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Applying SunSpec Modbus to Meet California Rule 21 Requirements

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ABSTRACT

In 2014, EPRI, the SunSpec Alliance, and a group of partners were awarded funding as part of the California Solar Initiative. The project is developing and field-demonstrating smart solar inverters with grid-supportive functionality and an open standard communication interface. The project is being conducted in parallel with ongoing activities in California to revise the Rule 21 interconnect guidelines for distributed energy resources. This revision process established draft functional and communication requirements that served to set the scope for this demonstration project.

The technical approach involves implementing the IEC 61850 standard smart inverter functions and using the SunSpec data models and Modbus protocol over the CEA-2045 plug interface. The project plan includes connecting these inverters in a variety of communication systems to assess interoperability and flexibility.

This document is a technical specification that describes how the SunSpec data models and Modbus protocol is used for each of the functions involved. This includes both monitoring and management functions.

This report has also been published by EPRI as EPRI Report 3002004696.[1]

Keywords
Sunspec
Modbus
smart inverter
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[1] http://www.epri.com

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1 INTRODUCTION

In 2014, EPRI, the SunSpec Alliance, and a group of utility, manufacturer, and laboratory partners were awarded funding as part of the California Solar Initiative for a project entitled "Standard Communication Interface and Certification Test Program." The project is centered on the development and field-demonstration of smart inverters. These inverters include grid-supportive functionality and an open standard communication interface. The project is being conducted in parallel with ongoing activities in California to revise the Rule 21 interconnect guidelines for distributed energy resources. This revision process produced draft functional and communication requirements that have served to establish the scope for this demonstration project.

The technical approach involves implementing the IEC 61850 standard smart inverter functions using the SunSpec data model and Modbus protocol over the CEA-2045 plug interface. The project plan includes connecting these inverters in a variety of communication systems to assess interoperability and flexibility.

This document is a result of the project. It is a technical specification that describes how the SunSpec data models and Modbus protocol are to be used to support each of the functions involved. This includes both monitoring and management uses. The intended audience for this paper includes inverter manufacturers intending to deliver CA Rule 21-compliant "Smart Inverter" products into the California market and network integrators needing to interact with and control Distributed Energy Resources (DER) containing these products.

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Specifically, this document identifies which functions are in scope, which SunSpec information models must be implemented, optional information models that are recommended for additional interoperability, and the relationship between these models and the physical communication interface that links smart inverters to communication networks. This project does not include any storage devices, so details pertaining to storage-specific uses are not included.

It is assumed that readers of this document are familiar with data communication systems in general, and the Modbus communication protocol in particular. For more information on the Modbus protocol, visit the Modbus website.[2]

As of this writing, there has not been a final ruling on CA Rule 21 technical recommendations. As a result, the project team has assumed that the draft CA Rule 21 technical recommendations that have been put forth in a joint motion to the California Public Utility Commission will be adopted. To the extent that this assumption is not accurate, this document will require revision.

[2] http://www.modbus.org/

Communication Interface Approach

The communication interface approach used for this project is comprised of a set of SunSpec information models described later in this document, a transport network protocol (Modbus), and a physical communication interface. This concept is illustrated in Figure 1-1.

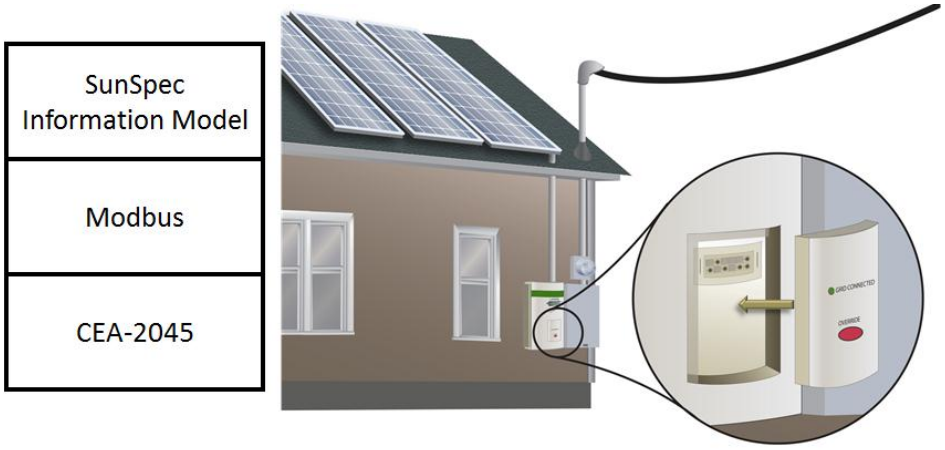

Figure 1-1, Communication Interface Layers and Concept

The CA Rule 21 technical recommendations[3] identify three implementation phases:

