QualityLogic

WHITE PAPER:

IEC 61850 and IEEE 2030.5: A Comparison of 2 Key Standards for DER Integration:

An Update

This paper provides an overview of the IEEE 2030.5 standard and a comparison with the IEC 61850 information model for DER.

IEC 61850 and IEEE 2030.5: A Comparison of 2 Key Standards for DER Integration: An Update

James Mater
QualityLogic
Portland, OR, USA
jmater@qualitylogic.com

Steve Kang
QualityLogic
Santa Barbara, CA, USA
skang@qualitylogic.com

Robby Simpson, PhD
GE Grid Solutions
Atlanta, GA, USA
robby.simpson@ge.com

Keywords: IEC 61850-7-420, IEC 61850, IEEE 2030.5, SEP 2, IEEE 1547-2018, smart grid standards, information models, semantic models, DER, CA Rule 21

Abstract

Since we authored this paper in 2016, significant advancements in both IEEE 2030.5 and IEC 61850 have taken place. This paper is an update to the original. The IEEE 2030.5 standard (formerly known as Smart Energy Profile 2 or SEP 2) is being adopted in California as the default communications protocol for residential distributed energy resource (DER) integration applications. The IEEE 2030.5 standard is an IP-based protocol that is independent of the underlying physical transport (Wi-Fi, ZigBee, etc.) and uses the IEC 61968 data model for most of its semantics. The IEEE 2030.5 protocol adopts the IEC 61850-7-420 logical node classes for DER components. In 2018, the IEEE approved a revision to IEEE 2030.5 that adopted extensions to intended to make the standard consistent with IEC 61850 extensions for DER. The 2018 update also adopted the DER information model used by the IEEE 1547-2018 interconnection standard for DERs.

IEEE 2030.5 currently supports smart inverter functions such as the ability to limit real power output, set Volt-Watt parameters, set fixed power factor, update VAR curves, and monitor DER status, as well as the capability to manage groups of inverters such as those in a targeted feeder geography.

While IEC 61850 (and in the US, DNP3) will be important protocols for communicating with large-scale DER, the use of the IEC CIM and 61850 DER information models in IEEE 2030.5 will enable easier integration of grid-scale and local-scale DER resources.

The IEEE 2030.5 standard now has a state mandated DER profile and companion certification and testing program. The new program has approved test labs throughout the world and is attracting global DER inverter vendors, aggregators and gateway vendors with an interest in selling product into the IOUs in CA. The standard can be expected to be an important component of interoperability as new DER resources are better integrated into grid operations.

The paper provides an overview of the IEEE 2030.5 standard and a comparison with the IEC 61850 information model for DER.

Section 1 of this paper provides background on the two standards and the underlying information models.

Section 2 provides an overview of the developing application of IEEE 2030.5 for the integration of DER in the state of California in the US. It is being adopted as the default communication standard for utility communication to residential DER such as solar, storage and EV systems. Since the 2016 version of this paper, significant progress has been made and is added to the paper.

Section 3 compares IEC 61850 and IEEE 2030.5 as it is being applied in DER integration and identifies gaps between the standards. QualityLogic has participated in multiple workshops on DER communications and presented an updated comparison of the two standards.

Section 4 provides a summary of the paper along with key conclusions and observations.

1. BACKGROUND

The IEC 61850 standard has become a leading international standard for electrical system communications. While initially focused on sub-station communications, 61850-7-420 has been developed specifically for communication with DER assets outside of the substation.

IEEE 2030.5 is an evolution of ZigBee Smart Energy 1.x (SEP 1.x) and provides new capabilities such as control of plug-in electric vehicle (PEV) charging, HAN deployments in multi-dwelling units such as apartment buildings, support for multiple energy service interfaces into a single premises and support for any physical transport capable of communication using the Internet Protocol (IP), such as Wi-Fi, HomePlug, and ZigBee. It was known initially as SEP 2 because of its genesis in the ZigBee Smart Energy 1.x standard.

Work on the standard began in 2008 and it formally became an IEEE standard in 2013, adopted as IEEE 2030.5-2013. SEP 2 was selected in 2009 by the United States National Institute of Standards and Technology (NIST) as a standard for home energy management devices. In June 2016, the California Public Utilities Commission accepted the recommendation to mandate IEEE 2030.5 as the default standard for communication with smart inverters in part because of its use of the IEC 61850 information model.[1] The same information model is used by both the IEC 61850 and IEEE 2030.5 standards and provides a valuable bridge between the two standards.

The rest of this section provides detailed background and overviews of IEC 61850, IEEE 2030.5 and IEC 61968 as they relate to the integration of DER into distribution operations.

1.1. IEC 61850 Overview

IEC 61850 started during a conference in 1989 with the development of the Electric Power Research Institute (EPRI) Utility Communications Architecture (UCA). The result was a 6-volume report completed in 1991.

Those volumes spelled out the need for communication standards and a UCA protocol that used MMS[2] as the standard’s basis. The need for data objects was recognized and began to be developed - actually first for distribution automation, but then for substation automation.

The effort was then standardized by the IEC around 1995 and IEC 61850, “Communication Networks and Systems in Substation Automation” was born. The first set of object models was called GOMSFE[3], which eventually morphed into IEC 61850. Work is on-going. The name changed in 2010 to “IEC 61850 Ed 2 Communication Networks and Systems for Power Utility Automation” to extend to other applications like distributed energy resources (DER).

