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SEP 2.0 Mapping for Grid Control Enabled Inverters

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ABSTRACT

This technical update addresses how Smart Energy Profile 2.0 (SEP2) can be used to support grid control enabled inverters. This implementation is intended for use in the Standard Communication Interface and Certification Test Program project.

This project consists of the development and demonstration of advanced inverters with standardized functionality and an open communication interface that can meet the requirements of the new California (CA) Rule 21 interconnection guideline. The communication interface will utilize the IEC standard information model, the SunSpec protocol, and the CEA-2045 modular interface to enable off-the-shelf inverters to be mass produced, and compatible with SCADA, AMI, or any other system.

This report is intended for the member utilities involved in the Standard Communication Interface and Certification Test Program project.

Keywords
Smart Inverters
Distributed Energy Resources
DER
SEP 2.0
SEP2
California (CA) Rule 21

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INTRODUCTION

Overview

The Standard Communication Interface and Certification Test Program project consists of the development and demonstration of advanced inverters with standardized functionality and an open communication interface that can meet the requirements of the new California (CA) Rule 21 interconnection guideline. The communication interface will utilize the IEC standard information model, the SunSpec protocol, and the CEA-2045 modular interface to enable off-the-shelf inverters to be mass produced, and compatible with SCADA, AMI, or any other system.

The project will also develop a certification test program, including the test procedures, software, and facilities needed to validate that new inverter designs function and communicate per the standards. A certification process is a must-have because standards alone are not sufficient to produce interoperability. The certification process will be based on the California Rule 21 requirements, and will include testing of both the power and communication interfaces of the inverter. In this way, the inverters could be fielded immediately, with confidence that they could be successfully integrated with control systems at a later time, if and when needed.

One of the communication protocols being demonstrated in this project is SEP2. This protocol was designed to support smart inverter functions required to take advantage of new capabilities, some of which are being demonstrated in this project.

Functions to Be Supported

The following functions will be supported using SEP2:

- Download of Volt-VAR mode with Watt-Priority curves
- Download of Frequency-Watt mode curves
- Download of Volt-Watt mode curves
- Enable/disable specific Volt-VAR/Frequency-Watt/Volt-Watt curves
- Download of ramp rates for specific functions
- Fixed Power Factor settings
- Report inverter alarm status
- Report inverter instantaneous power, power factor, connection status, and totalized real power output

SEP2 supports most of the required distributed energy resources (DER) functionality without modification or hijacking of other functions. The only identified exception to this is alarm reporting.

Some of the information on the functions to be supported was drawn from the publically available technical update, Common Functions for Smart Inverters, Version 3, EPRI product ID 3002002233. It is assumed that the parameters for Rule 21 functions to be supported will be similar.

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INDIVIDUAL FUNCTION MAPPING

This chapter provides details on how the individual DER functions to be supported for this field demonstration are mapped to the SEP 2.0 functions. Four models will be used to support the required functions: DERCurve, DERControl, DERStatus, and meter mirroring.

1) DERCurve will be used to download the three required curve types to the inverter.
2) DERControl will be used to limit the inverter power output, enable or disable DER curves, and connect/disconnect.
3) DERStatus and Meter mirroring will support the status provided to the SEP 2.0 server.

SEP 2.0 uses programs to contain function sets, such as DERControl. Per the specification, a program cannot have more than one DER event active at one time. Since many of the DER functions to be implemented are meant to coexist with other functions, a separate program must be created for each of these functions. Only functions that are mutually exclusive may reside in the same program.

Each function will be discussed in detail in the following sections.

Volt-VAR Curve Download

The Volt-VAR curves loaded into the inverter define how dynamic reactive power is injected through autonomous responses to local voltage measurements. The SEP2 client will request a download of a DER Curve from the SEP2 server. Multiple curves may be downloaded and are identified by their mRID value.

SEP2 Function set: DERCurve / DERCurveType: 0 - Volt-VAr Curve Mode: opModVoltVAr

A simple Volt-VAR curve is shown in Figure 2-1.

