agreement between the Customer-Generator and the Company.

(1) Reactive capability adjustable range for the Volt-var (VV) function must minimally meet the requirements in Section II.A (Reactive Power Capabilities). Adjustable Ranges may optionally be up to the stated capability.

Table 2: Volt-var (VV) ranges of adjustability and default settings

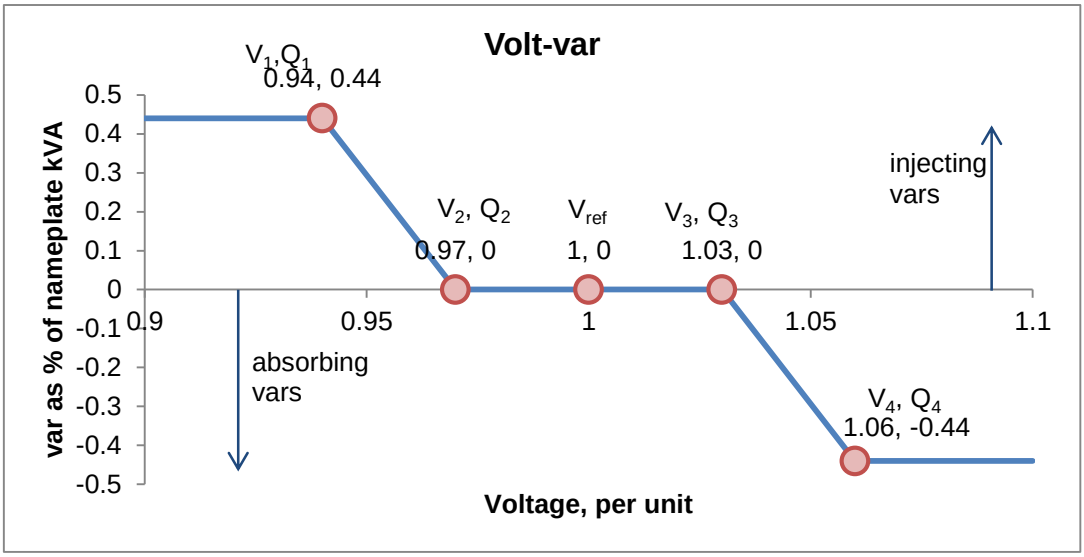

Figure 2: Illustrative Volt-var (VV) curve

When in Volt-var (VV) mode, the Inverter shall reduce active power if needed to maintain the specified reactive power, i.e. volt-var takes priority over active power production.

II.B Volt-watt (VW) - UL1741 SA15

When in Volt-watt (VW) P_{rated} mode of Mandatory Operation, the Inverter shall actively limit the active power output to be equal to or less than the active power output as a function of the voltage. (See also, an illustrative example in Figure 3 and the default values in Table 3.) The Inverter shall have minimum and maximum adjustable ranges per Table 3.

The Volt-watt (VW) function shall remain active while any of the other voltage and reactive power modes are enabled.[5]

For purposes of certification testing, the Inverter can be set to either $P_{pre\text{-}disturbance}$ or P_{rated} mode of operations with either an adjustable or a non-adjustable Response Time implementation. The allowance for $P_{pre\text{-}disturbance}$ mode of permissive operations is for certification testing purposes and is pending the IEEE determination of the applicable P1547 standard.

When in Volt-watt (VW) $P_{pre\text{-}disturbance}$ mode, active power output is modulated based on a power reference of the pre-disturbance power level, that is, when the active power at the Point of Interconnection crosses voltage, V_1. Where Table 3 calls for a power level below the Inverter's minimum active power (P_{min}), the Inverter shall not be required to reduce power below P_{min}. For Inverters that can only inject active power, P_{min} shall approach zero. In this mode, if the available input power increases when the voltage is above V_1, the output power shall not immediately increase but shall continue to follow the volt-watt curve as defined by the pre-disturbance power level until the voltage falls below V_1.

$P_{pre\text{-}disturbance}$ shall be a fixed value throughout the duration of the voltage deviation event and shall be reset when either occurs, (a) the voltage at the Point of Interconnection returns below V_1 or, (b) the Inverter next Enters Service.

[5] Note: A $P_{pre\text{-}disturbance}$ or a P_{rated} mode, and an adjustable or non-adjustable Response Time implementation may be used until the publication by IEEE of the related Volt-active (real) power (Volt-Watt) mode modifications to P1547, or upon mutual agreement between the Customer-Generator and the Company.

Active power output shall stay at or below the power defined by Volt-watt (VW) function curve shown in Figure 3 and listed in Table 3.