- Phase 1: Autonomous functions. Parameters associated with Phase 1 functions are set in the inverter factory. Accordingly, while it is convenient that smart inverters have communication capabilities for testing purposes, communication capabilities need not be present in field-installed units in order to comply with Phase 1 requirements.
- Phase 2a: Communication capabilities for DER functions. In Phase 2a, communication capabilities must be present in field-installed smart inverters. This document describes communication capabilities that are anticipated to be compliant with Phase 2a requirements, including SunSpec information models and the CEA-2045 modular (physical) communication interface.
- Phase 2b: DER functions requiring communication capabilities. Phase 2b describes DER functions that rely on communication capabilities in smart inverters in order to be managed. This document describes many of these functions and how they can be managed via communication.

California Rule 21 communication requirements are introduced in Phase 2 of the CA Rule 21 Technical Recommendations. However, in order to facilitate test automation of Phase 1 requirements, the technical recommendations also suggest that smart inverters support communication as part of Phase 1.

[3] http://www.energy.ca.gov/electricity_analysis/rule21/

SunSpec Information Model

The International Electrotechnical Commission (IEC) 61850-90-7 smart inverter functions and model are a reference point for the CA Rule 21 revision process. The SunSpec information models are based on this IEC 61850 standard. These information models are described in three SunSpec interoperability specifications that are freely available to download and use from www.sunspec.org.

- The SunSpec **Common Models** specification describes how information models, including those for smart inverters, are organized, constructed, and presented for use.
- The SunSpec **Inverter Monitoring Models** specification describes how parameter values and status codes are read on smart inverters.
- The SunSpec **Inverter Control Models** specification describes how parameter values and status codes are written to smart inverters.

CA Rule 21 Profile Information Models

The parameters and values referenced in each of the aforementioned SunSpec Information Models are contained in the Protocol Information Conformance Statement (PICS). This file is named "SunSpec Specification - PICS - A12033-1.1.xlsb" and is also freely available to download and use.[4]

As described generally in the SunSpec **Common Models** specification, and in detail here, a SunSpec-based CA Rule 21 Smart Inverter must contain the mandatory models identified in Table 1-1 to support all required functionality. This information is typically encoded in a standard Modbus map.

[4] www.sunspec.org

Table 1-1, SunSpec Mandatory Models

Model ID	Model Name	Note
1	Common Model	Mandatory. Contains manufacturer name, model number, serial number, and version information.
101, 102 or 103	Inverter Model	Mandatory. Contains basic monitoring info such as inverter status values, event flags, and power output for single phase and three phase inverters.
120	Nameplate Ratings	Mandatory.
121	Basic Settings	Mandatory.
122	Extended Measurements	Mandatory.
123	Immediate Controls	Mandatory.
126	Volt-VAr Arrays	Mandatory.
129	Low Voltage Ride Through (Must Disconnect)	Mandatory.
130	High Voltage Ride Through (Must Disconnect)	Mandatory.
132	Volt-Watt	Mandatory.
134	Frequency-Watt Curve	Mandatory.
135	Low Frequency Ride Through	Mandatory.
136	High Frequency Ride Through	Mandatory.
137	Low Voltage Ride Through (Must Remain Connected)	Optional.
138	High Voltage Ride Through (Must Remain Connected)	Optional.
139	Rule 21 Extensions	Optional. This model is added to capture Rule 21 requirements that have not already been defined.
65535	End Device Model	Mandatory.

Note: For inverters with advanced computational capabilities, SunSpec also provides “C” and Python Application Programming Interfaces (API’s). Users of these interfaces are relieved from the details of Modbus programming and instead interact with familiar data structures and classes that expose device properties as named attributes with well-defined operations for implementation of monitoring and control applications.

