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DER Orchestration - Request for Information

Additional submitted attachment is included below.

CEC RFI on VPP Capabilities to Support the Grid

1 Use Cases that Require Validation through Demonstration

1.1 Question

As California transitions away from traditional centralized fossil-gas generation and approaches a high penetration of intermittent renewables and inverter-based resources, what are the most needed grid service functions that aggregated DERs should be able to dispatch and that require validation in the near-term?

1.2 Grid support by Both DER Generation and Consumption

IEEE 1547-2018 only addresses grid support for DER generation and ignores grid support for DER loads (i.e., charging storage, charging EVs, HVACs, pumps, data centers, and other controllable loads). However, controllable loads are becoming a significant portion of loads and can provide most grid support functions equivalently to generation. Whether these controllable loads are mandated to perform grid services or are incentivized to provide these services, it is critical to understand what capabilities they could have and what performance criteria they should be expected to meet. Aggregations of DER will have even more flexibility on when and how to use controllable loads, and therefore VPPs seem to be a good place to start outlining these capabilities and performance criteria.

From a technical perspective, it is understood that power system modeling, power flows, contingency analysis, communications capabilities, and other technologies will need to be significantly improved for controllable loads to also be included as “DER”. In addition, it is clear that regulations will need to take into account the capabilities of controllable loads. This has started in California with the Smart Inverter Operationalization Working Group (SIOWG) report which identifies the ability to schedule the import of power, while UL 3141 defines the requirements in more detail.

In the rest of this document, the term “DER” does include controllable loads, as defined in IEC 61850-7-420:2021. Many of the functions described below reflect the US and European DER requirements described in that IEC standard. They are also included in IEEE 1815.2, the DER profile using DNP3.

1.3 Distribution-level voltage regulation

1.3.1 Volt-Var Control

Volt-Var is usually considered as the first DER function to implement for voltage support, since other DER methods involve decreasing the export of active power and could impact revenue. However, as storage and EV charging/discharging systems become more prevalent, modifying active power is less of a revenue issue since these system have other purposes than exporting active power.

For VPPs, Volt-Var control could be implemented by the DER aggregator using different parameters for different circuits so that the voltage stability/reliability requirements of local conditions are met while still meeting the overall feeder voltage requirements.

1.3.2 Volt-Watt advanced functionality

The Volt-Watt functionality defined by IEEE 1547 is very limited, since it defines the gradient for the Volt-Watt function as applicable only to limiting the DER’s maximum active power while generating, even if the voltage exceeds its normal range threshold while the DER is not generating at its maximum. This means that hybrid DER systems like PV systems combined with storage systems or electric vehicle V2G systems will rarely affect the voltage when it first exceeds its high threshold (and never its low threshold), since it would be very rare that all the systems are generating at maximum active power at the same time, much less if some portions are not in service at the time the function is enabled. Only if the voltage exceeds its threshold by a significant amount might the active power be decreased. Although PV systems or wind power systems can argue that decreasing their active power output is detrimental to their revenue, this argument is not as strong for hybrid DER with storage systems (including electric vehicles) since they usually have the capability to modify active power with minimal impact on revenue.

This approach thus fails to utilize the ability of hybrid DER systems and VPPs to actively affect low voltage levels or to start supporting voltage levels immediately when they cross either the high or low voltage thresholds.

The VPPs could include the following capabilities that they could issue as appropriate to different DER systems on different circuits or areas:

a. The ability to establish a gradient for the low voltage situation which would require DER systems to increase generation or decrease consumption if the voltage exceeds a low voltage threshold (see left side of Figure 1).

b. The ability to require the DER systems to respond immediately whenever the voltage exceeds a threshold, regardless of what level of active power is currently being generated or consumed (see Psnapshot green stars and dashed green lines in Figure 1).

c. The ability to specify what the DER systems would be permitted to do while the voltage exceeds the threshold, for instance, staying only on the gradient or permitted to change active power levels so long as they stay within the gradient area (see pink areas constraining DER active power in Figure 1).

d. The ability to specify hysteresis for the DER systems as the voltage returns to normal rather than following the same gradient back, once the voltage returns within the normal range (see hysteresis as green dotted double arrows in Figure 2).

e. The ability to include delay times or voltage deadbands when the DER is crossing a voltage threshold to ensure that the voltage is persistently either exceeding the threshold or persistently within the normal range (see deadbands as short green bars across thresholds in Figure 2).

f. The ability to specify ramping for the DER systems as the voltage returns within the normal range (see ramping as green dotted arrows in Figure 2).

g. The ability to allow the gradients to change if the DER system’s operational maximums change due to DER units being in or out of service.