Volt-watt Parameters	**Default Values**	**Minimum Adjustable Range**	**Maximum Adjustable Range**
V_1	1.06 of Nominal Voltage (V_N), (e.g. 120 Volts)	1.05 of V_N	1.09 of V_N
P_1	P_{rated}	N/A	N/A
V_2	1.1 of V_N	V_1 + 0.01 of V_N	1.10 of V_N
P_2	Inverter's Minimum Active Power (P_{min}) (for Inverters that can only inject active power, P_{min} should approach 0)	P_{min} (For Inverters that can inject active power)	P_{rated}
Response Time	10 seconds	0.5 seconds	60 seconds

Table 3: Volt-watt (VW) ranges of adjustability and default settings.

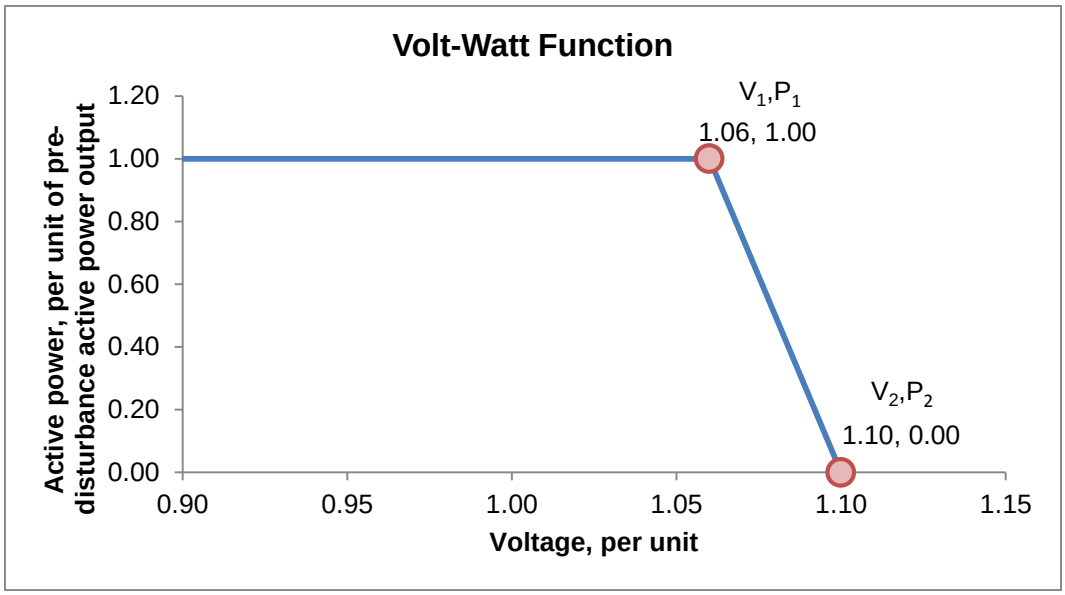

Figure 3: Illustrative Volt-watt (VW) curve

II.C Voltage Trip and Ride-Through (L/HVRT) – UL1741 SA9

The Inverter shall ride through voltage excursions shown in Table 4 below. The default values and ranges of adjustment for tripping settings shown in the voltage ranges in Table 4 define protective Trip limits for the protective function and are not intended to define or imply a voltage regulation function. Inverters shall Cease to Energize the Distribution System and Trip within the prescribed trip time durations whenever the voltage at the Point of Interconnection deviates from the allowable voltage operating range for the prescribed clearing time duration as defined in Table 4. For overvoltage, the protection function shall detect and respond to highest voltage on all phases to which the Inverter is connected. For undervoltage, the protection function shall detect and respond to lowest voltage on all phases to which the Inverter is connected.

Unless provided alternate settings by the Company, all Inverters must comply with the standard Voltage Ride-Through and Trip settings and operating mode specified in Table 4.

1. The Inverter shall Ride-Though and shall not Trip while the grid remains within the "Ride-Through Until" voltage-time range and must operate in accordance with the "Operating Mode" specified for each "Operating Region".

2. In the Continuous Operation ("CO") region, the Inverter shall reduce power output as a function of voltage or frequency, in accordance with Section II.B (VW) and II.F (FW), if the VW or FW function is enabled

3. Different settings than that specified in Table 4 and Section II.B (VW) may be specified by the Company.

While Inverter is connected to the Distribution System, any requirements for Voltage Ride-Through (L/HVRT) as specified below shall not be inhibited by any methods utilized to meet the unintentional islanding detection.

