



IEEE Standard Profile for Communications with Distributed Energy Resources (DERs) Using IEEE Std 1815™ [Distributed Network Protocol (DNP3)]

IEEE Power and Energy Society

Developed by the
Power System Communications and Cybersecurity Committee

IEEE Std 1815.2™-2025

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**Power System Communications and Cybersecurity Committee
of the
IEEE Power and Energy Society**

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IEEE SA Standards Board

Abstract: A standard profile for communications with distributed energy resources (DERs) using IEEE Std 1815™ [Distributed Network Protocol (DNP3)] is established. A high-level data model for DER communications, based on selected data objects from International Electrotechnical Commission (IEC) 61850-7-420:2021 mapped to a fixed list of DNP3 data points, comprises the profile. The data objects needed for many DER and inverter-base resources (IBRs) functions, including those in IEEE Std 1547™-2018, IEEE Std 2800™-2022, and IEEE Std 1547.9™-2022, as well as additional functions needed for storage systems, are also specified. In addition, a mapping to detailed equipment-related data objects, including meters, DER units, inverters, and batteries, is provided. The profile is presented in both a written and an electronic format (IEEE 1815.2 Profile Companion Data Point Tables) for ease of implementation.

Keywords: battery storage systems, communications, DER, distributed energy resources, DNP3, IEEE 1815.2™, IBR, inverter-base resources, photovoltaic systems, plant controllers

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Introduction

This introduction is not part of IEEE Std 1815.2-2025, IEEE Standard Profile for Communications with Distributed Energy Resources (DERs) Using IEEE Std 1815™ [Distributed Network Protocol (DNP3)].

This document establishes a standard profile for communications with distributed energy resources (DERs) using IEEE Std 1815™ [Distributed Network Protocol (DNP3)].⁶ The purpose of defining this profile is to make it both easier for a utility to communicate with a variety of DNP3 outstations supplied by many different DER manufacturers and easier for manufacturers to build systems that can interoperate with various utility systems. The standard does this by defining a standardized implementation of data location, data semantics, and other information to develop an additional layer of interoperability between systems and utilities otherwise not established by the DNP3 protocol.

This profile consists of a high-level data model for DER communications, based on selected data objects from the International Electrotechnical Commission (IEC) 61850-7-420 Ed. 2.0 2021 data model, mapped to a fixed list of DNP3 data points, thus providing interoperability across utilities and across DER implementations. It specifies the basic communication data objects for photovoltaic systems, battery storage systems, and plant controllers used to manage different types of DERs. It also specifies the data objects needed for many DER functions and inverter-base resource (IBR) functions, found in IEEE Std 1547™-2018, IEEE Std 2800™-2022, and IEEE Std 1547.9™-2022 [B20],⁷ as well as additional functions needed for storage systems. In addition, it specifies detailed equipment data objects for DER meters, DER units, inverters, and battery devices. Vendor-specific data objects can be added in a fixed area of DNP3 data points. This profile is provided in both a written and an electronic format (Profile Companion Data Point Tables) for ease of implementation.

This standardized data model provides the interoperability identified by IEEE Std 1547™-2018: A utility can communicate with many different DNP3 outstations supplied by many different DER manufacturers, while those DER manufacturers can also communicate with many different utilities.

This interoperability is assured by the unique string assigned to each DNP3 point, using the IEC 61850-7-420 or IEC 61850-7-4 [B12] data object name. If there is no equivalent IEC 61850 data object, this specification assigns a unique name that may be updated to IEC 61850 names in the future. Because the model comes from IEC 61850, a utility using this profile can communicate using DNP3 and yet be easily integrated with an IEC 61850 network by means of a gateway (i.e., using IEEE Std 1815.1™).

⁶ Information on references can be found in Clause 2.

⁷ The numbers in brackets correspond to those of the bibliography in Annex F.