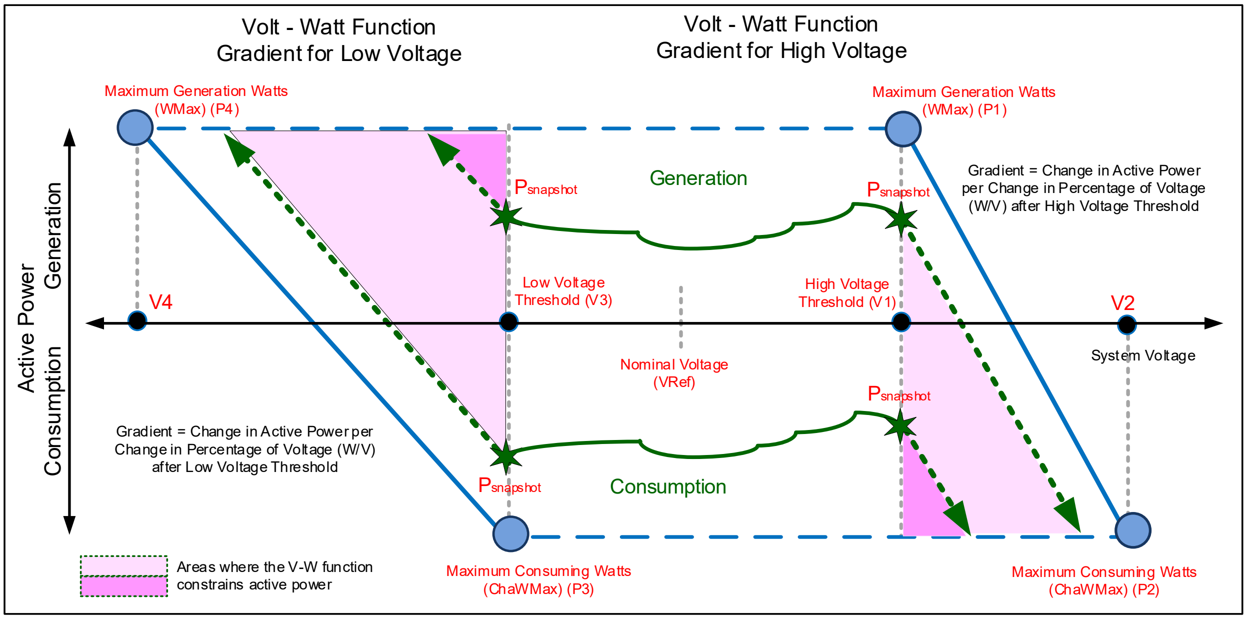

Figure 1 – Volt-Watt Advanced Functionality

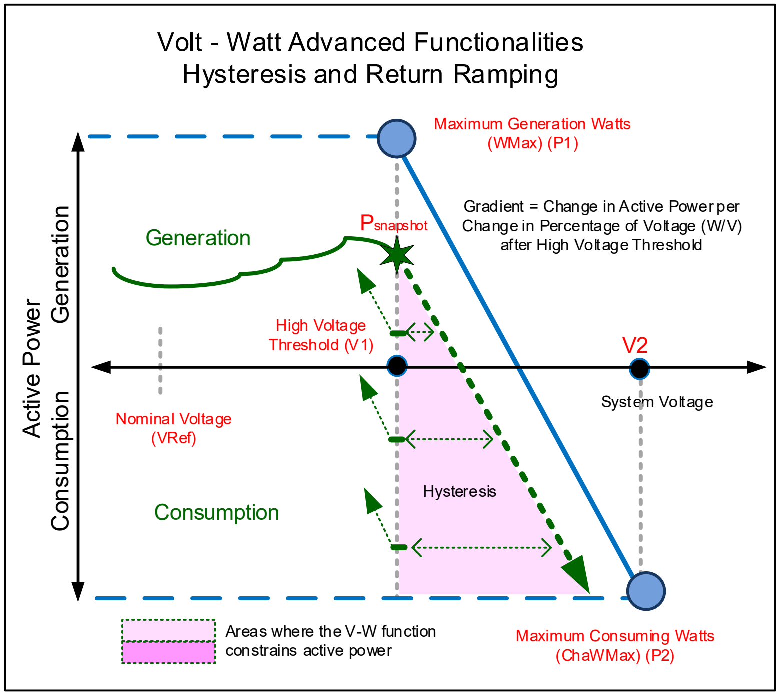

Figure 2 – Volt-Watt Advanced Functionality with Hysteresis and Return Ramping

1.3.3 Dynamic Reactive Current Support

The Dynamic Reactive Current Support function defines the requirements for DER to support the stabilization of the electrical system during short periods of abnormally high or low voltage levels by feeding reactive current in proportion to the instantaneous difference from a moving average of the measured voltage, until the voltage either returns within its normal range or the DER is forced to disconnect.

1.3.3.1 Basic Operation

Figure 3 illustrates how the outstation calculates a continuous Moving Average Voltage over a specified number of seconds known as the Filter Time.

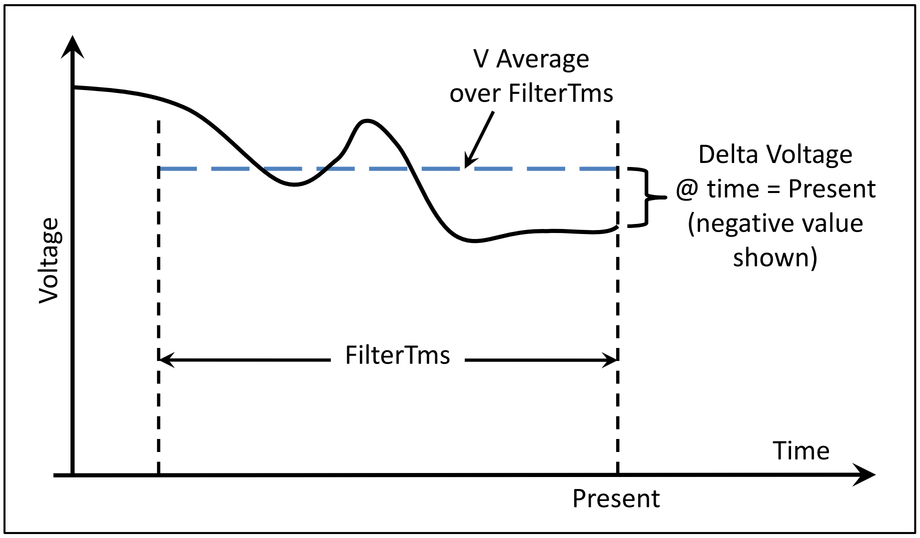

Figure 3 — Delta Voltage Calculation

Figure 4 illustrates how the outstation provides reactive current, either inductive or capacitive, in proportion to the Delta Voltage at any moment, *in addition* to any reactive current that may be applied by other functions such as the static Volt-Var curve functions.

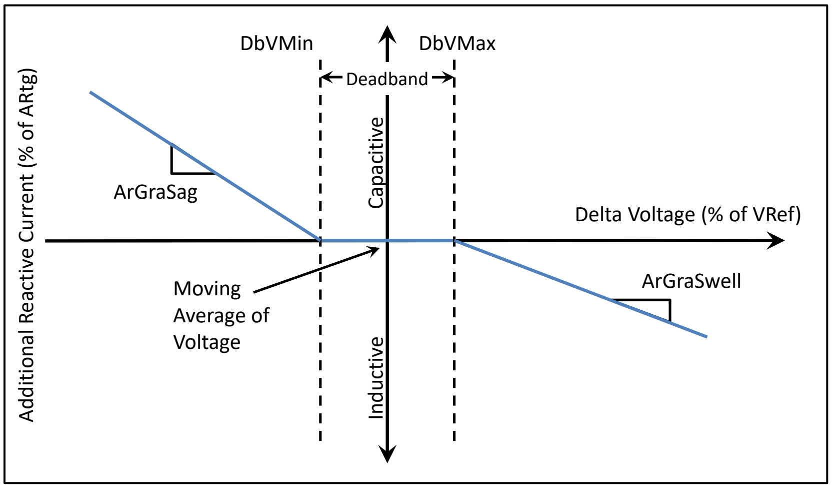

Figure 4 — Dynamic Current Support Function

1.3.3.2 Alternative Gradient Option

The controlling station can also specify the alternate curve shape shown in Figure 5.