Operating Region	**Voltage at Point of Interconnection (% of Nominal Voltage)**	**Operating Mode**	**Ride-Through Until (s)**	**Default Maximum Trip Time (s)**	**Range of Adjustability Voltage Trip Magnitude (% of Nominal Voltage)**	**Range of Adjustability Clearing Time (s)**
OV2	V > 120	Cease to Energize	N/A	0.16 [(1)]	N/A	N/A
OV1	120 ≥ V > 110	Mandatory Operation	0.92	1	110 – 120	1 – 13
CO	110 ≥ V > 100	Continuous Operation (Volt-Watt)	N/A	N/A	N/A	N/A
CO	100 > V ≥ 88	Continuous Operation	N/A	N/A	N/A	N/A
UV1	88 > V ≥ 70	Mandatory Operation	20	21	50-88	21-50
UV2	70 > V ≥ 50	Mandatory Operation	10-20	11-21[(2)]	50-88	11-50
UV3	50 > V	Momentary Cessation	N/A	2	N/A	0.5-21

Table 4: Voltage Ride-Through (L/HVRT) ranges of adjustability and default settings

[(1)] Must trip time under steady state condition. Inverters will also be required to meet the Company's Transient Overvoltage criterion (TrOV-2). Ride-Through shall not inhibit TrOV-2 requirements. (See Rule 14H)
[(2)] May be adjusted within these ranges at manufacturer's discretion.

II.D. Frequency Trip and Ride-Through (L/HFRT) – UL1741 SA10

The utility controls system frequency and the Inverter shall operate in synchronism with the utility system. Upon loss of synchronism, the Inverter shall Trip. Whenever the utility system frequency at the Point of Interconnection varies from and remains outside normal (nominally 60 Hz) by the predetermined magnitudes and durations set forth in Table 5, the Inverter's protective functions shall Cease to Energize and Trip from the EPS system within the stated maximum Trip time.

While Inverter is connected to the Distribution System, any requirements for Frequency Ride-Through (L/HFRT) as specified below shall not be inhibited by any methods utilized to meet the unintentional islanding detection.

II.D.1 Frequency Ride-Through Requirements

Inverter systems shall continue to produce active power when the grid is within the frequency-time ranges indicated in Table 5, and shall Cease to Energize and Trip during a high or low frequency event that is outside the must trip frequency-time ranges. The frequency values are shown in Table 5. These values provide default interconnection system response to abnormal frequencies. The Inverter shall Cease to Energize and Trip by the Default Maximum Trip times. The Inverter shall reduce active power output as a function of frequency in accordance with Section II.E and Section II.F (FW). Electrical islands and microgrids may require different default frequency settings.

Operating Region	Frequency at Point of Interconnection	Operating Mode	Ride Through Until (s)	Default Maximum Trip Time (s)	Range of Adjustability Frequency	Range of Adjustability Clearing Time (s)
OF2	f > 64.0 f > 65.0 [L+M]	Permissive Operation	None	0.16	62.0-66.0	0.16-1,000
OF1	64.0 ≥ f > 63.0 65.0 ≥ f > 63.0 [L+M]	Mandatory Operation (Freq-watt)	20	21	61.0-66.0	21-1,000
CO	63.0 ≥ f > 60.0	Continuous Operation (Freq-watt)	Indefinite	N/A	N/A	N/A
CO	60.0 > f ≥ 57.0	Continuous Operation	Indefinite	N/A	N/A	N/A
UF1	57.0 > f ≥ 56.0 57.0 > f ≥ 50.0 [L+M]	Mandatory Operation	20	21	50.0-59.0	21-1,000
UF2	56.0 > f 50.0 > f [L+M]	Permissive Operation	None	0.16	50.0-57.0	0.16-1,000

Table 5 O'ahu, Maui, Hawai'i Island frequency ranges of adjustability and default settings
[L+M] denotes Lana'i and Moloka'i specific settings

II.E. Enter Service

At initial startup or when returning to service or after a power system disturbance that caused an Inverter to Trip, the Inverter shall be equipped with automatic means to prevent reconnection of the Inverter(s) with the Distribution System until the utility service voltage and frequency are within the default setting ranges, and are stable for, at minimum, the reconnection time delay as defined in Table 6, unless otherwise directed by the Company.

When entering service following the reconnection time delay, the active power export to the EPS shall be increased in accordance with Soft-Start Ramp Rates (SS) as defined in Section II.G.