IEC 61850 manages the integration of multifunctional Intelligent Electronic Devices (IED) based on the development and implementation of advanced distributed protection and control functions. An IED is defined as any device incorporating one or more processors with the capability of receiving or sending data/control from or to an external source (for example, electronic multifunction meters, digital relays, controllers). The original definition was intended to cover power substations, but the specification is expanding to meet the needs below 1000 volts (micro-grids and residential smart meters for example).

Intellectual Property Rights are owned by The International Electrotechnical Commission (IEC) and maintained by Technical Committee (TC) 57. IEC TC 57 develops and maintains International Standards for power systems control equipment and systems including EMS (Energy Management Systems), SCADA (Supervisory Control And Data Acquisition), distribution automation, teleprotection, and associated information exchange for real-time and non-real-time information, used in the planning, operation and maintenance of power systems.

The IEC TC57 Working Group (WG) 10 is responsible for IEC 61850 for substation automation. The IEC TC57 WG17 is actively working on updating IEC 61850-7-420 as well as object models for batteries, electric vehicles, hierarchical DER, and distribution automation. A draft of an updated IEC 61850-7-420 standard was first published in May of 2018 and formally published by IEC in June, 2019[4].

1.1.1. Class Model

The basic IEC 61850 class model that governs the creation of all logical nodes within IEC 61850 allows for easy access to the data and control capabilities. The primary classes are:

- Physical Device (IED. Accessed by network address)

---

[1] Rulemaking 11-09-011, Agenda ID #14667, June 23, 2016, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M163/K822/163822449.pdf.

[2] Manufacturing Message Specification (MMS) is an international standard (ISO 9506) dealing with messaging system for transferring real time process data and supervisory control information between networked devices and/or computer applications.

[3] GOMSFE - Generic Object Models For Substation And Feeder Equipment

[4] Available for purchase at https://www.techstreet.com/standards/din-en-iec-61850-7-420-draft?product_id=2074504#jumps.

- Logical Device (LD, Collections of logical nodes, implemented in one IED, not distributed)
- Logical Node (LN, Functions in real devices)
- Data (Properties of the logical nodes)
- Data Attribute (Position, Measurements)

The object-oriented approach supports standardized device models using names instead of object/register numbers and indexes. These names are defined in a standardized configuration language (SCL) that any client can access for a description of any IED. There are many pre-defined logical nodes and they are extensible.

A logical device will have multiple logical nodes (LN) which define the device. Information categories for logical nodes include. The logical nodes (LNs) for DER devices are defined in the tables found in the IEC 61850 Standard. For each LN implemented, all mandatory items must be included. These LNs are organized by typical logical devices that they may be a part of, but they may be used or not used as needed.

The IEC 61850 DER information model[5] typically includes:

a) “Standard data types: common digital formats such as Boolean, integer, and floating point.

b) “Common attributes: predefined common attributes that can be reused by many different objects, such as the quality attribute. These common attributes are defined in Clause 6 of IEC 61850-7-3.

c) “Common data classes (CDCs): predefined groupings building on the standard data types and predefined common attributes, such as the single point status (SPS), the measured value (MV), and the controllable double point (DPC)…

d) “Data objects (DO): predefined names of objects associated with one or more logical nodes. Their type or format is defined by one of the CDCs. They are listed only within the logical nodes…

e) “Logical nodes (LN): predefined groupings of data objects that serve specific functions and can be used as “bricks” to build the complete device…

f) “Logical devices (LD): the device model composed of the relevant logical nodes for providing the information needed for a particular device. For instance, a circuit breaker could be composed of the logical nodes: XCBR, XSWI, CPOW, CSWI, and SMIG. Logical devices are not directly defined in any of the documents, since different products and different implementations can use different combinations of logical nodes for the same logical device.”[6]

1.1.2.Communications

As noted in IEC 61850-1 there are several categories of communication services defined for use in these nodes and devices:

- retrieving the self-description of a device,
- fast and reliable peer-to-peer exchange of status information (tripping or blocking of functions or devices),
- reporting of any set of data (data attributes), Sequence of Event (SoE) – cyclic and event triggered,
- logging and retrieving of any set of data (data attributes) – cyclic and event,
- substitution,
- handling and setting of parameter setting groups,
- transmission of sampled values from sensors,
- time synchronization,
- file transfer,

[5] For details of the IEC 61850 Standard for DER see “IEC 61850 Part 7-420 DER Logical Nodes Final Draft International Standard (FDIS), Communication Networks and Systems for Power Utility Automation for Distributed Energy Resources (DER)”, undated. http://osgug.ucaiug.org/sgsystems/OpenAMIEnt/Shared%20Documents/AMI-ENT1.0/USB%20Docs/DER%20Logical%20Nodes%20FDIS%2057-61850-7-420.pdf

[6] Ibid.

- control devices (operate service),
- Online configuration.

Two methods of communication, the Generic Object Oriented Substation Event (GOOSE) and Manufacturing Message Specification (MMS ISO 9506) are of particular interest to DER integration. GOOSE provides fast and reliable system-wide distribution of data, based on a multicast publisher-subscriber mechanism within Generic Substation Event – GSE management. GOOSE is one of the two control classes within the GSE control model (the other is Generic Substation State Events – GSSE). GOOSE uses Data-set to group the data to be published. The use of Data-set allows grouping many different data and data attributes. A single GOOSE message broadcast can be received and used by many receivers at the same time without additional effort on the part of the originator. This would be particularly appropriate to the broadcast new smart inverter settings where the same signal would be made available to many smart inverters at the same time within a defined group of inverters.