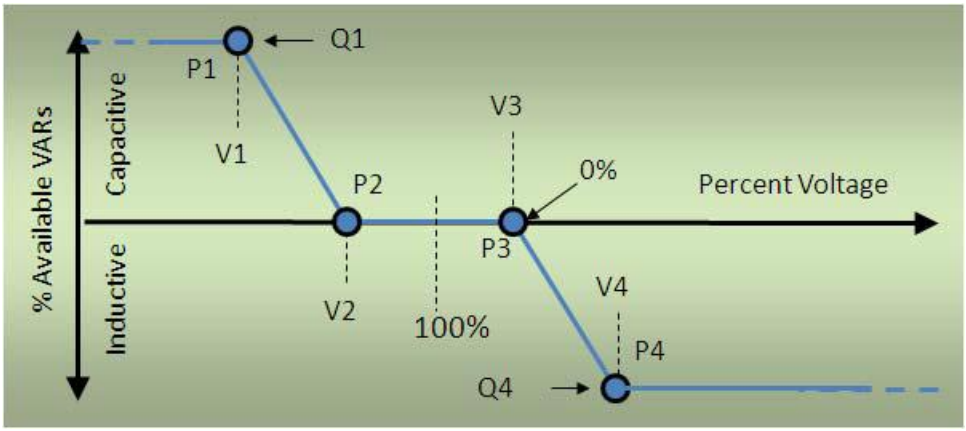

Figure 2-1
Simple Volt-VAR curve

Some of the primary elements of interest in this function are shown in**Error! Reference source not found.** See the SEP 2.0 specification for full details.

Table 2-1
Subset of the Volt-VAR curve parameters

Structure		Description
DERCurve		Defines a DER curve
	mRID	The global identifier of the curve
	CurveData	Contains the X/Y data pairs that define the curve shape
	curveType	0 - Volt-VAr Mode
	rampDecTms	Defines the decreasing ramp rate limit
	rampIncTms	Defines the increasing ramp rate limit
	xMultiplier	Exponent for the X-axis values
	yMultiplier	Exponent for the Y-axis values

Frequency-Watt Curve Download

This function is intended to counteract frequency deviations by modifying real power output. The inverter will adjust the inverter real power output based on the frequency at the point of inverter connection using an X/Y curve. The X axis is the frequency and the Y axis is the percentage of available real power output from the inverter. The SEP2 server provides the curves to support this function. An example Frequency-Watt curve is shown in Figure 2-2.

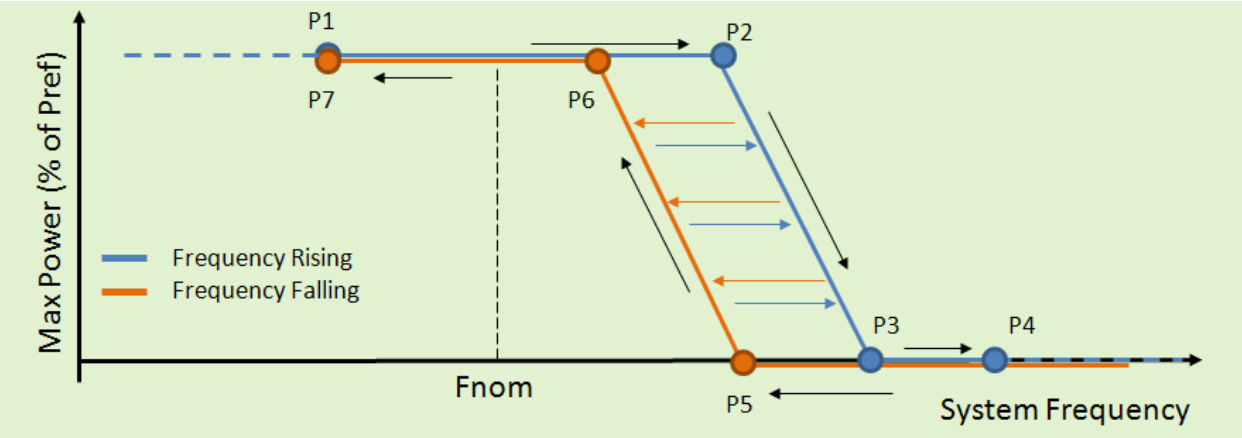

Figure 2-2
Example Frequency-Watt curve with hysteresis

The Frequency-Watt function limits active power generation or consumption when the line frequency deviates from nominal by a specified amount. The Frequency-Watt curve is specified as an array of Frequency-Watt pairs that are interpolated into a piecewise linear function with

hysteresis. The x value of each pair specifies a frequency in Hz. The y value specifies a corresponding active power output in percent of the inverter maximum real power output.

SEP2 Function set: DERCurve / DERCurveType: 1 - Frequency-Watt Curve Mode: opModFreqWatt

Multiple curves may be supported to adapt to changing conditions. Some of the primary elements of interest in this function are shown in Table 2-2. See the SEP 2.0 specification for full details.

