DER Information Model and UL1741 Supplement SA Interoperability Report

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ABSTRACT

This document outlines the current state of prominent DER communication information models relative to relevant grid requirements and outlines possible updates to achieve better harmonization. The information presented is believed to be accurate as of the publication date but will likely become inaccurate as the various referenced standards are updated. When these updates occur, SunSpec will update this document accordingly.

Change History

D-1: Initial draft.

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1 Introduction

This document outlines the interoperability of the prominent distributed energy resources (DER) communication information models in relation to relevant grid requirements. These information models provide the mechanism for implementing standardized communication with DER.

It is anticipated that communications functionality in a system containing DER may be comprised of a communications path consisting of different protocols and information model types. It is important for interoperability and data fidelity that the information models used in the communications path be harmonized as much as possible.

The initial focus of the report is on the functional requirements outlined in UL1741 SA which is used as a basis for implementation of California Rule 21 and Hawaii Rule 14H grid requirements. The information models considered in this report are: IEC 61850-7-420/520, IEEE 2030.5 (SEP2), SunSpec Alliance, and the IEEE 1815 (DNP3) Application Note.

This report is not intended to provide a detailed description of the DER functionality but is intended to describe implementation differences between the information models of the relevant standards and their compliance with the grid standard being considered.

The report is intended to be an ongoing summary of communication functionality related to important requirements associated with DER deployment and will be updated regularly.

2 U.S. Grid Codes

In the U.S., there are a number of grid code requirements. In general, most states have adopted IEEE Std. 1547 as the interconnection for their state. However, in some cases (CA, HI), the states have drafted additional requirements for interconnection in their jurisdictions.

2.1 IEEE 1547

IEEE 1547-2003[1] currently does not include any advanced grid functions.

2.2 CA Rule 21

California Rule 21 Phase 1 functionality includes the following functions:

- Anti-Islanding Protection

[1] *IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems*, IEEE 1547-2003

- Low/High Voltage Ride-through
- Low/High Frequency Ride-through
- Normal Ramp Rate
- Soft-Start Ramp Rate
- Fixed Power Factor
- Volt-Var Mode

These functions are mapped to the UL 1741 SA required functions.

Rule 21 specifies specific values for L/HVRT and L/HFRT.

Anti-Islanding is also required but does not have any settings associated with an information model.

2.3 Hawaii Rule 14H Requirements

Hawaiian grid codes will require all of the UL1741 SA functions as well as:

- Connect/disconnect

There are several sets of L/HVRT and L/HFRT settings based on location.

Remote configurability is required and is interpreted as including the capability to change settings for any of the required functions.

Anti-Islanding and Transient Overvoltage (TrOV-2) are also required but do not have any settings associated with an information model.

3 Certification Standards

3.1 UL 1741 Supplement SA

UL 1741 SA specifies a set of DER grid support functions that are currently not covered in IEEE 1547. The functionality contained in UL1741 SA addresses the initial requirements identified in California Rule 21 and most of the requirements identified in Hawaii Rule 14H.

UL 1741 SA does not identify any DER communications requirements. This analysis is based on providing the adjustable parameters specified in UL 1741 SA over a communications interface using the information models of the identified standards.

3.2 IEEE 1547.1

The testing protocols in 1547.1 are being revised for DER grid-support functions.

These test protocols may also include interoperability tests in future revisions.

4 Information Model Overview

4.1 IEC 61850

The IEC 61850 information models associated with DER are described in the IEC 61850-7-420[2] and IEC 61850-7-520[3] documents. IEC 61850-7-420 defines the information models for DER and IEC 61850-7-520 provides a conceptual description and usage guidelines for the DER information models.

Both 61850-7-420 and 61850-7-520 are currently under revision.

The assessment in this document is based on the versions under revision and not the published standard.

4.2 IEEE 2030.5 (SEP 2)

The original SEP 2.0 specification is now supported as IEEE 2030.5[4]. The information models referenced in this document are contained in that specification.