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IEEE Standard Profile for Communications with Distributed Energy Resources (DERs) Using IEEE Std 1815™ [Distributed Network Protocol (DNP3)]

1. Overview

1.1 Scope

This document establishes a Standard Profile for communications with distributed energy resources (DERs) using IEEE Std 1815™ [Distributed Network Protocol (DNP3)]. This profile consists of a high-level data model for DER communications, based on selected data objects from International Electrotechnical Commission (IEC) 61850-7-420:2021 mapped to a fixed list of DNP3 data points. It also specifies the data objects needed for many DER and inverter-base resource (IBR) functions found in IEEE Std 1547™-2018, IEEE Std 2800™-2022, and IEEE Std 1547.9™-2022, as well as additional functions needed for storage systems. In addition, it specifies a mapping to detailed equipment-related data objects. The profile is provided in both a written and an electronic format (Profile Companion Data Point Tables) for ease of implementation.

1.2 Purpose

The data model defined in this standard permits a utility to communicate with DER sites supplied by different DER manufacturers, while those DER manufacturers can communicate with different utilities using this standardized profile. These DER sites can comprise either a plant controller, which can manage multiple DER units, or DER controllers, which each manage a single DER unit. In addition, because the model underlying this profile comes from IEC 61850-7-420:2021, a utility using this profile can communicate using DNP3 and yet be easily integrated with an IEC 61850 network by means of a gateway (i.e., using IEEE Std 1815.1™-2015).

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{8, 9}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

1.4 Background

CAUTION

This subclause contains references to commercial entities to set the background of the genesis of this standard. IEEE Std 1815.2 does not endorse the activities of, or the products and services sold by, these entities.

IEEE Std 1815.2 is the first edition of this standard within the IEEE; however, it follows a series of industry documents and activities that have existed outside of the IEEE for over a decade prior to this standard. These activities span hundreds of organizations, including utilities, manufacturers, national labs, trade organizations, and others.

IEEE Std 1815.2 is predated by the following related documents, which were instrumental in developing and refining its current contents:

- a) **IEC**, IEC 61850-7-420:2009, Communication networks and systems for power utility automation—Part 7-420: Basic communication structure—Distributed energy resources logical nodes [B13]
- b) Electric Power Research Institute (EPRI), Common Functions for Smart Inverters
 - 1) 1st Edition, 2011 [B7]
 - 2) 2nd Edition, 2012 [B8]
 - 3) 3rd Edition, 2014 [B9]
 - 4) 4th Edition, 2016 [B10]
- c) **DNP Users Group**, DER Application Notes
 - 1) DNP Application Note AN2011-001: DNP3 Profile for Basic Photovoltaic Generation and Storage [B2]
 - 2) DNP Application Note AN2013-001: DNP3 Profile for Advanced Photovoltaic Generation and Storage [B3]
 - 3) DNP Application Note AN2018-001: DNP3 Profile for Communications with Distributed Energy Resources (DERs) [B4]

⁸ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁹ The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

- d) **IEC**, IEC/TR 61850-90-7:2013, Object models for power converters in distributed energy resources (DER) systems [B17]
- e) **IEEE Standards Association**, IEEE Std 1815.1-2015, IEEE Standard for Exchanging Information Between Networks Implementing IEC 61850 and IEEE Std 1815™ [Distributed Network Protocol (DNP3)]
- f) **MESA Standards Alliance**, MESA-ESS Specification, 2018 Version 1 [B24]
- g) **IEEE Standards Association**, IEEE Std 1547-2018, IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
- h) **IEC**, IEC 61850-7-420:2021, Communication networks and systems for power utility automation—Part 7-420: Basic communication structure—Distributed energy resources and distribution automation logical nodes
- i) **IEEE Standards Association**, IEEE Std 2800-2022, IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems
- j) **Modular Energy System Architecture (MESA) Standards Alliance**, MESA-DER PICS spreadsheet, June 2022 for IEEE 1815.2 protocol testing [B23]

The DER functional requirements covered by this DER communications profile were developed by international groups, including European, U.S., Canadian, Japanese, and Chinese members of the IEC 61850-7-420:2021 working group, as well as North American members of the IEEE Std 1547-2018 working group. Most of these functional requirements are consistent or compatible with each other, but some functional requirements include more depth or additional flexibility than others since they were developed by different groups.