Table 2-2
Subset of the Frequency-Watt curve parameters

Structure		Description
DERCurve		Defines a DER curve
	mRID	The global identifier of the curve
	CurveData	Contains the X/Y data pairs that define the curve shape
	curveType	1 - Frequency-Watt Curve Mode
	rampDecTms	Defines the decreasing ramp rate limit
	rampIncTms	Defines the increasing ramp rate limit
	xMultiplier	Exponent for the X-axis values
	yMultiplier	Exponent for the Y-axis values

Volt-Watt Curve Download

This function is intended to counteract voltage fluctuations on the feeder by modifying real power output. The inverter will adjust the inverter real power output based on the voltage at the point of inverter connection using an X/Y curve. The X axis is the voltage and the Y axis is the percentage of available real power output from the inverter. The SEP2 server provides the curves to support this function.

A simple Volt-Watt curve is shown in Figure 2-3.

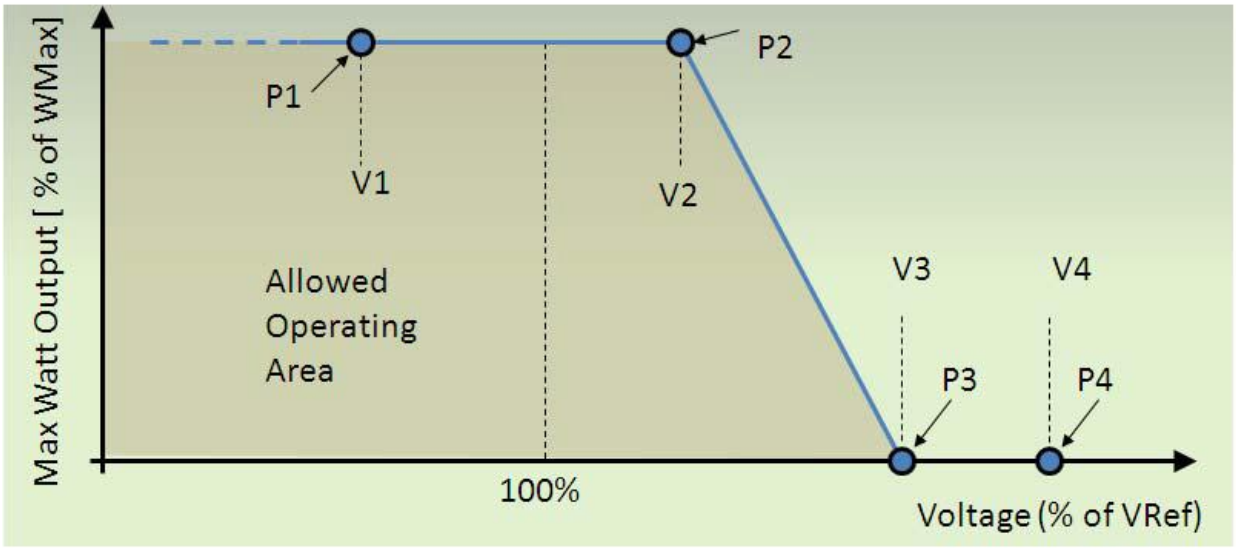

Figure 2-3
Example Volt-Watt curve

The Volt-Watt function limits active power generation or consumption when the line voltage exceeds nominal by a specified amount. The Volt-Watt curve is specified as an array of Volt-Watt pairs that are interpolated into a piecewise linear function with hysteresis. The x value of each pair specifies an AC RMS voltage. The y value specifies a corresponding active power output in percent of the inverter maximum real power output.

SEP2 Function set: DERCurve / DERCurveType: 3 - Volt-Watt Curve Mode: opModVoltWatt

Multiple curves may be supported to adapt to changing conditions. Some of the primary elements of interest in this function are shown in Table 2-3. See the SEP 2.0 specification for full details.

Table 2-3
Subset of the Volt-Watt curve parameters

Structure		Description
DERCurve		Defines a DER curve
	mRID	The global identifier of the curve
	CurveData	Contains the X/Y data pairs that define the curve shape
	curveType	3 - Volt-Watt Mode
	rampDecTms	Defines the decreasing ramp rate limit
	rampIncTms	Defines the increasing ramp rate limit
	xMultiplier	Exponent for the X-axis values
	yMultiplier	Exponent for the Y-axis values

DER Curve Enable/Disable

This function will activate a specific Volt-VAR, Frequency-Watt, or Voltage-Watt curve. The curve enable uses the DERControl function from the SEP2 server. The DERControlBase identifies the curve type to be enabled, and the DERCurveLink specifies the specific curve to be enabled.

SEP2 Function set: DERControl / DERControlBase / DERCurveLink

When the event expires the DER curve function will be disabled. The event can also be terminated at any time changing the duration.