MMS is a client/server communication model. MMS defines the difference between the entity that establishes the application association and the entity that accepts the application association. The entity that establishes the association is called the client and the one that accepts the association is the server. In a client/server model, the client is able to submit a request for the data at any point of time when the association is valid. The messages exchanged follow a request/response mechanism. MMS was the first protocol for which an implementation of Abstract communication service interface (ACSI defined in 7-2) was defined. As its name implies, it was originally developed for automobile manufacturing. The specification IEC 61850-8-1 explains how the ACSI services and the IEC 61850 data models are implemented using MMS. IEC 61850-8-1 also defines how the other members of the protocol stack, for example, TCP/IP and Ethernet, are to be used with MMS or in the case of GOOSE, Ethernet. Utilities and aggregators could use MMS when targeting an individual controller with a new set of control curves which might be relevant only to that controller.

The IEC 61850 standard manages the control functions and data flow of information primarily within electric utility substations. Efforts are underway to expand the reach of 61850 into micro-grids (as might be represented in the diesel system above), individual DER applications and possibly into the lower voltage domain of residential customers.

1.2. IEEE 2030.5 Overview

Prior to the development of IEEE 2030.5, the ZigBee Smart Energy 1.0 (SEP 1.0) specification was ratified as a final specification by the ZigBee Alliance in December 2007. Since that time, it has been updated and expanded with several versions, including the version of 1.1b in November 2012. The initial application was focused on smart grid communications to residential appliances and other energy consuming devices within a home area network.

The standard was developed by many stakeholders across the energy supply ecosystem including manufacturers of smart meters, appliances, programmable thermostats and other devices in homes, utilities, energy service providers as well as various government and standards organizations around the world. Work on the standard started in 2008 and formally became an IEEE standard in 2013, adopted as IEEE 2030.5-2013. SEP 2 was selected in 2009 by the United States National Institute of Standards and Technology (NIST) as a standard for home energy management devices.

Between development of IEEE 2030.5 (known at the time as SEP 2.0) and adoption as an IEEE standard, the Consortium for SEP 2 Interoperability (known as CSEP) was formed by the HomePlug Powerline Alliance, the Wi-Fi Alliance and the ZigBee Alliance.

CSEP focused on accelerating the market availability of interoperable SEP 2 products. The Consortium created a comprehensive testing and certification specification and qualified a set of certification test tools to validate conformance of wired or wireless devices with IEEE 2030.5 interfaces. It formally announced completion of the first version Test Specification and approval of the first certification test tools in January of 2015.

Although CSEP completed its work in 2015, there was little interest in the standard until the California CPUC sponsored Smart Inverter Working Group (SIWG) concluded that IEEE 2030.5 would be the protocol of choice for communications with DER assets by the IOUs. The recommendation was formally adopted in 2016 and a application profile and Test Specification were completed in 2018 with mandated compliance in process. The first formal certification program for an IEEE 2030.5 application has been designed and is in the process of implementation.

In order to address some gaps in the IEEE 2030.5 specification related to DER communications, the standard was updated and formally adopted by IEEE in 2018.

1.2.1. IEEE 2030.5 Technical Description

IEEE 2030.5 is an IP-based application protocol for smart metering and automation of demand/response and load control in local or home area networks. It can be used in residential and commercial building settings to connect and manage devices using the Smart Grid.

In IEEE 2030.5, a device can be a client or a server; and the differentiation is based on whether or not the device contains the resource. For example, a server would host a resource created by an energy service provider (e.g. demand response program), while a client is accessing server resources for consumption (e.g. text message) or to modify them. IEEE 2030.5 organizes many resources into the notion of functions sets: a set of device behaviors to deliver a specific functionality. Resources and function sets are organized into three basic categories; *Support*, *Common*, and *Smart Energy*.

IEEE 2030.5 is built on the representational state transfer (REST) architecture that is used to deploy Web services over HTTP. The REST architecture is based on a client server model in which servers contain and perform operations on resources. Servers expose resource representations to clients via URIs, and clients access these resources using the HTTP GET, PUT, POST and DELETE operations.

Many of the functions sets in IEEE 2030.5 have dependencies on other resources. For example, the DRLC function set has a dependency on Response resources. Figure 3 provides an abstract overview of the function sets and resources defined in IEEE 2030.5 and illustrates any dependencies between them. The remainder of this section provides more information about the SEP function sets: *Support*, *Common*, and *Smart Energy*.