The IEEE 2030.5 specification is currently under revision.

The assessment in this document is based on the versions under revision and not the published standard.

4.3 SunSpec

The SunSpec information models associated with DER are described in the SunSpec Information Model Reference[5] and Proposed Addition SunSpec Models[6].

Also see *SunSpec UL1741 Supplement SA Implementation Guide* for detailed information about using SunSpec information models for UL1741 Supplement SA support. This guide is based on draft versions of the UL1741 Supplement SA specification and will be updated once the UL1741 Supplement SA specification is approved.

4.4 IEEE 1815 (DNP3) Application Note

The DNP3 information models[7] associated with DER are currently described in the draft DNP3 application note, *Draft DNP3 Profile for DER Communications*[8]. The

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[2] *IEC 61850 Basic Communication Structure - Distributed Energy Resources Logical Nodes*, IEC 61850-7-420, Edition 1.0. (Edition 2.0 is in Draft)

[3] *IEC 61850 Basic Communication Structure - Distributed Energy Resources Modeling Concepts and Guidelines*, IEC 61850-7-520, Edition 1.0, Draft

[4] *IEEE Adoption of Smart Energy Profile 2.0 Application Protocol Standard,* IEEE 2030.5-2013

[5] *SunSpec Information Model Reference*. Retrieved from http://www.sunspec.org/download.

[6] *SunSpec UL1741 Supplement SA Implementation Guide*. Retrieved from http://www.sunspec.org/download.

[7] *DNP3 Profile for Advanced Photovoltaic Generation and Storage*, DNP3 Application Note AN2013-001

[8] *DNP3 Profile for DER Communication, Draft*

application note is currently undergoing revision. The assessment is this document is based on the revision and not on the currently published application note.

A goal of the DNP3 implementation is the map the naming and functionality as closely as possible to IEC 61850-7-420.

4.5 Information Model Implementation Summary

This section summarizes the information models support for UL1741 Supplement SA functions.

Table 1 – UL 1741 Supplement SA Summary

Function	CA	HI	IEC 61850	IEEE 2030.5	SunSpec	DNP3
L/HVRT	x	x	Note 1	Note 4	Y	Note 7
L/HFRT	x	x	Note 2	N	Y	Note 7
Normal Ramp Rate	x	x	Y	Note 5	Y	Note 5
Soft-Start Ramp Rate	x	x	Y	N	Y	N
Specified Power Factor	x	x	Y	Y	Y	Y
Volt/Var Mode	x	x	Y	Y	Y	Y
Frequency/Watt Param			Y	N	Y	N
Volt/Watt			Note 3	Note 3	Note 3	Note 3
Connect/Disconnect		x	Y	Note 6	Y	Y

Note 1: The 61850-7-420 information model definitions do not specify the valid curve types within the regions and do not specify how the curves within a region are identified.

The momentary cessation region is not considered in the 61850-7-520 general description or 61850-7-420 information model definitions.

Note 2: The 61850-7-420 information model definitions do not specify the valid curve types within the regions and do not specify how the curves within a region are identified.

Note 3: Open issue: Can the UL1741 volt/watt function can be specified with a generic piece-wise linear curve? How is rate of return to normal operation handled in that case?

Note 4: The 2030.5 specification does not support the momentary cessation region.

Note 5: Ramp rate is specified as applying to changes in active power and is specified as a percentage of maximum power. UL1741 specifies the ramp rate as applying to changes in current and is expressed as a percentage of rated current.

Note 6: Connect/Disconnect is implemented as a setting rather than a control. Implementation as a control should be considered.

Note 7: The DNP3 draft has been updated to extend the functionality specified in 61850 by specifying each curve explicitly but needs further consideration based on the coordination of ride-through information in general.

4.6 Recommendations

This section outlines a set of recommendations based on the analysis of the information models considered.