2 COMMUNICATION BASICS

For the approach used in this project, inverters shall support the CEA-2045 modular connector interface (the AC form factor) and Modbus/RTU over the RS-485 physical layer. Inverters may also support the CEA-2045 link layer but it is not required for this demonstration. See the CEA-2045 standard[5] for more details.

To establish communication with inverters complying with the aforementioned communication requirements, follow these steps.

Communications Interface

Smart inverters are accessed by utility- and operational networks via the CEA-2045 interface port on the inverter system. Use these settings to enable access:

- Serial port parameters: 19200 baud, 1 stop bit, and no parity
- Modbus parameters: RTU protocol at Modbus slave ID 1

Modbus Map Location

As specified by SunSpec, the Modbus map supported by the inverter is accessed with the holding register function (3) and is located at one of three base addresses:

- 0
- 40000
- 50000

A base address of 40000 is recommended.

Modbus Map Layout

The Modbus map consists of an initial SunSpec marker string followed by a series of SunSpec specified information models. Information is read and written to the Modbus register locations as specified in the information models.

To determine the specific location of any specific Modbus register, a discovery process must be performed to determine the Modbus address offset of each model present in the device. The first two registers of a SunSpec Modbus map contain the well-known values of: 0x5375 and 0x6e53 (ASCII representation of 'SunS').

Following the initial marker is the set of SunSpec information models. Each information model starts with two registers containing the model ID and length of the model, respectively. The

[5] www.ce.org/CorporateSite/media/Standards-Media/Standards Listings/ANSI-CEA-2045-Preview.pdf

offset of each data point in the model is determined from the model definition associated with the model ID.

Using the length field of each model, the Modbus map can be traversed to determine all the models present in the Modbus map and the actual Modbus address of each model. It is not necessary to understand the contents of any particular model to complete the discovery process. The map is terminated with a model ID of 0xffff and length of 0. The standard SunSpec definition mechanism for information models is the SunSpec Model Definition XML (SMDX) encoding. Each model is defined in XML encoding for programmatic access and is contained in an SMDX file with the name reflecting the model ID of the model. The SMDX representation of all the models used in the inverter devices are available for download from the SunSpec website. For convenience, an Excel spreadsheet of SunSpec model information (SunSpec Specification - PICS - A12033-1.1.xlsb) is also available. Each tab in the spreadsheet represents the contents of the respective model.

The specific models (and associated documents) that are related to the functionality identified in the draft CA Rule 21 revisions are outlined below. Those documents contain the information required to invoke the functionality provided by the specific model.

3 CA RULE 21 FUNCTIONS AND ASSOCIATED SUNSPEC INFORMATION MODEL DETAILS

The SunSpec information models used in smart inverter devices provide flexibility regarding the type and amount of device functionality. To ensure required functionality is present, and to enhance device interoperability, specific values are specified within the information models in the following sections. Refer to the specific information model definitions for the complete context of the data point values being specified.

CA Rule 21 Phase 1 Functions

Anti-Islanding Protection

Anti-islanding protection is beyond the scope of SunSpec. Enablement of any advanced functions shall not break the anti-islanding projections.

Low/High Voltage Ride Through

Use SunSpec models 129,130,137,138.
The L/HVRT function provides for a set of four separate curves to define High/Low Must Remain Connected and Must Disconnect regions of operation.
Implementations shall support a minimum of four voltage ride-through curve sets with a maximum of 10 points per curve (recommended: exactly 10 points). Curves may be pre-programmed at the factory and may be read-only.
The region between the "Must Disconnect" and "Must Remain Connected" curves shall be the "Momentary Cessation" region. Equipment shall follow the Soft-Start Ramp-Up rate (or default MaxRmpRte) upon transition from "Momentary Cessation" to "Continuous Operation" mode. Equipment that disconnects shall follow the Soft-Start procedures.