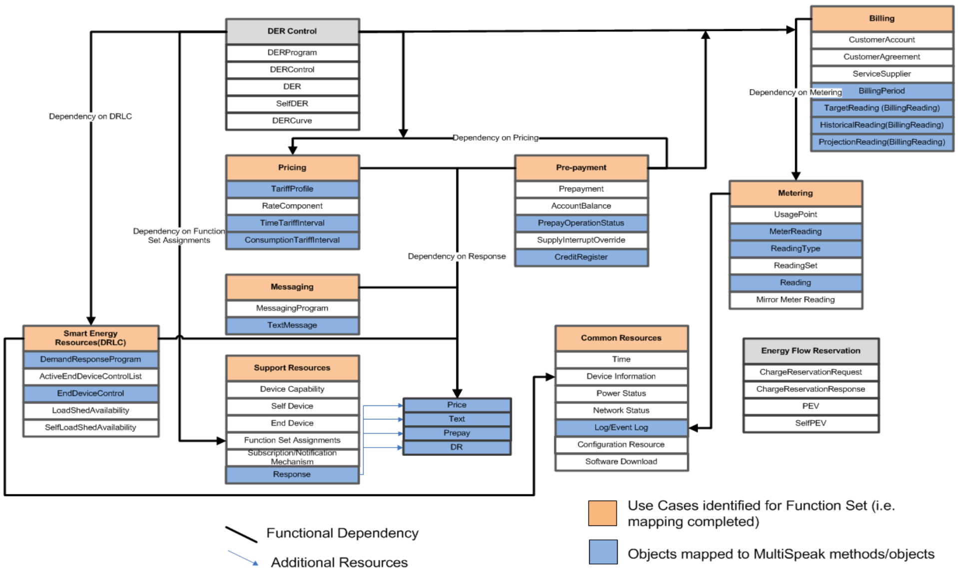

Figure 1 IEEE 2030.5 Function Sets and objects

1.2.2. Support Resources

Included in the *Support* services is the *DeviceCapability* Function Set: a set of discovery services that allow services provided by a device to be ascertained by other devices. Servers must support the *DeviceCapability* Function Set, which then provides the URIs of the additional services that it supports.

The *Response* Function Set is also provided that allows a device to respond to requests indicating that the message was received, opt-in/opt-out or other status information. Several functions sets use the *responseRequired* attribute to indicate whether or not a particular event requires a response from the client.

Other function sets include *EndDevice*, *FunctionSetAssignments*, *Subscription/Notification Mechanism* and *Time*. The *EndDevice* Function Set provides an interface that is used to exchange information related to a client. The *FunctionSetAssignments* Function Set defines a collection of function set instances. This allows for a service provider to indicate which function set instances are used for a particular program. In the DER use case, FunctionSetAssignments are used to group inverters into operational areas which can be commanded via a single fleet-wide message.

The *Subscription/Notification Mechanisms* Function Set provides information on all resources to which a client has subscribed. Subscriptions allow rapid notification of a change in a given resource. The client implements a notification resource to receive the notifications sent by the server. Although technically not required by the base IEEE 2030.5, the use of subscriptions for communications between utilities and aggregators and commercial plants improves network efficiency.

A server uses the *Time* Function Set to distribute the current time to clients. Time is expressed in Coordinated Universal Time (UTC). Server event timing is based on this function set.

1.2.3.Common Resources

The *Common* resources cover functionality needed to obtain the current time, query network interface status, determine power status of devices, and query devices for manufacturer information. Services for software upgrades to devices are included as part of the Common resources. An event logging capability is also available via the common resources. A function set may have one or more events defined and these can be posted to a server providing the *Log Event* Function Set.

1.2.4.Smart Energy Resources

These resources were formerly known as the Application Layer Business Object Messages and provide the core functionality related to business objectives of utilities or energy aggregators. IEEE 2030.5 supports the following service related function sets:

- *Billing*
- *Demand Response/Load Control (DRLC)*
- *Distributed Energy Resources*
- *Messaging*
- *Metering*
- *Energy Flow Reservation*
- *Prepayment*
- *Pricing*

Several of the Smart Energy Resources function sets have dependencies on other function sets (as shown in Figure 3). The remainder of this section provides more detailed information about each of the function sets relevant to DER integration as currently adopted in California Rule 21. The other smart energy resources defined by IEEE 2030.5 may become relevant as the use cases mature. It should be noted that, while much attention is currently focused on energy, IEEE 2030.5 is applicable to other commodities such as water and natural gas.

Distributed Energy Resources

This function set provides an interface for controlling Distributed Energy Resources (DER); i.e. provides the capability for servers to expose controls to client devices. Client devices of this function set include solar inverters, generation units, and battery storage systems. The *DER* Function Set can also be used in conjunction with the *Response* Function Set to provide confirmation of events.

The DER Function Set can be divided into two categories: DER Controls and DER Settings.

DER Controls

A DER Control is based on an IEEE 2030.5 event. The characteristics of an IEEE 2030.5 event are that it has a definite start time and a finite duration. Examples of a DER Control include setting a fixed output power, setting a fixed power factor, setting a Volt-VAr curve, and setting a Volt-Watt curve.

Another important characteristic of an IEEE 2030.5 event is that it can be applied to a group of devices, not just a single device.

DER Settings

DER Settings exist under the *EndDevice* Function Set. Since they are a part of EndDevice, they can only be applied to a single device – that is, you cannot apply a DER Setting to a group of devices unless those devices are all aggregated under a single EndDevice. Examples of a DER Setting include connect/disconnect and maximum output power limit.

Metering

The *Metering* Function Set provides interfaces to exchange measurement information such as reading type and meter reading results. The *Metering* Function Set provides a collection of meter readings for a usage point. Each set of meter readings are associated with a meter reading type that is derived from the definitions provided by IEC 61968-9. Information such as the commodity being measured, the flow direction, and accumulation behavior of the meter is supplied by the ReadingType.

The *Metering* Function Set supports the ability to perform instantaneous readings, readings of summed values, and interval data, as well as many additional measurements. Usage data can be summed across time of use (TOU) tiers and/or consumption blocks. Meter data mirroring is supported that allows for a function set server to report data for itself as well as for the meter it is mirroring. This functionality is particularly useful for meters that may be unable to serve their own data due to various constraints such as battery limitations.