4.6.1 Develop a uniform terminology and representation for ride-through/trip settings

There is a general need to consolidate the terminology used for ride-though/trip functionality including the naming and exact specification of the curves associated with the related regions.

4.6.2 Update the respective information models in each standard to address noted and unimplemented items in the summary

The summary analysis outlines functionality that is only partially compliant or unimplemented relative to UL1741 Supplement SA. It is necessary to update the information models of the respective standards to achieve harmonization with the requirements and across the information models.

4.6.3 Determine compatibility of ramping based on current and ramping based on power

Is it necessary to support ramp settings based on both current and power or are they effectively the same thing? See Note 5.

5 Information Model Detail

This section provides overview information about the information models associated with each standard and more a detailed description of the implementation of the relevant functionality.

5.1 Mode Invocation Timers

Some information model modes support invocation timers. Invocation timers relate to enabling and terminating a mode. These timers do not affect the mode operation once it is active. All mode invocation timers are optional.

5.1.1 IEC 61850

This section describes the invocation timers that may be optionally supported.

5.1.1.1 Time Window (WinTms)

The time window in seconds within which to randomly start the mode. If the time window is zero, the command is executed immediately.

5.1.1.2 Reversion Time (RvrtTms)
Timeout period in seconds after which the DER reverts to its default behavior for the mode. If the reversion time is zero, there is no timeout period.

5.1.1.3 Ramp Time (RmpTms)
Ramp time is seconds for moving from current operational mode settings to new operational mode settings. The invocation ramp time only apples during the initial enabling of the function.

5.1.2 IEEE 2030.5
IEEE 2030.5 supports the RmpTms invocation timer (as rampTms).

5.1.3 SunSpec
SunSpec supports the same mode invocation timers as IEC 61850.

5.1.4 DNP3
The DNP3 application note supports the same mode invocation timers as IEC 61850.

5.1.5 Mode Ramp Rates
This section describes the mode specific ramping that may be used while the mode is enabled. Support for all mode ramp settings is optional.

5.1.5.1 Ramp Time (RmpPt1Tms)
The time in seconds the function requires reaching 95% of the grid voltage change (3 times the RC time constant).

5.1.5.2 Ramp Rate Decrease (RmpDecTmm)
The maximum rate at which the dependent value (output) may be reduced in response to changes in the independent value (input). This is represented in terms of % of Reference value (e.g. WMax) per minute.

5.1.5.3 Ramp Rate Increase (RmpIncTmm)
The maximum rate at which the dependent value (output) may be increased in response to changes in the independent value (input). This is represented in terms of % of Reference value (e.g. WMax) per minute.

5.1.6 IEEE 2030.5
IEEE 2030.5 supports the same mode specific ramp rates as IEC 61850.

5.1.7 SunSpec
SunSpec supports the same mode specific ramp rates as IEC 61850.

5.1.8 DNP3
The DNP3 application note supports the specific ramp rates as IEC 61850.

5.2 L/HVRT

There is a general need to consolidate the terminology used for ride-though/trip functionality including the naming and exact specification of the curves associated with the related regions.

5.2.1 IEC 61850

The functional description describes a Must Disconnect (MD) curve and a Must Remain Connected (MRC) curve for both low and high voltage. The curve components are time in seconds and voltage in percentage units.

The information model definitions provide curve enumerations and enable/disable for low and high voltage ride-though.

Voltage percentage is defined as percentage of nominal voltage.

The mode and curve is specified in DGSM and FMAR. Curve types are enumerated in CurveModeKind.

5.2.2 IEEE 2030.5

High and low voltage ride-through settings are specified as piece-wise linear curves. Supports curves for "must disconnect" and optionally for "must remain connected". The curve components are time in seconds and voltage in percentage units.

Voltage percentage is defined as (100% * (locally measured voltage - setVRefOfs)/setVRef).

The opModHVRT and opModLVRT attributes in DERControl are used to specify the voltage ride-through curves.