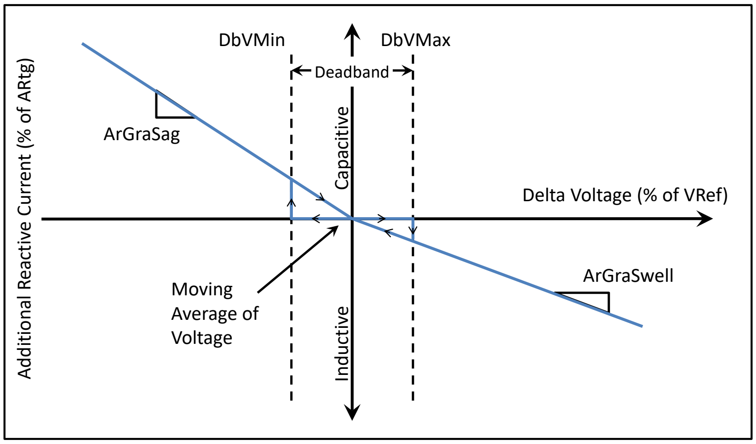

Figure 5 — **Alternate Dynamic Current Gradient Function**

1.3.3.3 Event-Based Behavior Option

Event-based dynamic current support is illustrated in Figure 6. When this feature is enabled, a voltage sag or swell "event" is considered to start when the voltage exceeds one of the deadband thresholds (shown as time t0). When this option is activated, the Moving Average Voltage and any reactive current levels that might exist due to other functions - such as the static Volt-Var function – are frozen at t0 when the event begins and are not free to change again until t2 when the event ends. The additional reactive current level specified by this function (as shown in Figure 4 or Figure 5) continues to vary throughout the event and is added to any frozen reactive current. Assuming the voltage returns within the deadband at t1, additional reactive current support continues until a specified Hold Time (AO46) has elapsed (t2 = t1 + Hold Time).

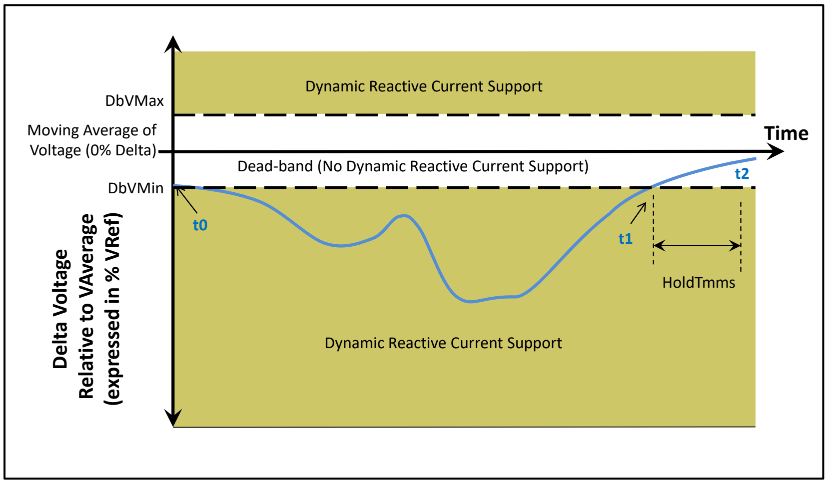

Figure 6 — **Event-Based Dynamic Current Support**

1.3.3.4 Blocking Zone Option

A "blocking zone" can be defined in which no dynamic reactive current support is applied, as illustrated in Figure 7.

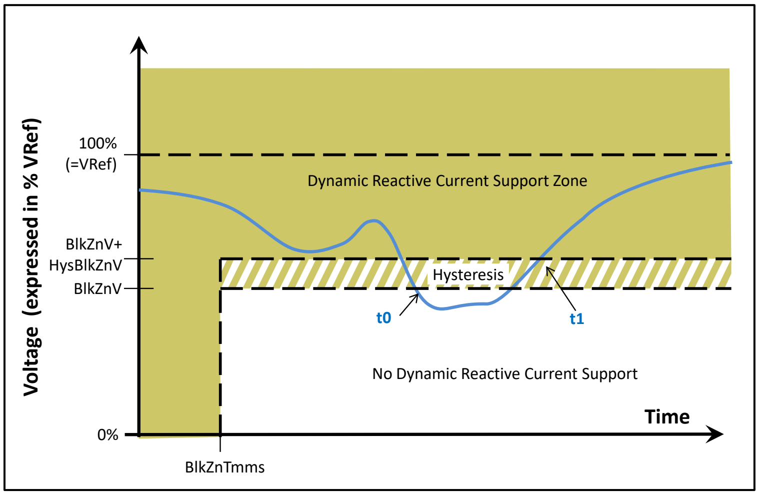

Figure 7 — Settings to Define a Dynamic Reactive Current Blocking Zone

1.4 Wholesale frequency regulation (dispatched by California Independent System Operator)

1.4.1 Frequency Regulation Functions

The Frequency-Watt function modifies active power input and/or output of the DER based on frequency. The most common use is for imitating the “droop” of mechanical generators or motors (see subclause **Error! Reference source not found.**), but this function can be used for many other purposes, depending on the settings and the use of curves.

There are multiple different purposes that the Frequency-Watt (frequency-active power) function can provide, as described in the following bullets. The first two would necessarily use the frequency-active power function autonomously, the third (Automatic Generation Control, see Clause **Error! Reference source not found.**) requires direct commands from a balancing authority, while the others may be autonomous or may rely on external signals:

a) **Frequency sensitivity function**: the frequency rapidly decreases or increases beyond normal limits (e.g. due to a loss of a large generator and possibly within a frequency ride-through situation). The frequency-active power function is used to sharply and rapidly increase (or reduce) power. The DER goes to WMax (or ChaWMax) using the slope (WGra) to try to bring the frequency within normal limits.

b) **Frequency droop or "primary frequency response"**: Droop is a control function used for AC electrical power generators to maintain the frequency within the normal operating zone, focused on returning the frequency to its nominal value (e.g. 50 Hz or 60 Hz). Specifically, the power output of a generator reduces as the line frequency increases above nominal frequency, and vice versa. It is commonly used as the speed control function of the governor of a prime mover driving a synchronous generator connected to an electrical grid. With droop speed control, when the grid is operating at the maximum normal operating frequency (e.g. 60.6 Hz), the prime mover's power is reduced to 0 % (cease-to-energize), and when the grid is at the minimum normal operating frequency (e.g. 58.5 Hz), the power is set to 100 % (WMax), and intermediate values at other operating frequencies.