There are many log events that may be raised by the *Metering* Function Set to report various operating condition events and alerts (e.g., ground fault, service disconnect). These events are posted to the *LogEvent* Function Set.

Demand Response Load Control (DRLC) Function Set

Client devices of this function set include thermostats or other devices that are capable of adjusting their electrical load. Server devices of this function set include premises energy management systems that may be acting as a proxy for upstream systems. Load control event parameters are distributed to devices through the use of the EndDeviceControl resource, where each event may be targeted toward a specific device type. The EndDeviceControl resource exposes all of the necessary attributes that load control clients need to process an event including start time, duration, and if randomization is needed at the start and end of the event.

Because DRLC can exert direct control over the device, the EndDeviceControl resource is a subscribable resource. When a device subscribes to the resource, it will be notified of any changes or updates. If a device does not subscribe, it must poll the resource for new information.

When a response is requested, the URI for the corresponding *Response* Function Set is provided in the EndDeviceControl resource for the event. Clients can POST responses for each action taken on the event (e.g. “event received”, “event started”, “event completed”).

An additional resource is provided as part of the *DRLC* Function Set: LoadShedAvailability. Clients can POST their ability to shed load to a server. The amount of load reported by the client represents a commitment to the amount of load that it can provide to each demand response program it supports. Updates to the LoadShedAvailability resource are dependent on the update thresholds provided by the server.

Energy Flow Reservation

The *Energy Flow Reservation* Function Set provides an interface for reserving and scheduling energy flow events (both charge and discharge). This function set can be used by devices that may draw large amounts of power such as plug-in electric vehicles (e.g., fast-charging stations), or storage devices (batteries).

Servers of this function accept FlowReservationRequests from client devices and may manage the client behavior in order to distribute the load across multiple reservation periods.

Pricing

The *Pricing* Function Set provides for the distribution of the tariff structure of the service provider. The tariff structures supported by IEEE 2030.5 include flat-rate, time-of-use, consumption, hourly day ahead, and real-time tariffs. Application specific tariffs are also supported for devices (e.g., PEV, DER), as well as special event-based prices like critical peak pricing (CPP).

Much like the *DRLC* Function Set, the *Pricing* Function Set contains resources that are subscribable. The *Response* Function Set may also be utilized to understand a client's reaction to a given price.

2. DER INTEGRATION REQUIREMENTS FOR CA RULE 21

The State of California regulates the interconnection of DER through Rule 21: Interconnecting Customer-owned Electric Generation Equipment to the Electric Utility Distribution System[7]. Several utilities identified the following relevant principles in developing their communication requirements[8]:

1. (Principle 1) Our goal is to establish communications between the utility and external smart inverters and aggregator systems, and not internal utility systems communications...
2. (Principle 2) Where DER systems may have a "material impact" on the power system, utilities will create the necessary communication infrastructure for real-time monitoring and control.
3. (Principle 3) While SEP 2.0 / IEEE 2030.5 is the default protocol, there is potential under mutual utility/3rd party agreement that alternative protocols may be used.
4. (Principle 5) For external system interactions, utilities want a single default mandatory communications profile that addresses all communications layers to ensure interoperability across California.
5. (Principle 6) A common test harness and 3rd party certification processes are preferred for validating implementations. The utilities do not want to be in the device/protocol validation business for DER.
6. (Principle 8) Utilities recognize that communications with DER systems under Rule 21 are not intended for sub-second interactions and protection.

The SIWG recommended that the following communication requirements are included in Rule 21[9]:

1. (Requirement 1) All inverter-based DER systems shall be capable of communications
2. (Requirement 2) The scope of the SIWG Phase 2 shall be the communications requirements between (1) Utilities and individual DER Systems, (2) Utilities and Facility DER Energy Management Systems (FDEMS) which manage DER systems within a facility, plant, and/or microgrid, and (3) Utilities and Retail Energy Providers (REP) / Aggregators / Fleet Operators which manage and operate DER systems at various facilities.
3. (Requirement 5) The data exchange requirements shall be defined in "DER Data Exchange Requirements" document that shall be referenced by each utility's Generation Interconnection Handbook as the minimal that must be available to be compliant with Rule 21. Additional types of data may be exchanged by mutual agreement between the utility and DER operator/owner.
4. (Requirement 6) The DER system software shall be updateable via communications either remotely or at the customer site. The update protocol may be vendor specific.
5. (Requirement 7) The Transport Level protocol shall be TCP/IP.
6. (Requirement 8) The default Application Level protocol shall be the IEEE 2030.5. The details of the IEEE 2030.5 profile are defined in the California IEEE 2030.5 Implementation Guide.
7. (Requirement 9) Other Application Level protocols may be used by mutual agreement, including IEEE 1815/DNP3 for SCADA real-time monitoring and control and IEC 61850.
8. (Requirement 10) Utility Generation Handbooks and the Protocol-Specific documents shall include cyber security and privacy requirements.

---

[7] See, for instance, http://www.energy.ca.gov/reports/2003-11-13_500-03-083F.PDF

[8] CEC and CPUC "Recommendations for Utility Communications with Distributed Energy Resources (DER) Systems with Smart Inverters", Smart Inverter Working Group Phase 2 Recommendation, Draft v9, February 28, 2015. The Recommendation was formally adopted by the CPUC in June of 2018. See http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M163/K822/163822449.pdf for th eorder.