Procedures

1. Curve Information
    a. (8) NCrv. Number of curves supported. Shall be >= 4.
    b. (9) NPt. Maximum number of points per curve. Shall be 10 (recommended: exactly 10 points).
    c. (10) Tms_SF. Scale factor for duration. Shall be -3.
    d. (11) V_SF. Scale factor for %VRef. Shall be -3.
2. For each curve in the set {129,130,137, 138}, program the desired curve.
    a. Curves begin at offset 13 with each curve being exactly 50 registers long.
    b. Curve Settings
        i. (13) ActPt. Actual number of points for this curve. Shall be <= 10 (recommended: exactly 10 points).
        ii. (14-53) <Tms,%VRef>. 10 data points of time (Secs) .vs. voltage (%VRef). Shall be zero padded if ActPt < 10..
        iii. (54) CrvNam. 16-character common name of the curve
        iv. (62) ReadOnly. Non-zero value indicates this curve is pre-programmed from the factory as read-only. Subsequent curves may be user settable.

3. Function Enablement. Curves shall be enabled in a set.
    a. (3) ActCrv, active curve. Default 0, Range 0-NCrv. Note: 0 means no active curve.
    b. (4) ModEna, mode enable. Default 0, Range 0/1. Note: Disable/Enable. Mode is enabled immediately.
4. Function Status (Model 122). Determine if function is enabled and active.
    a. () StActCtl, Active control bit mask, Bits: (7)LVRT, (8)HVRT
    b. () RtSt, Ride-Through Status bit mask, Bits: (0)LVRT_ACTIVE, (1)HVRT_ACTIVE

Low/High Frequency Ride-Through

Use SunSpec models 135,136
The L/HFRT function provides for a set of two separate curves to define High/Low Must Disconnect regions of operation.
Implementation shall support a minimum of four frequency ride-through curve sets with a maximum of 20 points per curve. Curves may be pre-programmed at the factory and may be read-only.

Procedures

1. Curve Information
    a. (8) NCrv. Number of curves supported. Shall be >= 4.
    b. (9) NPt. Maximum number of points per curve. Shall be 10 (recommended: exactly 10 points).
    c. (10) Tms_SF. Scale factor for duration. Shall be -3.
    d. (11) Hz_SF. Scale factor for Hz. Shall be -3.
2. For each curve in the set {135,136}, program the desired curves.
    a. Curves begin at offset 13 with each curve being exactly 50 registers long.
    b. Curve Settings
        i. (13) ActPt. Actual number of points for this curve. Shall be <= 10 (recommended: exactly 10 points).
        ii. (14-53) <Tms,%VRef>. 10 data points of time (Secs) .vs. voltage (%VRef). Shall be zero padded if ActPt < 10.
        iii. (54) CrvNam. 16-character common name of the curve.
        iv. (62) ReadOnly. Non-zero value indicates this curve is pre-programmed from the factory as read-only. Subsequent curves may be user settable.
3. Function Enablement. Curves shall be enabled in a set.
    a. (3) ActCrv, active curve. Default 0, Range 0-NCrv. Note: 0 means no active curve.
    b. (4) ModEna, mode enable. Default 0, Range 0/1. Note: Disable/Enable. Mode is enabled immediately.
4. Function Status (Model 122). Determine if function is enabled and active.
    a. () StActCtl, Active control bit mask, Bits: (13)LFRT, (14)HFRT
    b. () RtSt, Ride-Through Status bit mask, Bits: (2)LFRT_ACTIVE, (3) HFRT_ACTIVE

Volt-VAr Mode with Watt Priority

Use SunSpec model 126

Volt-VAr mode is provided through curve-based control of reactive power based on voltage. Reactive power may be supplied as a percentage of real power, maximum reactive power, or available reactive power. Watt priority mode provides available reactive power without sacrificing watts.

Implementations shall support a minimum of four Volt-VAr Mode curves with a maximum of 10 points per curve. Curves may be pre-programmed at the factory and may be read-only. Implementations shall allow for at least one field programmable curve.