The 2018 DNP Application Note AN2018-001 [B4] was funded in part through the California Energy Commission's Electric Program Investment Charge (EPC-15-089) [B1]. Led by the EPRI,¹⁰ the effort included the MESA Standards Alliance,¹¹ SunSpec Alliance,¹² EnerNex,¹³ and Xanthus Consulting International,¹⁴ with support from the DNP Users Group Technical Committee.¹⁵ This effort spanned two years and merged the parallel efforts by MESA on the MESA-ESS specification [B24], existing efforts from the DNP User Group on AN2011-001 [B2] and AN2013-001 [B3], and new information from groups such as IEEE SC 21 (formerly IEEE SCC 21, overseeing the IEEE 1547 series of standards), the Energy Storage Integration Council (ESIC), and IEC TC57 WG17 (responsible for IEC 61850-7-420).

This standard updates the contents of the DNP3 Application Note AN2018-001 [B4], while remaining backward compatible as much as possible.

1.5 Profile Companion Data Point Tables, versioning, and indexing of DNP3 points

This standard includes a profile of DNP3 points that is specified in the IEEE 1815.2 Profile “Companion Data Point Tables” (CDPT), which is a spreadsheet associated with this document. The content of the spreadsheet file is considered normative as it is needed to properly implement this standard. The file is distributed on the IEEE Standards Association Downloads Page.¹⁶

The version of the profile defined in this document is Version 1.1 and is set in AI0 of the CPDT spreadsheet.

¹⁰ <https://www.epri.com/>

¹¹ <http://mesastandards.org/>

¹² <https://sunspec.org/>

¹³ <https://enernex.com/>

¹⁴ <http://xanthus-consulting.com/>

¹⁵ <https://www.dnp.org/>

¹⁶ <https://standards.ieee.org/downloads/>

In Version 1.1, an extensible indexing capability has been included to facilitate updates to the standard and to support additions for capabilities not yet defined, while maintaining the association of additional data points to the appropriate categories. The implementation of extensible indexing in this document still maintains the original mapping of Version 1.0 in order to be backward compatible with the points list published in DNP3 Application Note AN2018-001 [B4], thus supporting legacy software and interactions.

For interoperability, it is recommended that implementers of Version 1.1 rely on the extensible indexing capability instead of hardcoding DNP3 point numbers.

In Version 1.1 of the IEEE 1815.2 Profile CDPT, the SCADA and Configuration (System) points have fixed absolute point numbers with the starting indexes always beginning at zero (0). The functions, curves, scheduling, equipment, and vendor points are relative to their starting index values. The DNP3 data point numbers can be calculated from the starting index values in the key tab of the IEEE 1815.2 Profile CDPT, or if supported by the controlling station, the controlling station can read the starting index values starting at DNP3 point AI65000 and use those to calculate the remainder of the DNP point numbers during operation.

It is recommended that controlling stations read the starting indexes from outstations before beginning communications.

Compliance with this standard does not require the implementation of all data objects. Compliance, however, does require that if specific functions are implemented, then the data objects identified to be mandatory to those functions shall be implemented. The IEEE 1815.2 Profile Companion Data Point Tables spreadsheet contains columns labeled “Mandatory for IEEE Std 1815.2: M, C (plus specific condition), or blank,” which define which data objects are always mandatory, which are conditionally required, and which are optional (blank). Conditionally required data objects include those that are only required for storage or for specific functions if they are implemented. A few other conditions are also indicated. Points that are marked conditional, unless set at implementation, are not required to be writable past the commissioning stage of the DER and may be set via alternative configuration methods.

1.6 Overview of DER functions

Table 1 lists the functions of a DER as defined in this profile. It provides a brief description of each function, identifies the document subclause where the function is described in more detail, and lists the range of DNP3 points. The complete list of DNP3 points is in the IEEE 1815.2 Profile Companion Data Point Tables spreadsheet. Refer to 1.10 and 5.1 for a description of the types, notation, and terminology for DNP3 points.