[9] Ibid.

9. (Requirement 11) Generic device communications registration management requirements shall be defined in each Utility Generation Implementation Handbook, including how to register individual DERs, Facility DER Energy Management Systems, and Aggregators.

The Recommendations go on to specify additional requirements for Rule 21 including that the California IOU's develop a "California IEEE 2030.5 Implementation Guide"[10] and which specific requirements are common to all the utilities and which are utility-specific. For instance, each utility determines how it will register and enroll DER; categorize DER (type, size, location, etc); optional IEEE 2030.5 parameters and messages; and any testing and certification requirements in excess of the commonly defined requirements.

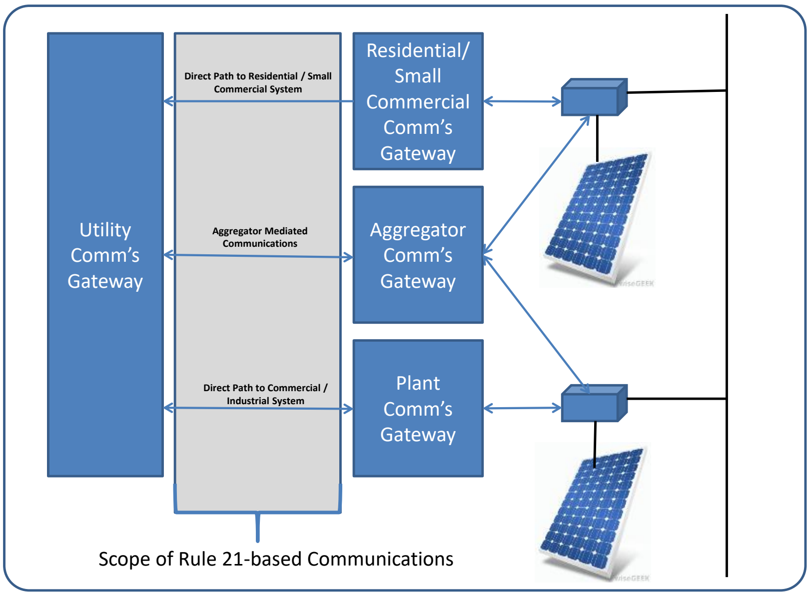

Figure 2: Scope of CA Rule 21 DER Communications

The Implementation Guide furthers defines requirements for default data schemas, specific configuration requirements, an IEEE 2030.5 CA Rule 21 specific profile, testing and certification requirements, and additional abstract IEC 61850 information model objects that could be translated into IEEE 2030.5 functionality.

The IEEE 2030.5 Implementation Guide for Rule 21[11] specifies a clear interpretation of all data elements and objects, required services, cybersecurity and optional fields.

[10] Download the latest version at https://sunspec.org/ieee-2030-5-common-california-iou-rule-21-implementation-guide-smart-inverters/.
[11] Ibid.

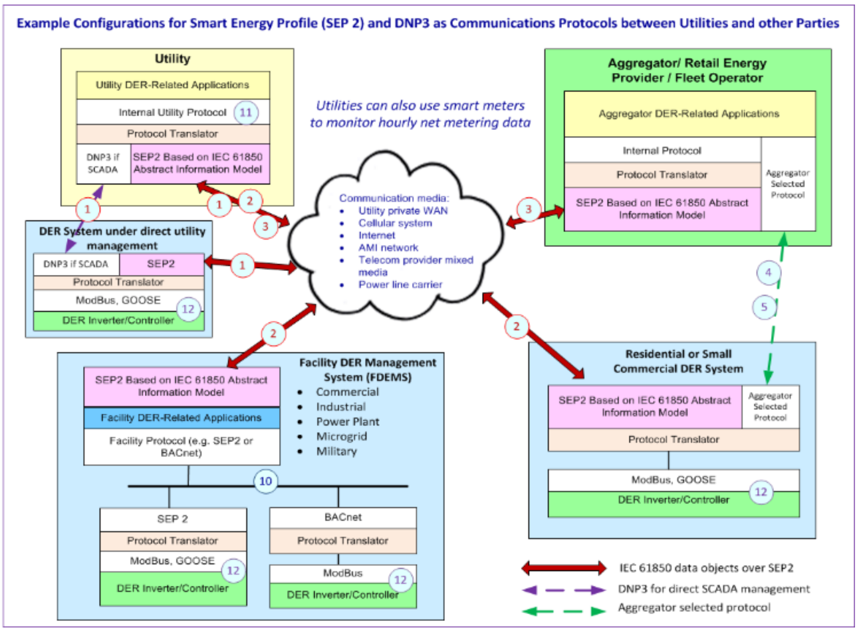

Figure 3: Conceptual Implementation of IEEE 2030.5 (SEP2) Communications with DER[12]

Figure 3 is a simplistic view of the three major use cases for communications between a utility and smart DER resources. Communications from the utility application is through a gateway that sends IEEE 2030.5 messages directly to a smart inverter (possibly through its own gateway that converts to Modbus or SunSpec commands), to an aggregator's gateway (which then converts and forwards the messages to smart inverters under its control), or directly to a larger facility's energy management system (which then converts and sends messages to DER under its control).

Figure 5 is a more detailed illustration of the communications paths and logical components that send, receive, and convert the IEEE 2030.5 signals to appropriate commands and protocols.

The Phase 2 recommendations for Rule 21 communications with DER were formally adopted in a June 23, 2016, CPUC Order[13].