Procedures

1. Curve Information
    a. (8) NCrv. Number of curves supported. Shall be >= 4.
    b. (9) NPt. Maximum number of points per curve. Shall be 10 (recommended: exactly 10 points).
    c. (10) V_SF. Scale factor for % of VREF. Shall be -3.
    d. (11) DeptRef_SF. Scale factor for dependent reference (VArAval). Shall be -3.
    e. (12) RmpIncDec_SF. Scale factor for increment and decrement ramp rates. Shall be -3.
2. For each curve, program the desired curve.
3. Curves begin at offset 13 with each being exactly 54 registers long.
4. Curve Settings
    a. (13) ActPt. Actual number of points for this curve. Shall be <= 10 (recommended: exactly 10 points).
    b. (14) DeptRef. Meaning of DeptRef. Shall be 3=%VArAval, 2=%VARtg, or 1=%WMax. Note: VArAval is the preferred mode.
    c. (15-54) <%VRef, DeptRef>. 20 data points of voltage (%VRef) .vs. % Available VArs. Shall be zero padded if ActPt < 10.
    d. (55) CrvNam. 16 character common name of the curve.
    e. (63) RmpTms. The time of the PT1 in seconds.
    f. (64) RmpDecTmm. The maximum rate at which the VAr value may be reduced in response to voltage changes. Note: 0 means no limit.
    g. (65) RmpIncTmm. The maximum rate at which the VAr value may be increased in response to voltage changes. Note: 0 means no limit.
    h. (66) ReadOnly. Non-zero value indicates this curve is pre-programmed from the factory as read-only. Subsequent curves may be user settable.
5. Function Enablement. Select the active curve and enable the function.
    a. (3) ActCrv, active curve. Default 0, Range 0-NCrv. Note: 0 means no active curve.
    b. (4) ModEna, mode enable. Default 0, Range 0/1. Note: Disable/Enable. Mode is enabled immediately.
6. Function Status (Model 122). Determine if function is enabled and active.
    a. () StActCtl, Active control bit mask, Bit: (3)Volt-VAr

Ramp Rates

Use SunSpec models 121, 139

The California IOUs propose establishing two types of ramp-up rates for use by different functions. The California Smart Inverter Work Group (SIWG) states "… although they may be implemented as one general ramp rate …"

1. Nominal ramp-up/down.
2. Soft-start connect ramp-up/down.

SunSpec Model 121 Basic Settings defines the default ramp rate WGra (%WMax/sec) and maximum ramp rate MaxRmpRte (%WGra) to control real power ramp up under all conditions. It is understood that the ability to ramp down is dependent on available power.

Procedures (Model 121)

1. (13) WGra, %WMax/sec. Default 100%, Range 1-1000%
2. (20) MaxRmpRte, %WGra. Default 100%, Range 1-100%.

Procedure (Model 139 CA Rule 21 Extensions)

SunSpec model 139 Rule 21 Extensions, defines additional ramp rates. This model is optional and all attributes are optional. This model provides overrides for the default MaxRmpRte per CA Rule 21 requirements. All ramp rates are expressed in terms of a percentage of the default ramp rate.

1. (3) NomRmpUpRte, %WGra. Default 100, Range 1-100%.
2. (4) NomRmpDwnRte, %WGra. Default 100, Range 1-100%.
3. (7) StrtRmpRte, %WGra. Default 2, Range 1-100% Default ramp up rate for commanded or soft reconnect.
4. (8) StopRmpRte, %WGra. Default 2, Range 1-100%. Default ramp down rate for commanded disconnect.

Fixed Power Factor

Use SunSpec model 123
Provide reactive power at a fixed power factor to offset reactive loads on a circuit.

Procedures (Model 123)

1. (11) OutPFSet. Default 1. >15kW: Range -0.850 <-> +0.850, <=15kW: Range -0.900 <-> +0.900. Note: EEI/IEEE sign convention is used.
2. (25) OutPFSet_SF. Range: Shall be -3.
3. (12) OutPFSet_WinTms. Default 0. Range 0 – 1 min. Note: 0 means do not wait.
4. (13) OutPFSet_RvrtTms. Default 0. Range 0 – 8 hours. Note: 0 means do not revert.
5. (14) OutPFSet_RmpTms. Default 0. Range 0 – 1 min. Note: 0 means no ramp limit.
6. (15) OutPFSet_Ena. Default 0. Range 0/1. Note: Disable/Enable Fixed Power Factor mode.

Soft Start

Use SunSpec model 121, 123, 139
Soft Start addresses requirements for re-energizing the circuit following a power outage and applies equally to a commanded "Connect" (Phase 3).

Procedures (Model 121)

1. (20) MaxRmpRte. The default ramp rate is used barring any soft overrides.