5.2.3 SunSpec

High and low voltage ride-through settings are specified as piece-wise linear curves. Supports curves for must disconnect, must remain connected, and cease to energize. The curve components are time in seconds and voltage in percentage units.

Voltage percentage is specified as percentage of VRef.

SunSpec models 129, 130, 137, 138, 139, and 140 are used to specify the curves.

5.2.4 DNP3

The DNP3 draft has been updated to extend the functionality specified in 61850 by specifying each curve explicitly but needs further consideration based on the coordination of ride-through information in general.

The mode and curve is specified in AO.DGSMn.ModTyp, AO.FMARn.

5.3 L/HFRT

There is a general need to consolidate the terminology used for ride-though/trip functionality including the naming and exact specification of the curves associated with the related regions.

5.3.1 IEC 61850

Provides curve definitions for low and high frequency ride-though. Does not specify the valid curves within the low and high frequency region. Does not specify how the curves within a region are identified.

The mode and curve is specified in DGSM and FMAR. Curve types are enumerated in CurveModeKind.

5.3.2 IEEE 2030.5

Currently not supported.

5.3.3 SunSpec

High and low frequency ride-through settings are specified as piece-wise linear curves. Supports curves for must disconnect, must remain connected, and cease to energize. The curve components are time in seconds and frequency in Hertz.

SunSpec models 135, 136, 141, 142, 143, and 144 are used to specify the curves.

5.3.4 DNP3

The DNP3 draft has been updated to extend the functionality specified in 61850 by specifying each curve explicitly but needs further consideration based on the coordination of ride-through information in general.

The mode and curve is specified in AO.DGSMn.ModTyp, AO.FMARn.

5.4 Normal Ramp Rate

UL 1741 specified the ramp rate as being based on change in current, expressed as a percentage of rated current. Is it permissible to use active power for the test instead of current if current is not supported?

5.4.1 IEC 61850

The default ramp for change in active power is specified as a percentage of the maximum power output per second.

An alternate ramp is defined based on current rather than power. The ramp rate is specified as a percentage of maximum current per second.

DRCT.WGra is the default ramp rate for changes in power. DRCT.AGra is the default ramp rate for changes in current.

5.4.2 IEEE 2030.5

A default ramp rate for changes in active power can be specified. The ramp rate units are % of maximum power setting per second.

The ramp rate setting is specified in setGradW in the DERSettings object. The valid range is 1 – 20000.

5.4.3 SunSpec

A default ramp for change in active power is specified as a percentage of the maximum power output per second.

An alternate ramp is defined based on current rather than power. The ramp rate is specified as a percentage of maximum current per second.

The default ramp for change of active power is model 121.WGra. The default ramp for change of active current is model 145.AGra.

5.4.4 DNP3

The default ramp for change in active power is specified as a percentage of the maximum power output per second.

AO.DRCT1.WGra is the default ramp rate for changes in power.

5.5 Soft Start Ramp Rate

5.5.1 IEC 61850

The soft-start ramp up rate is specified as a percentage of maximum current per second.

The soft-start ramp rate setting is DRCT.ConnRmpUpRte.

5.5.2 IEEE 2030.5

Currently not supported.

5.5.3 SunSpec

The soft-start ramp up rate is specified as a percentage of maximum current per second.

The soft-start ramp rate setting is model 145.ConnRmpUpRte.

5.5.4 DNP3

Currently not supported.

5.6 Fixed Power Factor

5.6.1 IEC 61850

The fixed power factor function is implemented as a power factor setpoint and mode enable indication. This function is described in function INV3.

The power factor setpoint is DRCT.OutPFSet and the enable indication is DOPM.OpModConsPF.

The optional mode invocation timers are available when the mode is enabled.

5.6.2 IEEE 2030.5

Fixed power factor can be specified within the range of the minimum and maximum power factor settings.

The opModFixedPF attribute in DERControl are used to specify the power factor setpoint.

The standard also states: "If issued simultaneously with other reactive power controls (e.g. opModFixedPF) the control resulting in least var magnitude takes precedence".