2.1. Establishment of an IEEE 2030.5 Certification Program

The CPUC orders mandated IEEE 2030.5 as the default communications protocol for DERs in California also mandated establishment of a certification program for the Phase 2 communications requirements.[14] The SunSpec Alliance was tasked with setting up a certification program for the IEEE 2030.5 DER communications based on the SIWG CSIP document. This is the first formal industry certification program for IEEE 2030.5 and has been designed for maximum impact on interoperability of the envisioned DER communications infrastructure for the CA IOUs.

The program is in place and began operating in Q2 of 2019. The compliance deadline for DER systems to be certified for interconnection in CA was recently delayed a 2nd time to January 22, 2020.[15] The key elements of the certification program are:

- A formal Test Specification based on an application profile (CSIP). The Test Specification addresses over 600 testable requirements in the CSIP document[16].

[12] From CEC and CPUC "Recommendations for Utility Communications with Distributed Energy Resources (DER) Systems with Smart Inverters", Smart Inverter Working Group Phase 2 Recommendation, Draft v9, February 28, 2015. Not copyrighted.
[13] Rulemaking 11-09-011, Agenda ID #14667, June 23, 2016, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M163/K822/163822449.pdf.
[14] See CPUC Resolution E-4898, March 1, 2018, at http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M209/K761/209761456.PDF.
[15] See CPUC Resolution E-5000, July 11, 2019, at https://sunspec.org/wp-content/uploads/2019/06/E-5000DraftCommentResolution.pdf
[16] See SunSpec announcement and download at https://sunspec.org/test-criteria-california-rule-21-communication/.

- A Public Key Infrastructure for the IEEE 2030.5 required security certificates[17].
- Authorized Test Labs with global presence.[18]
- Open Source Reference Test Platform.[19]

3. COMPARISON OF IEC 61850 AND IEEE 2030.5

The fact that IEEE 2030.5 is derived from the IEC 61850 information model is an important step forward in making communications systems in the smart grid standardized and interoperable. However, for the specific application of consumer-owned DER integration, there are significant differences between the two standards. Fortunately, work is in progress, stimulated by the work in California on Rule 21 that is addressing gaps in both standards and bringing them in closer harmony.

The use of a common information model means that the definition of specific logical nodes, functions, and related objects are common to both standards. For instance, both standards recognize a function called Volt-Var Control and define it as injecting dynamic reactive power into the distribution system. IEC 61850 implements this function with DOPM.OpModConsVAr and a DRCT.VarMaxPct commands while IEEE 2030.5 uses DERControl:opModVoltVAr combined with specific DERCurve resources.

In practice, the IEC 61850 and IEEE 2030.5 objects would require mapping and protocol conversion to be interoperable. But the level of effort and opportunities for error are reduced by the use of the common information model.

There are a number of other differences between the two standards including:

- IEEE 2030.5 was derived from use cases related specifically to customer-owned assets and is structured with the goal of controlling numerous specific devices including residential DER.
- IEC 61850 is derived from a top-down, generalized model of the electric utility system and requires discreet extensions to address new devices and functions.
- Both standards required enhancements to address all of the CA Rule 21 requirements. IEEE 2030.5-2018 incorporates those enhancements and IEC 61850-4-720 is making significant progress in doing so.
- IEEE 2030.5 is XML based, while IEC 61850 is being extended to include XML schema and XMPP support.
- IEC 61850 has a well-developed community of vendors and a generic IEC 61850 certification program but not a DER specific one. As of 2019, there is an established IEEE 2030.5 test and certification program and test tools that address a DER specific profile as required by CA Rule 21.
- The IEEE 2030.5 is in the process of producing the first industry sponsored certifications of a standard protocol for for an adopted industry DER profile. By the end of 2020, all the major inverter vendors will likely be certified for the CA 21 IEEE 2030.5 communications requirements.

In the past three years, we have completed a formal analysis of IEEE 2030.5 and IEC 61850 as they apply to DER communications applications. The following Tables summarize the capabilities of IEEE 2030.5 and IEC 61850 to meet a set of communications requirements that may be necessary in a number of DER deployment scenarios. Details of the communications requirements and an initial analysis can be found in the presentations and documents produced for the “OpenADR DER Tutorial and Workshop in April of 2017”[20].

Subsequent work presented by QualityLogic as DistribuTech in 2018 and 2019 and IEEE T&D in 2018 led to the development of the summary tables below:

[17] See https://sunspec.org/sunspec-public-key-infrastructure-pki-program/ for details.
[18] See https://sunspec.org/sunspec-certified-authorized-test-laboratories/ for a current list of authorized labs and qualification criteria.
[19] See https://sunspec.org/sunspec-open-source-reference-test-platform/ for details.
[20] See https://www.openadr.org/index.php?option=com_content&view=article&id=157:derworkshop&catid=20:general-site-content for workshop description and presentations.