Procedures (Model 123)

1. (3) ConnWinTms, randomization window prior to re-energizing. Default 0. Range 0-300. Note: 0 means do not wait.

Procedures (Model 139 CA Rule 21 Extension)

1. (7) StrtRmpRte, The default ramp up rate for reconnect is used barring any soft overrides.
2. (8) StpRmpRte, The default ramp down rate for commanded disconnect.
3. (9) ConnDly. Default 300 secs, Range 1 – 600. Note: Amount of time to delay before attempting to reconnect after any outage.

CA Rule 21 Phase 2 Functions

Data Model

The data model shall be derived from the IEC 61850 model and shall include Nameplate, Settings, Controls, Measurements, and Status information elements. SunSpec models comply with this definition.

Procedures

None. This requirement applies broadly to all the models. Implementations shall conform to this profile.

Monitor Alarms

Use SunSpec model 101, 102, or 103
Implementations must provide alarms and supporting emergency information. Note: There are no alarms defined in CA Rule 21 at this time.

Procedures (Model 10x)

1. (39) St. Note: see enumeration of status values defined by SunSpec.
2. (41) Evt1. Note: see bitmask of events defined by SunSpec.

Monitor DER Status and Output

Use SunSpec models 101, 102, 103, 122
Implementations must provide current status, power measurements, etc.
(Note: There are no statuses defined in CA Rule 21 at this time.

Procedures (Model 101, 102, 103)

The following values shall be implemented. See SunSpec Model 10x for details.
Note: Some optional values are included in this list as required. Other optional values may be included.

1. (4-7) A, phase currents.
2. (11-14) PPV, phase voltages.
3. (15,16) W, real power.

4. (17,18) Hz, frequency.
5. (19,20) VA, apparent power.
6. (21,22) VAr, reactive power.
7. (23,24) PF, power factor.
8. (25,27) Wh, lifetime energy.
9. (34) TmpCab, cabinet temperature.
10. (39) St. Note: see enumeration of status values defined by SunSpec.

Procedures (Model 122)

1. (3) PVConn, PV connected (inverter available).
2. (5) ECPConn, inverter connected.
3. (30,31) VArAval, available VArs.
4. (32,33) WAval, available Watts.
5. (34) StSetLimMsk. Bitmask status indicating setpoint limits reached.
6. (35) StActCtl, Bitmask status indicating active controls.
7. (44) RtSt. Bitmask status indicating active ride-through event.

4 CA RULE 21 PHASE 3 FUNCTIONS

Limit Maximum Real Power

Use SunSpec model 123
Limit Maximum Real Power is a direct command to limit the maximum real power output of the inverter. The inverter must not exceed the percentage of rated power specified on an available basis.

Procedures (Model 123)

1. (6) WMaxLimPct, WMax%.
2. (24) WMaxLimPct_SF, scale factor shall equal 0.
3. (10) WMaxLimEna, enable mode. Default 0. Range 0/1. Note: Disable/Enable.

Connect / Disconnect

Use SunSpec model 123
A direct command to disconnect or (re)connect the inverter at the electrical coupling point. A transfer trip map may occur.

Procedures

1. Conn_WinTms, randomization window. Default 0. Range: 0 – 5 minutes. Note: 0 means do not wait.
2. Conn_RvrtTms, revert time. Default 0. Range: 0 – 8 hours. Note: 0 means do not revert.
3. Conn, connection control. Default 1. Range: 0/1. Note: Disconnect/Connect.

Provide DER Information at Interconnection / Startup

Use SunSpec model 1, 120
Provide nameplate ratings.

Procedures (Model 1)

1. (5) Mn, Manufacturer. Max 32 character String.
2. (21) Md, Model. Max 32 character String.
3. (45) V, Version, Max 16 character String.
4. (53) SN, Serial Number. Max 32 character String.

Procedures (Model 120)

1. (3) DERTyp, type of DER. Default 4 (PV).
2. (4,5) WRtg, Watt Rating.
3. (6,7) VARtg, VA Rating.
4. (8) VArRtgQ1, VAr Rating for Q1.
5. (11) VArRtgQ4, VAr rating for Q4.
6. (12) VArRtg_SF, VAr rating scale factor. Scale factor shall be 3 (kVAr).