c) **Secondary frequency response**: The frequency is managed by the Balancing Authority which sends active power signals every 4 to 10 seconds to all DER participating in the balancing or "Automatic Generation Control (AGC)" ancillary service (see Clause **Error! Reference source not found.**). This function cannot be performed autonomously but is commanded by the Balancing Authority.

d) **Tertiary or spinning reserve frequency response**: The Balancing Authority requests additional active power to be available within a few seconds or minutes. The Balancing Authority may provide an actual watt value, or the DER may be expected to ramp to a specified watt output upon receiving the signal. The reverse situation, namely requiring additional consumption immediately, may also be possible.

e) **Fast Frequency Response (FFR)**: Balancing Authorities may need sub-second responses to large frequency deviations. Such rapid responses preclude the use of communications to signal a response, as is expected in the tertiary or spinning reserve response. Therefore the active power response to such frequency deviations are preset and acted upon whenever necessary by the DER.

f) **Synthetic or artificial inertia**: Synchronous generators naturally provide inertia to changes in frequency as their rotors are forced to slow down or speed up. Inverter-based systems do not have this natural inertia since they can respond almost instantaneously to frequency changes. However, inertia is useful to slow changes in frequency (df/dt) with the aim of preventing sharp or rapid changes in frequency. Therefore, the frequency-active power function can be used by inverter-based systems to counter frequency changes and thus provide artificial inertia. This synthetic inertia function is not specifically focused on returning the frequency toward its nominal value, but rather providing transient stability. This function may be autonomous or may require direct and rapid commands from a utility (e.g. Fast Reserve).

g) **Frequency Containment Reserve (FCR)**: Frequency containment reserve (FCR) is a market-based ancillary service defined in the European Union Internal Electricity Balancing Market, but applicable for any large interconnection grid. It requires the availability of adequate operating reserves for constant containment of frequency deviations (fluctuations) from nominal value in order to constantly maintain the power balance across the entire synchronously interconnected system. FCR-D are operating reserves if the power system is experiencing a disturbance. FCR-N are operating reserves for normal power system operations.

h) **Frequency static boundary response**: The DER needs to remain within the frequency-active power boundaries, but it is not required to "go to" the boundary. This function could be of particular use within microgrids to avoid DER from causing frequency problems.

1.4.2 Basic Frequency-Watt functions

A conceptual Frequency-Watt function is illustrated in Figure 8 with six curve points defined as P1 through P6.

a) The frequency of the P1 pair frequency-watt points defines the high frequency start (HiHzStr) for the DER to start decreasing watts from its current level (termed its Snapshot value) by reducing generation or increasing consumption per the P1-P2 gradient. If the frequency reaches the P2 frequency, the DER decreases watts per the P2-P3 gradient.

b) The frequency of the P4 pair of frequency-watt points defines the low frequency start (LoHzStr) for the DER to start increasing watts from its current level (termed its Snapshot value) by increasing generation or decreasing consumption per the P4-P5 gradient. If the frequency reaches the P5 frequency, the DER increases watts per the P5-P6 gradient.

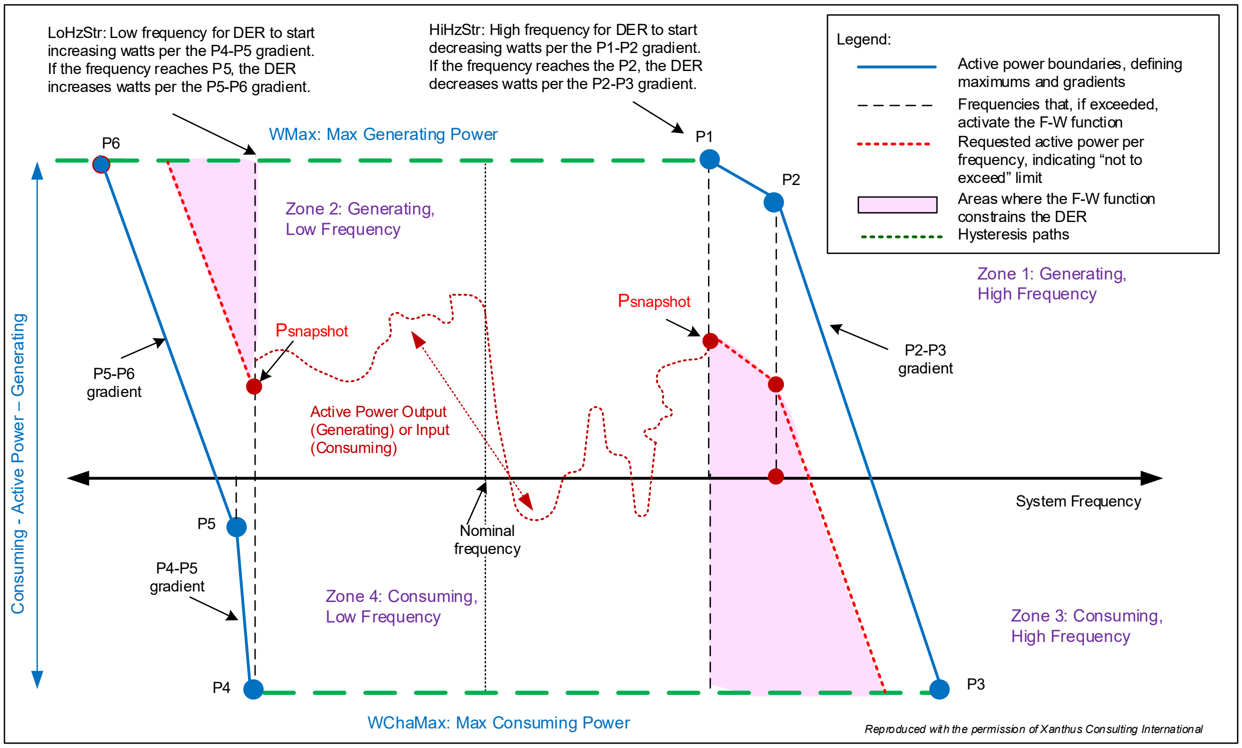

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Figure 8 — Basic Frequency-Watt Curve

If hysteresis is used, the boundaries of hysteresis shall be defined by two more curves, one for use in high-frequency events, the other for low-frequency events. An example of a hysteresis curve for high-frequency events is illustrated in Figure 9. If a hysteresis curve index is 0, hysteresis is not used for that high or low frequency. The controlling station may enable and disable hysteresis in the Frequency-Watt Curve function.