Return to Service	**Default Setting**	**Ranges of Adjustability**
Voltage (% of nominal voltage)	88% – 110%	88% - 110%
Frequency	59.9 Hz to 60.1 Hz	59.0Hz to 61.0 Hz
Reconnection time delay	300-600[(1)]	0 – 600 seconds
Soft-Start Ramp Rate	See Section II.G	

Table 6: Return to Service ranges of adjustability and default settings

[(1)] May be adjusted at within this range at manufacturer's discretion

II.F. Frequency-watt (FW) – UL1741 SA14

The Inverter shall modulate active power when the frequency at the Point of Interconnection is outside the frequency-watt Deadband in accordance with the parameters in Table 7 and Equations B and C. The power modulation shall be on a percentage basis of the nameplate rated active power.[6]

For purposes of certification testing, the Inverter can be set to either or both P_{pre} or P_{rated} mode of operations with either an adjustable or a non-adjustable Response Time implementation. The allowance for P_{rated} mode is for certification testing purposes and is pending the IEEE determination of the applicable P1547 standard.

The performance of the Frequency-watt (FW) (frequency-droop) operation shall have the following characteristics:

Frequency-watt (FW) response shall take priority over Ramp Rate Requirements. (See II.G)

Equation B: $$p = min_{f<60-db_{uf}}\left\{p_{pre-disturbance} + p_{rated}\cdot\frac{(60-db_{uf})-f}{60\cdot k_{uf}}, p_{avail}\right\}$$

Equation C: $$p = max_{f>60+db_{of}}\left\{p_{pre-disturbance} - p_{rated}\cdot\frac{f-(60+db_{of})}{60\cdot k_{of}}, p_{min}\right\}$$

Where:

1. p is the active power output of the Inverter in p.u. of the Inverter rating
2. f is the system frequency at the Point of Interconnection
3. p_{rated} is the rated active power, in p.u. of the Inverter rating
4. p_{avail} is the available active power, in p.u. of the Inverter rating
5. $p_{pre\text{-}disturbance}$ is the Inverter active power at the time the frequency exceeds the Deadband, in p.u. of the Inverter rating
6. db_{of} and db_{uf} are the single sided Deadband values, for high-frequency and low-frequency, respectively
7. k_{of} *and* k_{uf} is the per-unit change in frequency corresponding to a 1 p.u. change in frequency (i.e. the slope of the Frequency-watt (FW) function)
8. p_{min} is the Inverter's minimum active power output

[6] Note: $P_{pre\text{-}disturbance}$ or a P_{rated} mode of operations with either an adjustable or a non-adjustable Response Time implementation may be used until the publication by IEEE of the related Frequency-droop (frequency/power) operation modifications to P1547, or upon mutual agreement between the Customer-Generator and the Company.

Note: Rule 14H currently only requires over-frequency response. However, inverters should be certified with the capability to provide over- and under-frequency response.

Parameter	Ranges of Adjustability	Default Setting
dbOF, dbUF (Hz)	0.017 – 1.0	0.036
kOF, kUF	0.02 – 0.07	0.04
Response Time (seconds)	0.05 – 3	0.5[(A)]
[(A)] On an interim basis, the Frequency-Watt function may be activated with a Response Time between 0.5 and 3 seconds.		