7. (13, 14) ARtg, Amp Rating.
8. (15) PFRtgQ1, power factor rating for Q1.
9. (18) PFRtgQ4, power factor rating for Q4.
10. (19) PFRtg_SF, power factor rating scale factor. Scale factor shall be -2.

Initiate Periodic Tests of Software and Patches

This is vendor specific.
Note: This is critical issue for the industry and is a good candidate for standardization. The SunSpec Alliance is currently working standard for delivery of binary firmware/configuration payload (the payload content itself will be manufacturer specific). Rather than updating individual settings, only permit updating via a system update (i.e. firmware or configuration). Vendors/operators will test a configuration before pushing new settings.

Frequency-Watt Mode

Use SunSpec model 134
Adjust real power output in response to frequency deviation.

Procedures (Model 134)

1. Curve Information
    a. (8) NCrv, Number of curves supported. Shall be >= 4.
    b. (9) NPt, maximum number of points per curve. Shall be 10 (recommended: exactly 10 points).
    c. (10) Hz_SF, hertz scale factor. Note: scale factor shall be -2
    d. (11) W_SF, watt scale factor. Note: scale factor shall be -2.
2. For each curve, program the desired curve.
3. Curves begin at offset 13 with each being exactly 58 registers long.
4. Curve Settings
    a. (13) ActPt. Actual number of points for this curves. Shall be <=10 (recommended: exactly 10 points).
    b. (14-53) <Hz, %WRef>. 20 data points of Hz .vs. %WRef. Shall be zero padded if AcPt < 20.
    c. (54) CrvNam. Curve Name. Max 16 character String.
    d. (70) ReadOnly. Non-zero value indicates this curve is pre-programmed from the factory as read-only. Subsequent curves may be user settable.
5. Curves may be pre-programmed at the factory and may be read-only. Read only curves shall be indicated by the ReadOnly register value of 1.
6. Function Enablement. Select the active curve and enable the function.
    a. (3) ActCrv, active curve. Default 0, Range 0-NCrv. Note 0 means no active curve.
    b. (4) ModEna, mode enable. Default 0, Range 0/1. Note: Disable/Enable. Mode is enabled immediately.

Voltage-Watt Mode

Use SunSpec model 132
Adjust real power output in response to voltage deviation.

Procedures (Model 132)

1. Curve Information
    a. (8) NCrv, Number of curves supported. Shall be >= 4.
    b. (9) NPt, maximum number of points per curve. Shall be 10 (recommended: exactly 10 points).
    c. (10) V_SF, voltage scale factor. Note: scale factor shall be 0.
    d. (11) DeptRef_SF, dependent reference scale factor. Note: scale factor shall be -2.
2. For each curve, program the desired curve.
3. Curves begin at offset 13 with each being exactly 54 registers long.
4. Curve Settings
    a. (13) ActPt. Actual number of points for this curves. Shall be <=10 (recommended: exactly 10 points).
    b. (14) DeptRef. Meaning of DeptRef. Shall be 1 = %WMax.
    c. (15-54) <V, DeptRef>. 10 data points of Voltage .vs. %WMax. Shall be zero padded if AcPt < 20.
    d. (55) CrvNam. Curve Name. Maximum 16-character String.
    e. (66) ReadOnly. Non-zero value indicates this curve is pre-programmed from the factory as read-only. Subsequent curves may be user settable.
5. Curves may be pre-programmed at the factory and may be read-only. Read only curves shall be indicated by the ReadOnly register (offset 62) value of 1.
6. Function Enablement. Select the active curve and enable the function.
    a. (3) ActCrv, active curve. Default 0, Range 0-NCrv. Note 0 means no active curve.
    b. (4) ModEna, mode enable. Default 0, Range 0/1. Note: Disable/Enable. Mode is enabled immediately.

Scheduling of Operations

The Joint IOU filing does not mention scheduling. The SunSpec Scheduling model is under development and will be included in a future revision.

5 CA RULE 21 RESOURCES

For definitive information about California Rule 21, the work of the California Smart Inverter Working Group, and its work product, please see http://www.energy.ca.gov/electricity_analysis/rule21/.