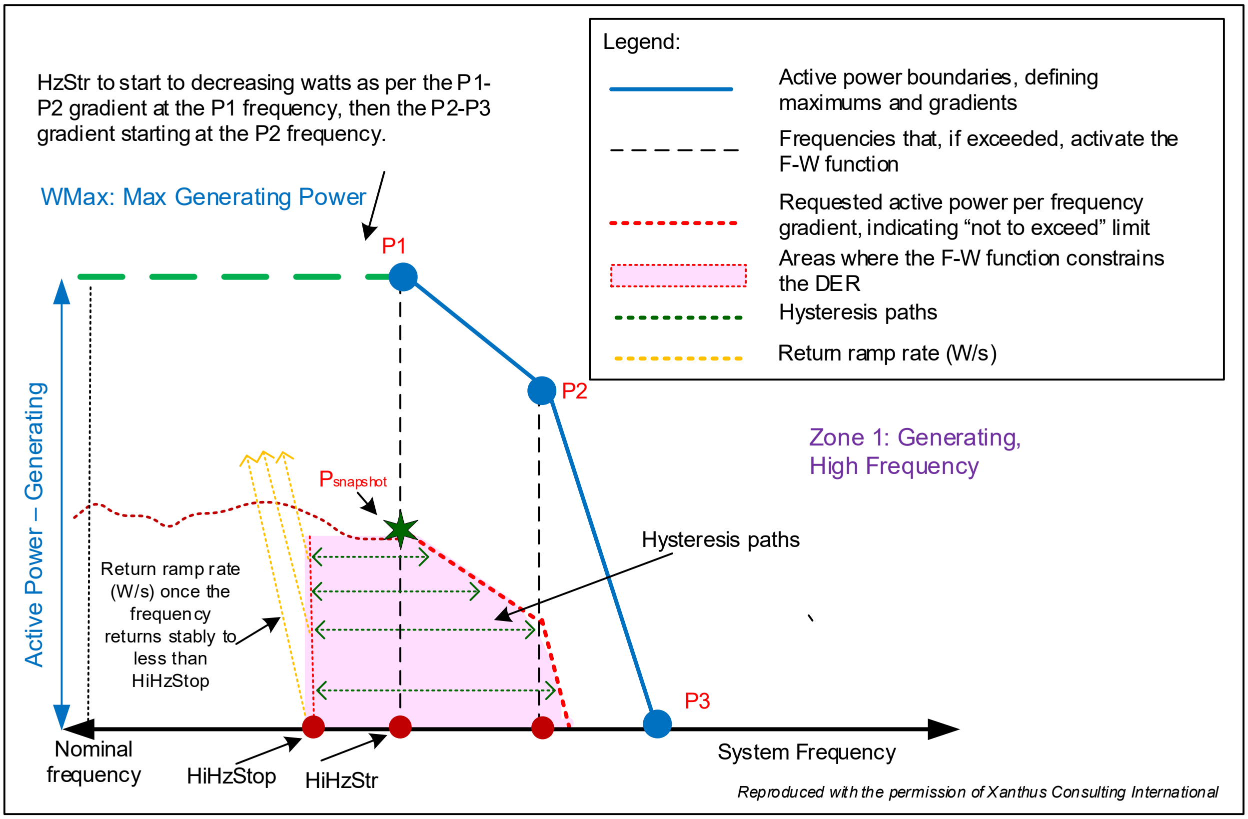

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Figure 9 — Example of hysteresis and return ramp rate in Zone 1

In most situations, the Frequency-Watt function would require the DER to immediately start changing its active power to follow the gradient when the frequency exceeds the HiHzStr level (or LoHzStr) at Psnapshot (see Figure 9). The active power at Psnapshot could be monitored to provide the data required to determine the constrained area (pink area).

In some situations, such as for the frequency static boundary purpose in microgrids, the controlling station would disable Snapshot of Power. In this case, the DER will not necessarily begin altering its active power output when the HiHzStr or LoHzStr limits are exceeded. It will maintain its output within the area bounded by the blue line (P1, P2, P3) in Figure 9, but will not be constrained by the pink area below the dashed red line.

A ramp rate (RtnRmpRte) (shown in Figure 9) is associated with returning from the frequency-active power constraints after the frequency has stably returned within the normal frequency band and the function has become inactive.

1.5 Ramping Support / Peak Power Injection (various markets)

1.5.1 Active Power Following: Peak Power Limiting, Load Following and Generation Following

Active Power Following functions can each be used to control the operation of a DER by following and responding to the active power at a different RPA, in any of three different situations:

a) **Peak Power Limiting**. The DER supplies active power such that the power imported at the RPA does not exceed a specified limit. Usually the RPA associated with limiting the import of power to serve the load is the PCC. If so, any excess load should be served from local generation, namely the source of the generation is *within* the RPA (PCC). This is similar to the active power consumption limiting which sets the limit, but this function also includes the ability to use a percentage of generation-to-load. Figure 10 illustrates a typical configuration for Peak Power Limiting.

b) **Load Following.** The DER supplies active power at one RPA which follows the load at another RPA, such that the net result is a leveling of the net import of power even if the load fluctuates. Although this function provides an activation threshold, it does not necessarily limit the load, it only levels the net import. It includes the ability to use a ratio of generation-to-load. Figure 11 illustrates a configuration for Load Following as well as Generation Following.

c) **Generation Following**. The DER supplies active power such that the power exported at one RPA follows the generation at another RPA (either internally or externally to the DER facility). It includes a ratio of generation-to-generation of the two generation sources. The concept is to have a leveling (not necessarily limiting) of the net export of power even if one generator fluctuates (e.g., solar or wind).

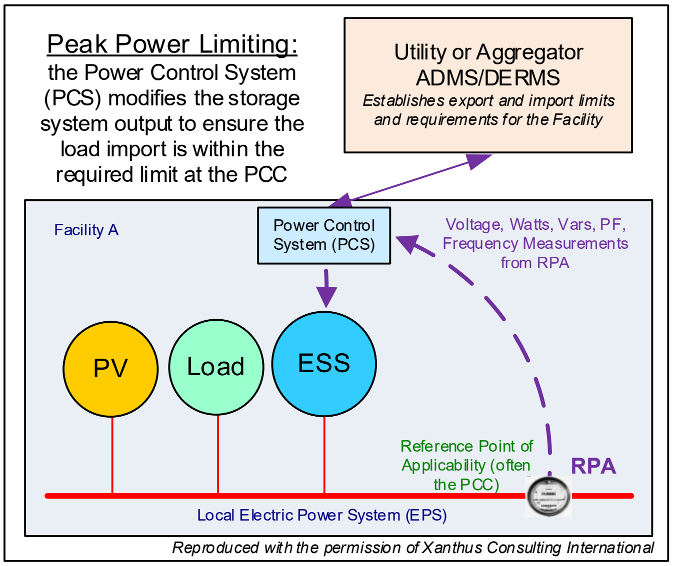

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Figure 10 — Configuration of Peak Power Limiting