Multiple curves may be supported to adapt to changing conditions. Some of the primary elements of interest in this function are shown in **Error! Reference source not found.** See the SEP 2.0 specification for full details.

Table 2-4
Subset of the DER curve enable/disable event structure

Structure		Description
DERControl		Defines a grid event
	mRID	Unique event identifier
	interval	The period during which the event applies
	randomizeDuration	Randomization time range to apply to the end of the event
	randomizeStart	Randomization time range to apply to the beginning of the event
	DERControlBase	Defines the event - opModFreqWatt, opModVoltVAr, opModVoltWatt

A smooth transition from one curve to another is possible using SEP2. Implementing a different curve does not require canceling the current event first before initiating a new event.

Ramp Rate Download

SEP2 DERControl events contain ramp rate parameters. These values must be provided to manage the transitions from one setting to another.

Fixed Power Factor

This function is intended to provide a simple mechanism through which the power factor (PF) of a DER may be set to a fixed value to generate or absorb reactive power.

SEP2 Function set: DERControl / DERControlBase: opModFixedPF

Refer to chapter 8, “Fixed Power Factor Function” in the EPRI *Common Functions for Smart Inverters* report. Some of the primary elements of interest in this function are shown in**Error! Reference source not found.** See the SEP 2.0 specification for full details.

Table 2-5
Subset of the DERControl fixed power factor event structure

Structure				Description
DERControl				Defines a DER event
	mRID			Unique event identifier
	interval			The period during which the event applies.
	randomizeDuration			Randomization time range to apply to the end of the event
	randomizeStart			Randomization time range to apply to the beginning of the event
	DERControlBase			Defines the event - opModFixedPF
		opModFixedPF		Fixed Power Factor Function
			displacement	Signed integer which translates to a value between -.9999 and 1.0000 defining the desired power factor
			multiplier	Specifies the exponent of the displacement.

Limit Maximum Real Power

This function is intended to provide a mechanism through which the maximum real power may be limited to a percentage of the DER maximum real power.

SEP2 Function set: DERControl / DERControlBase: opModFixedW

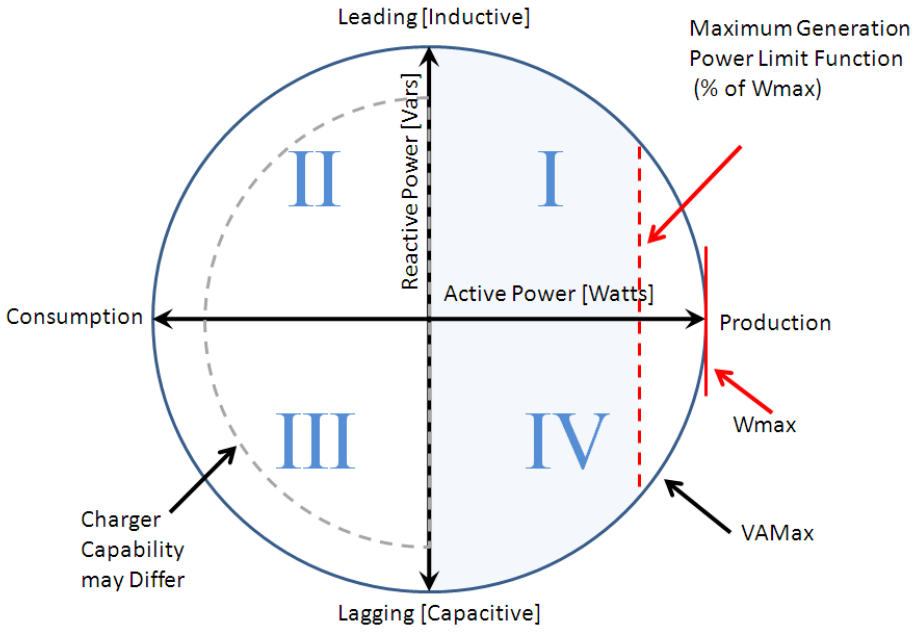

Figure 2-4
Limit Maximum Real Power

Refer to chapter 4, "Maximum Generation Limit Function" in the EPRI *Common Functions for Smart Inverters* report. Some of the primary elements of interest in this function are shown in **Error! Reference source not found.** See the SEP 2.0 specification for full details.