Table 7: Frequency-watt (FW) ranges of adjustability and default settings

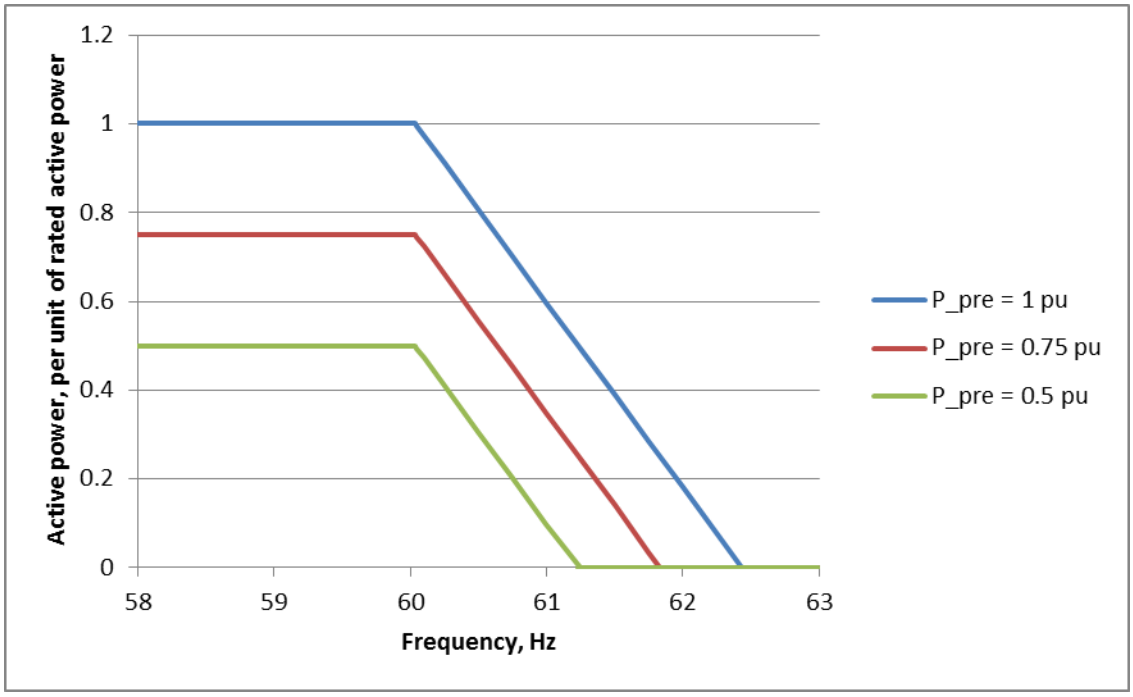

Figure 4: Illustrative Frequency-watt curve

II.G. Ramp Rate Requirements

The Inverter is required to have the following ramp controls for at least the following two conditions. These functions may be established by multiple control functions or by one general ramp rate control function. Ramp Rates are contingent upon sufficient energy available from the Inverter.

II.G.1Normal Ramp Rate (RR) – UL1741 SA11

Maximum upward ramp rate for transitions between energy output levels over the normal course of operation. The default value is 100% of maximum current output per second with a range of adjustment between 1.0% to 100%, with specific settings as mutually agreed by the Company and the Customer-Generator. Ramping more slowly than the prescribed rate shall be permitted.

II.G.2Soft-Start Ramp Rate (SS) – UL1741 SA11

Upon starting to inject power into the grid, following a period of inactivity, Trip, Return to Service, or a disconnection, the inverter shall limit the maximum rate of increase of active power to a ramp rate not greater than a default value of 0.33% of the Nameplate Rated Active Power per second.

The Inverter shall have a range of adjustment of the value of the connect/reconnect ramp rate from 0.1% to 100% maximum active power per second, with specific settings as mutually agreed upon by the Company and the Customer-Generator. Ramping more slowly than the prescribed rate shall be permitted.

Part III. - Prioritization of Inverter Responses (Optional)

The mandatory Grid Support Utility Interactive product functions referenced within the manuals and instructions that have been evaluated for compliance shall be clearly differentiated within the installation instructions from Grid Support Utility Interactive product functions that are optional and that have not been evaluated for certification testing. Where implemented, the priority of inverter response shall be stated in the manual or separately in documentation supplied to the Company. The preferred order of response is shown below:

A. Cease to Energize and Trip functions including anti-islanding and Voltage and Frequency trip functions shall take precedence over all other functions.

B. Voltage (L/HVRT) and Frequency Ride-Through functions shall take precedence over all other functions other than mandatory tripping and anti-islanding requirements.

C. Frequency-watt (FW) function as specified in Section II.F, when enabled, shall take precedence over other voltage regulation functions (i.e. Volt-watt (VW), Volt-var (VV), Fixed Power Factor (FPF)); but shall still operate within the parameters of the prescribed frequency ride-though settings. (See Section II.D) Frequency-watt (FW) shall take precedence over Ramp Rate as well. (See Section II.G) However, if both Frequency-watt (FW) and Volt-watt (VW) functions are activated, then the lesser of the two power values shall take precedence.

D. Volt-watt (VW) function as specified in Section II.B, when enabled, shall take precedence over all other functions with the exception of those listed in A, B and C in this Section III. However, if both Volt-watt (VW) and Frequency-watt (FW) functions are activated, then the lesser of the two power values shall take precedence.

E. Response to active power limit signal specified in Rule 14H shall take precedence over all other functions with the exception of those listed in A, B, C and D in this Section III. The response to changes in active power limit signal shall comply with the Normal Ramp Rate (RR). (See Section II.G)

F. All remaining functions shall have equal priorities.

Note: Inverter functions shall not inhibit active Anti-Islanding protection in accordance with IEEE 1547 (i.e. the Inverter shall detect the island and cease to energize the Distribution System within two (2) seconds of the formation of an island.)