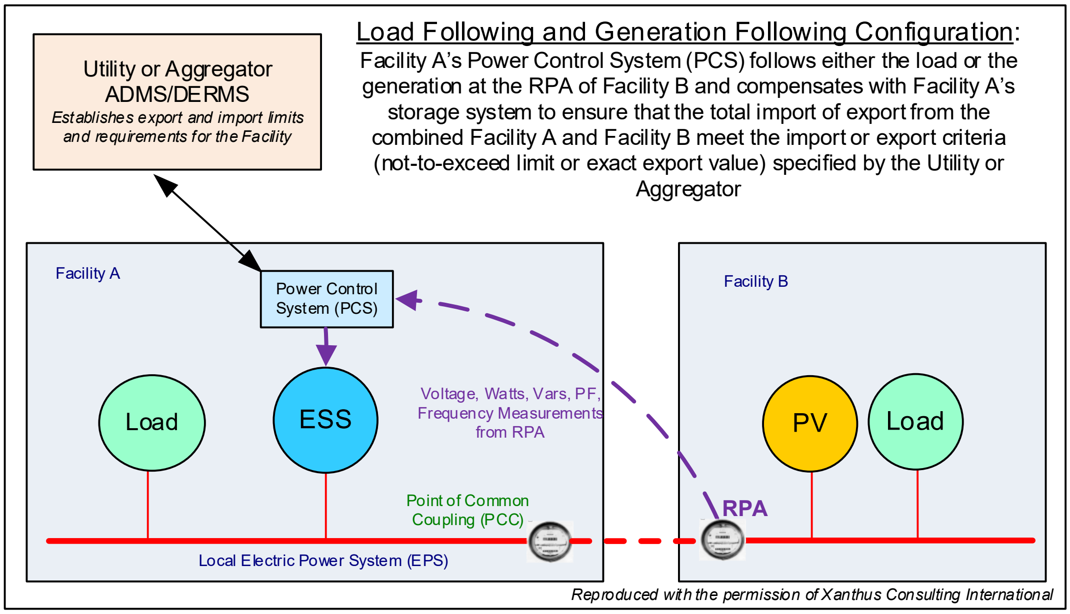

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Figure 11 — Configuration of Load and Generation Following

1.5.2 Peak Power Limiting Function

In the Peak Power Limiting function, the DER supplies active power such that the power transferred at a particular reference point does not exceed a specified limit. This concept is illustrated in Figure 12.

NOTE— When first developed in the DNP3 Application Note, Active Power Limiting was expected to be used for limiting generation, while this function, Peak Power Limiting, is expected to be used for limiting consumption. Since then, Active Power Limiting has been expanded to include both generation and consumption limiting.

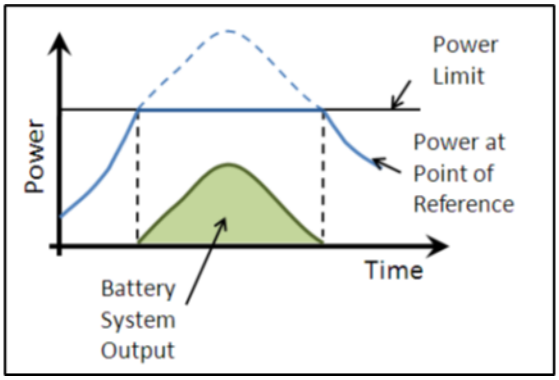

Figure 12 — Peak Power Limiting Function

The RPA for Peak Power Limiting may be located at the same site as the outstation or at another site. The assumption of this function is that increasing the active power output of the outstation will reduce the power transferred at the RPA.

When this function is enabled, the outstation shall continuously compare the active power at the RPA to a specified Peak Power Limit (the Power Threshold for the function) and adjust its active power output as needed to help ensure the RPA does not exceed the import limit.

1.5.3 Load Following Function

In the Load Following Function, the DER produces active power in proportion to a measured load as illustrated in the example in Figure 13. In the example, the generation source (e.g., storage system) is compensating 100% (FolWPct) for the load greater than the target (FolWSet) after the load reaches the threshold (FolWThr). The pink fill shows net load, while the blue star shows the desired threshold (FolWThr) and the green line shows desired follow value (FolWSet), namely the net result of the load following function.

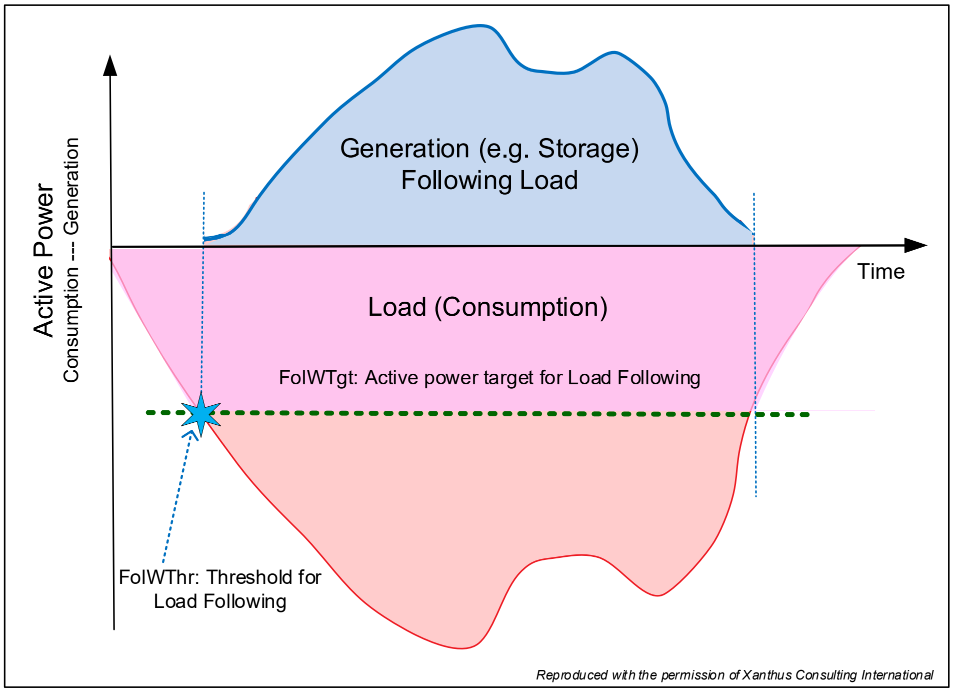

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Figure 13 — Load Following Function Arrangement and Waveform

1.5.4 Generation Following Function

In the Generation Following Function, the DER produces or consumes active power in proportion to a measured generation source as illustrated in the example in Figure 14. In this example, the generation/consumption source (e.g., storage system) is compensating 100% (FolWPct) for the generation from a different source (e.g., PV system) once that second generation source reaches the threshold (FolWThr). For 100% compensation, FolWSet = FolWThr. A common purpose of this function is to limit the net generation of the two generation sources, perhaps to meet utility-mandated generation constraints at the PCC.