5.6.3 SunSpec

The fixed power factor function is implemented as a power factor setpoint and mode enable indication.

The fixed power factor setpoint is model 123.OutPFSet and mode enable is model 123.OutPFSet_Ena.

5.6.4 DNP3

The fixed power factor function is implemented as a power factor setpoint and mode enable indication.

The power factor setpoint is AO.DRCT.OutPFSet and the enable indication is xxx.

5.7 Volt/Var Mode

5.7.1 IEC 61850

The volt/var mode is implemented as a piece-wise linear curve. The var dependent reference variable units can be specified as: percent max vars, percent of max available vars, percent of maximum watts. This mode is described in modes VV11 to VV14.

The mode and curve are specified in DGSM and FMAR. Curve types are enumerated in CurveModeKind. The dependent reference parameter units are enumerated in DependentRefUnitsKind.

5.7.2 2030.5

The volt/var mode is implemented as a piece-wise linear curve. The var dependent reference variable units can be specified as: percent max vars, percent of max available vars, percent of maximum watts.

Voltage percentage is defined as (100% * (locally measured voltage - setVRefOfs)/setVRef).

The opModVoltVAr attribute in DERControl is used to specify the curve.

5.7.3 SunSpec

The volt/var mode is implemented as a piece-wise linear curve. The var dependent reference variable units can be specified as: percent max vars, percent of max available vars, percent of maximum watts.

The volt/var mode parameters are specified in model 126.

5.7.4 DNP3

The volt/var mode is implemented as a piece-wise linear curve. The var dependent reference variable units can be specified as: percent max vars, percent of max available vars, percent of maximum watts.

The mode, curve, and dependent reference are specified in AO.DGSMn.ModTyp, AO.FMARn, AO.FMARn.DepRef.

5.8 Frequency/Watt (Parameterized)

5.8.1 IEC 61850

Parametrized frequency/watt is implemented as a set of parameters governing the mode behavior. This mode is described in FW21.

The mode parameters are specified in FWHZ.

5.8.2 IEEE 2030.5

The parametrized version of frequency/watt is currently not supported.

5.8.3 SunSpec

Parametrized frequency/watt is implemented as a set of parameters governing the mode behavior.

The frequency/watt parameters are specified in model 127.

5.8.4 DNP3

Currently not supported.

5.9 Volt/Watt

5.9.1 IEC 61850

The volt/watt mode is implemented as a piece-wise linear curve. The volt/watt mode behavior is described in VW51 and VW52.

The mode and curve are specified in DGSM and FMAR. Curve types are enumerated in CurveModeKind.

The optional invocation timers are available when the mode is enabled.

The optional mode timers are available while the mode is enabled.

5.9.2 IEEE 2030.5

The volt/watt mode is implemented as a piece-wise linear curve

Voltage percentage is defined as (100% * (locally measured voltage - setVRefOfs)/setVRef). Watt percentage is defined as % of the maximum watt setting (setMaxW).

The opModVoltVAr attribute in DERControl is used to specify the curve.

5.9.3 SunSpec

The volt/watt mode is implemented as a piece-wise linear curve.

The volt/watt parameters are specified in model 132.

5.9.4 DNP3

The volt/watt mode is implemented as a piece-wise linear curve.

The mode and curve is specified in AO.DGSMn.ModTyp, AO.FMARn.

5.10 Connect/Disconnect

5.10.1 IEC 61850

This function is supported as a physical connect/disconnect from the grid. The function behavior is described in function INV1.

5.10.2 IEEE 2030.5

The connect/disconnect is supported as a setting.

The setGenConnect attribute DERSettings is used to set the connect state.

5.10.3 SunSpec

The connect/disconnect function is implemented as control setting.

The connect/disconnect indication is model 123.Conn.

5.10.4 DNP3

This function is supported as a physical connect/disconnect from the grid.

The connect/disconnect indication is xxx.