Requirement	IEEE 2030.5	IEC 61850
Group Assignments	✔ (Update improves performance)	Not included at this time. Could support with addition of IEC 61968-5 Information Model, schema and functions.
Group Management	✔ (Update improves performance)	Not included at this time. Could support with addition of IEC 61968-5 Information Model, schema and functions.
Direct Control Operations	Some new features being added but not primary capability.	✔
Autonomous Controls	✔	✔ (Information model update in process)
Price/ Incentive Operations	✔	New information model elements, specification and schema required
Cyber-Security	✔	GOOSE does not include security
Registration	✔	Does not include discovery, identification or registration as used for CA Rule 21
Enrollment	✔	Does not include discovery, identification or registration as used for CA Rule 21
Device Discovery	✔	Does not include discovery, identification or registration as used for CA Rule 21
DER Config Reporting	✔	✔ (Update in process). Group reports and aggregations.
DER Information and Status	✔	✔ (Update in process)
Notifications and Alarms	✔	✔ (Update in process)
DER Performance	✔	✔ (Update in process)
Capabilities Reporting	✔	✔ (Update in process)

Table 1: Comparison of IEEE 2030.5 and IEC 61850 with Communications Requirements for DER

Table 1 includes requirements that are specified for the CA Rule 21 communications applications plus requirements that are not required – e.g., Direct Control Operations (SCADA). It is evident why the CA IOUs and CPUC selected the IEEE 2030.5 standard for the California DER infrastructure.

Requirement	IEEE 2030.5	IEC 61850
IEC 61850-7-420 Information Model	✔	✔
Product Interoperability	Implementations in process/ DER Certification Program 2019	Wide adoption. No DER Specific Certification
SCADA Speed Support	Not designed in standard	✔
Mandates for DER Communications	✔ CA Rule 21 and IEEE 1547	✔ IEC
Utility Adoption	✔ in process	✔

Table 2: Comparison of IEEE 2030.5 and IEC 61850 on Eco-system Requirements

The selection of a specific protocol for an application involves more than the technical analysis of protocol functionality. There are eco-system factors such as adoption, interoperability and mandates that make a protocol more or less attractive for a utility. Table 2 compares IEEE 2030.5 and IEC 61850 on these factors.

3.1. Support for CA Rule 21

Both IEC 61850 and IEEE 2030.5 required enhancements to completely support CA Rule 21 requirements. IEEE 2030.5 has completed the enhancements required for CA Rule 21 and IEC 61850 is continuing to work on such enhancements. However, for the most part, the current IEC 61850-7-420 addresses the information model aspects that are required. A table has been developed that summarizes in detail the comparison of the two standards as they relate to the CA Rule 21 functions[21]: However, additional work is required to update the table to account for the proposed enhancements to both standards.

4. SUMMARY AND CONCLUSIONS

This paper includes a review of both the IEEE 2030.5 and IEC 61850 standards as they are applied to DER integration in the state of California. Both standards use the IEC 61850 information model and both have the functionality to support the application. However, there is work in progress or completed for both standards to add additional capabilities to support even more comprehensive smart inverter functionality.

Vendors of DER controls and inverters can expect that both IEC 61850 and IEEE 2030.5 will become designated standards for DER communications. Jurisdictions around the world could choose to use one or the other or a combination of the two, based on regional and local preferences.

This leaves vendors having to support both international standards in some form. They could simply embed one or both standards in their products, rely on external gateways to perform translations to a single open or proprietary protocol, or adopt a solution such as the CTA 2045 universal adapter[22].

Utilities, grid operators, and aggregators can benefit from adoption of open standards and have the choice of requiring a vendor's to support a single open standard such as IEEE 2030.5 or a complimentary set that could include IEEE 1815 (DNP3), IEEE 61850, and IEEE 2030.5.

5. REFERENCES

[21] Source: CA "SIWG Phase 1 and 3 DER Functions – Mappings to IEC 61850 and to IEEE 2030.5", not dated.
[22] See http://www.usnap.org/

6. BIOGRAPHY

Robby Simpson, PhD, is a System Architect for GE Grid Solutions, where he guides the architectures for GE smart grid systems. He is active in IEEE (he is a member of the IEEE-SA CAG and Vice Chair of IEEE 2030.5), ANSI, IEC, IETF, SGIP (he is a member of the Board of Directors and Vice Chair of OpenFMB), and the ZigBee Alliance. Robby chaired the SEP 2 working group throughout the standard's development. Robby received his B.S. in Computer Engineering from Clemson University and his M.S.E.C.E. and Ph.D. (Electrical and Computer Engineering) degrees from the Georgia Institute of Technology (Georgia Tech), where he focused on Internet measurements, large-scale simulation, network protocols, and information security. For more information, please visit http://www.robbysimpson.com

James Mater founded and has held several executive positions at QualityLogic Inc. from June 1994 to present. He is currently Co-Founder and General Manager, Smart Grid, working on QualityLogic's Smart Grid strategy, including work with GWAC, the Pacific Northwest Smart Grid Demonstration Project, and giving papers and presentations on interoperability. From 2001 to October, 2008, James oversaw the company as President and CEO. From 1994 to 1999 he founded and built Revision Labs which was merged with Genoa Technologies in 1999 to become QualityLogic. Prior to QualityLogic, James held Product Management roles at Tektronix, Floating Point Systems, Sidereal and Solar Division of International Harvester. He is a graduate of Reed College and Wharton School, University of Pennsylvania.

Steve Kang is Sr. VP of Engineering for QualityLogic and has a long history in directing and managing engineering organizations. Prior to joining QualityLogic, he was a consultant at AHT, Inc., where he managed and developed on-going consulting projects with client companies. Before that, he was a manager at Sun Microsystems and Xerox Corporation where he developed technical strategy and managed engineering groups and software application development. Kang was also VP of Engineering at Colorbus and AHT, Inc. Kang holds an MS in Computer Science from USC and an MBA from UCLA Anderson School.