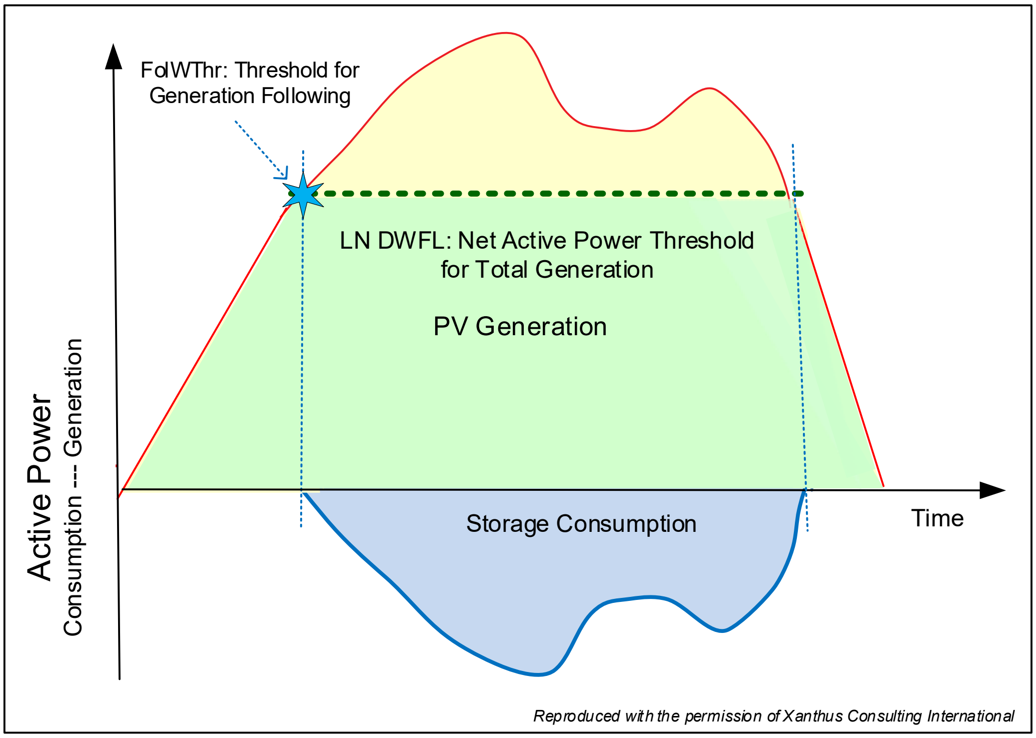

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Figure 14 — Generation Following Function to Limit Net Generation

If the threshold (FolWThr) is set to zero (0), the net generation is met at all times. The green line shows desired follow value (FolWSet), while the green fill shows net generation, as shown in figure Figure 15.

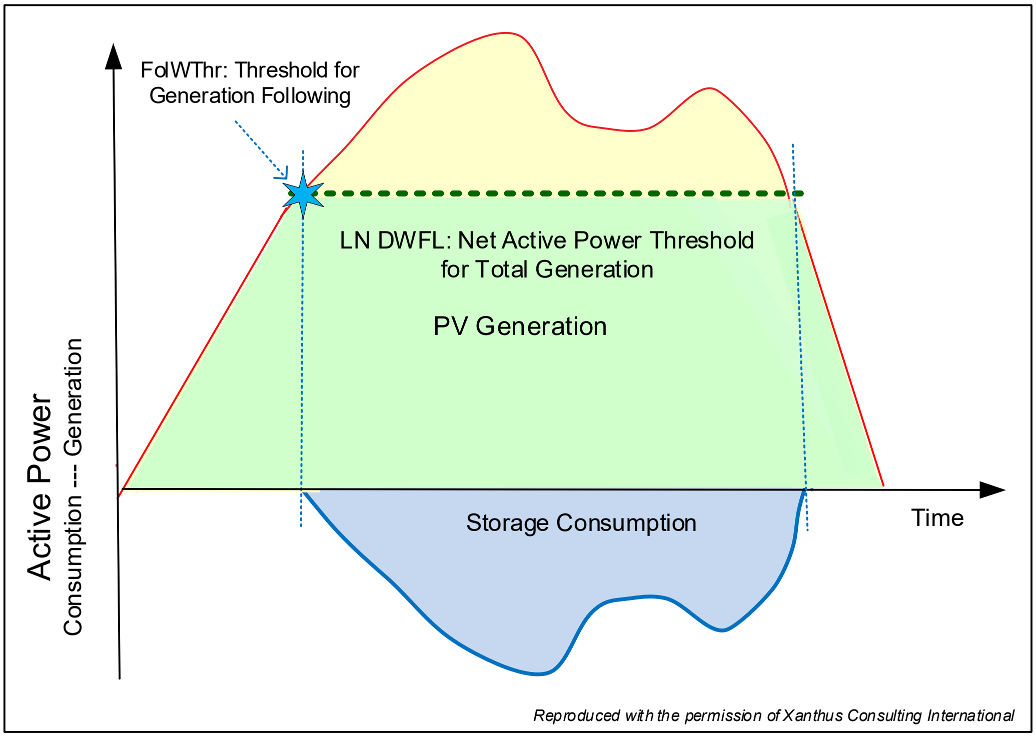

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Figure 15 — Generation Following Function with Constant Net Generation

1.6 Balance responding to multiple grid signals (i.e., Multi-Use Applications)

VPPs would be excellent choices for testing out how to manage multiple grid signals through the allocation of functions to different DER sites, in particular:

a. Active power constraint functions, such as scheduling active power export and import limits

b. Voltage support functions, including using controllable load

c. Frequency support functions, including permitting the use of stored NEM energy to be exported during emergencies, combining multiple sites to provide Automatic Generation Control (AGC), providing synthetic inertia to mimic rotating machines, and implementing fast frequency response by DERs for both high frequency and low frequency

d. Efficiency support functions, such as power smoothing, power factor correction, and coordinated charge/discharge.