Table 2-6
Subset of the DERControl limit maximum real power event structure

Structure	Description
DERControl	Defines a DER event
mRID	Unique event identifier
interval	The period during which the event applies.
randomizeDuration	Randomization time range to apply to the end of the event
randomizeStart	Randomization time range to apply to the beginning of the event
DERControlBase	Defines the event - opModFixedW
opModFixedW	Limits real power output to this percentage of maximum power output

Connect/Disconnect

This function is intended to provide a mechanism to connect or disconnect the DER from local loads and the grid. While this is intended to be a physical disconnect, it is possible to imitate this action on a DER without a disconnect switch by limiting the output to zero watts. This is not considered a preferred solution for production units but is workable for purposes of a demonstration. See Figure 2-5
DER Connect/Disconnect switch for a graphical description of the connect/disconnect switch.

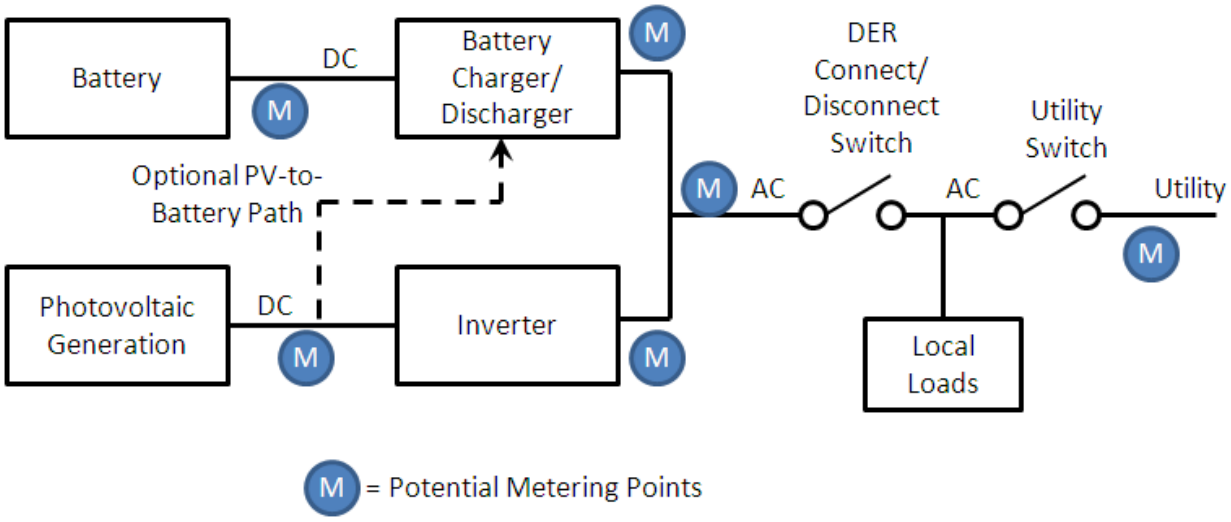

Figure 2-5
DER Connect/Disconnect switch

For purposes of this demonstration, this will be the same as Limit Maximum Power to Zero Watts. See the section above titled Limit Maximum Real Power for details on the implementation.

Upload Inverter Alarms and Status

Reporting inverter status is performed using the MirrorMeterReading and DERStatus functions. The SunSpec inverter interface provides values closely matched to the SEP2 DERStatus function for operational state information. The meter mirroring can provide power, energy and power factor values.

A method to report detailed alarm data has not yet been identified although DERStatus, but it does return a single alarm state. This single alarm flag can be used for this demonstration and the need for expanded alarm capability will be noted as a possible expansion to SEP2.

The data desired to be reported by the client is currently defined as:

- Instantaneous real power
- Instantaneous power factor
- Totalized real power output
- Connection status
- Alarm flags

The alarm status should be configured to report on a minimum time schedule and on status change.

3
IDENTIFIED ISSUES

One Event Active per Program

The SEP 2.0 specification calls out that a new event within a program supersedes the current event within the same program, basically limiting all programs to a single event. Within the DER control environment, it is expected to have multiple events active at the same time.

Ignoring these limitations can cause issues affecting inverter operation. For example, if a real power limit is in effect and a Volt-VAR curve is then enabled, it may be impossible to modify the real power limit since the server may consider that the event no longer exists.

Another issue is that a program may only have one default state, so the default state could not be having a Volt-Watt curve enabled and a real power limit if both resided in the same program.

The solution to this is to place the functions in their own program, or in a program with mutually exclusive functions. There appears to be no limitation on the number of programs that can run simultaneously. This would allow multiple functions to be enabled at the same time with multiple default states. This appears to be what was intended by the authors of the specification.

4
REFERENCES

The following documents were used in the preparation of this report:

1. Smart Energy Profile 2, 13-0200-00, April 2013. ZigBee Public Document 13-0200-00.
2. *Common Functions for Smart Inverters, Version 3*. EPRI, Palo Alto, CA: 2014. 3002002233.