2 What performance metrics should a research demonstration achieve to assure confidence in resource dispatchability?

Multiple areas would need to be addressed to develop good performance metrics. Some of these include:

a. Revenue metering that identifies when and which functions have been enabled and which are actively modifying DER functionality.

b. Submetering for individual DER units to confirm their actions.

c. Correlation between "real-time" power flow modeling and metered activities to determine if the requested DER functions were needed, and if the function parameters were adequate.

d. Correctness of GIS and other databases in reflecting the actual power grid equipment and configurations.

e. Since Limited Generation Profiles (LGP) and Limited Load Profiles (LLP) could also be demonstrated, the schedules used for those programs should be compared to the actual grid conditions, including the scheduled exports and imports, the actual exports and imports, the total power flows on the affected circuits, and assessments of why and how the differences can be explained.

3 What role would Investor-Owned Utilities (IOUs) play in potential field demonstrations?

3.1 Roles of IOUs

- Would IOUs need to develop new programs for grant recipients to bid into, or could projects use existing agreement structures?
- What role could dynamic hosting capacity have in expanding the depth of services that inverter-based DERs could provide to the grid?
- Should a Letter of Support from an IOU be a minimum requirement?
- Could utilities be potential technical reviewers during the application scoring phase as a means of providing insightful input to Evaluation Committee scorers?
- Are there additional considerations for utility's role in project demonstrations?

3.2 Assessment of the Roles of IOUs

(I am not an expert in the legal requirements for field demonstrations, so I'm commenting more on the bigger picture.)

IOUs will need to provide significant technical support, including:

- Use of revenue meters (while ensuring privacy and confidentiality) for comparisons between the theoretical use of functions and the actual results of using these functions
- Use of ICA data and day-ahead and hour-ahead power flow studies to establish the expected results of different functions.
- Assessments of the "expected results" versus the actual results.

4 Gateway Conformance Testing for Dispatchable DERs

4.1 Question

What is the industry need for dedicated testing and certification of DER gateway functionalities and conformance independent of the inverter or DER they are paired with? Would there be interest in a unified, open testing procedure that verifies DER gateways' functionality and adherence to utility-mandated communication requirements?

4.2 Gateway Conformance

UL 3141 is underdevelopment (and already being used), which provides the conformance testing requirements for a specific gateway capability, namely limiting export and/or import of power. At the same time, IEEE 1547.10 is being developed, but not as requirements. IEEE 1547 allows "DERs" to be combined at the PCC, but avoids any requirements for controllable loads.

Nonetheless, most DER systems today utilize some form of "gateway" rather than direct interactions with individual DER units. Controllable loads (charging storage and EVs) need to be included in any gateway requirements and testing. If the IEEE 1547-2018 requirements could be applied to such "gateways", then the same UL 1741-SB tests could be updated.

IEEE 2030.5, IEEE 1815.2 (DNP3), and IEC 61850 can already be used for gateways. The issue could be the conversion from these protocols to Modbus or other protocols within the DER (or EV) site.

So first, gateway requirements need to be defined (IEEE 1547.10 cannot do that). Rather than trying to define generic "gateway" requirements, it might be easier to define individual requirements for the testing of different functions at a gateway, similar to UL 3141.

5 Which requirements should this testing tool cover in its scope?

5.1 Question

These requirements may include:

- IEEE 2030.5-2023 “Standard for Smart Energy Profile Application Protocol”
- IEEE 1547-2018 “Standard for Interconnection and Interoperability of DERs with Associated Electric Power Systems Interfaces”
- IEEE 1547.1-2020 “Standard Conformance Test Procedures for Equipment Interconnecting DERs with Electric Power Systems and Associated Interfaces”
- IEEE 1547.3-2023 “Guide for Cybersecurity of DERs Interconnected with Electric Power Systems”
- Common Smart Inverter Profile (CSIP)
- Others that are not listed here

5.2 Testing Tool

Additional communications protocols include:

- IEEE 1815.2 (DER profile using DNP3)
- OCPP (for electric vehicles)

Communications testing should combine UL 1741-SB, UL 1741-SC, and UL 2941 (when the latter two are published).

6 What should be the baseline performance requirements of DER gateways for the following functions?

- Performance in DER communication
- Interoperability of communication between DER devices from various manufacturers
- Responsiveness in DER dispatch

Basically the answer is yes, but the devil is in the details. The requirements for DER gateways need to be fleshed out first.

7 Should this research scope (gateway conformance testing) be under a separate funding group to be conducted independent of the VPP demonstrations, or should this scope be incorporated as a phase of a larger VPP field deployment demonstration?

(No comment)

Valuation of Aggregated DER Services:

8 How could technology demonstrations be designed to increase confidence in the efficacy of market signals?

The market requirements need to be clearly defined before the market signals can be effective. Two types of grid services exist:

1. Grid constraints that are mandatory for utility safety and reliability for n-1 contingencies. These may include incentives if multiple sources could support these grid constraints, but could be contractual or mandatory. For these grid constraints, utilities would have to be confident that these mechanisms would meet their requirements absolutely.
2. Additional grid services that can provide efficiency and improved reliability as well as societal benefits. These services would be useful economically and socially, but would not have an impact on the utility's core requirements of providing power to customers.

9 Identify existing market mechanisms that enable DER aggregators and VPP platforms to provide each of the grid services identified in Question 3.

How effective are these market mechanisms in facilitating that service, and what barriers must be overcome for these market mechanisms to be more effective than they are now?

(No comment)

10 Are there existing market mechanisms for dispatching inverter-based resources to provide voltage regulation and transformer overload prevention at the secondary distribution level?

10.1 Question

- Which ancillary markets (e.g., fast frequency response, spinning/non-spinning reserves) would DER aggregations be best suited for? Note that these services may vary depending on a third-party aggregator's particular composition of DERs (e.g., energy storage, solar and hybrid smart inverters, Electric Vehicle chargers)

- What consumer protections measures must be put in place for DER aggregation? This is especially important for projects to be designed with an equitable focus. For example, solicitation requirements could require including protections that ensure DER enrollees are fairly compensated by aggregators for the value they provide to the DER portfolio being dispatched. What are some examples of best practices?

10.2 Market mechanisms

The market requirements, as noted in Item 8 above, need to be better defined, including the operational and financial benefits to CAISO as well as the DER owner/operators that could be dispatched for these ancillary services.