Table 1—Overview of DER data points and functions

Function	Brief description	Document clause	DNP3 points range
SCADA and configuration			
Nameplate data	Factory-related DER data.	See Table 2 for details	AI0-AI23;
Configuration data	Configuration of DER, including modifications due to implementation characteristics. Which functions are supported.	See Table 2 for details	AI24-AI31; AO0-AO2; BI31-BI51;
Operational settings	Installation-related DER data. Which functions are enabled. Enable function commands.	See Table 2 for details	AI32-AI49; AI62-AI68; AO3-AO6; AO18-AO19; BI64-BI85; BO12-BO33;
Counters	Parameters controlling how often meter counters should be frozen.	5.6.3	AI69-AI70; AO20-AO21;
Alarms	Alarms from the DER.	6.2.3	BI0-BI9; BI94-BI106;

Function	Brief description	Document clause	DNP3 points range
State	State of the DER.	6.2.5	BI10-BI30; BO0; BO3-BO11;
Protection	Indications of protection operation such as starting, tripping, and blocking.	6.2.4	BI52-BI63;
Functions			
Basic functions			
		6.3	
Connect/Disconnect	Cause the DER to electrically connect or disconnect at the DER's point of connection (PoC) or at the facility's point of common coupling (PCC).	6.3.1	AI60-AI61; AO16-AO17;
Cease To Energize/Return To Service	Causes the cessation of active power delivery, used primarily in voltage or frequency ride-through situations. Return-to-service function allows the DER to start active power delivery, if permission is granted.	6.3.2	AI50-AI59; AO6-AO15; BO1-BO2;
Voltage Ride-Through	Allows voltage excursions from the normal range to be tolerated for specific voltage excursion levels over specific lengths of time.	6.3.3	AI71-AI76; AO22-AO26;
Frequency Ride-Through	Allows frequency excursions from the normal range to be tolerated for specific frequency excursion levels over specific lengths of time.	6.3.4	AI77-AI82; AO27-AO31;
Active power functions		6.4	
Charge/Discharge (Set Active Power)	Manages the charging and discharging of energy storage by setting specific active power output or input targets for the DER and by indicating if the source is renewable.	6.4.1	AI142-AI149; AI592-AI593; AO82-AO88; AO482-AO483; BI113; BO45;
Active Power Limit	Active power generation and/or consumption are limited. Usually, this limit is applied at the PCC, although it may be applied at any DER's PoC.	6.4.2	AI142-AI149; AI619-AI620; AO82-AO88; AO509-AO510; BI113; BO45;
Frequency-Watt (used for Droop)	Active power is modified based on frequency. Usually used for imitating the "droop" of mechanical generators or motors, but can be used for other purposes, depending on the settings.	6.4.3	AI115-AI141; AI590-AI591; AO57-AO81; AO480-AO481; BI86-BI87; BO34-BO35;
Volt-Watt	Active power is modified based on the voltage at the reference point. Usually used to respond to voltage deviations from the norm.	6.4.4	AI242-AI256; AO168-AO180; BI92; BO40;
Coordinated Charge/Discharge	The storage system is charged up to a specified target state of charge by a specified target date/time. Usually associated with charging electric vehicles, but also for any type of storage system.	6.4.5	AI163-AI175; AO102-AO114;
Peak Power Limiting	The DER supplies active power such that the power transferred at a particular reference point does not exceed a specified limit. Usually, the reference point associated with limiting load is the PCC, so excess load ought to be served from local generation.	6.4.6.2	AI176-AI186; AI584-AI585; AO115-AO123; AO474-AO475;

Function	Brief description	Document clause	DNP3 points range
Load Following	The DER supplies active power in proportion to the excess power measured at a particular reference point. Although similar to Peak Power Limiting, the load and generation may be located in different sites, thus not limiting the load at a specific PCC. The load reference point may therefore be one PCC while the generation may be at a different PCC.	6.4.6.3	AI187-AI197; AI586-AI587; AO124-AO132; AO476-AO477;
Generation Following	The DER absorbs active power in proportion to the excess power measured at a particular reference point. Although similar to peak power limiting, the load and generation may be located in different sites, thus not limiting the load at a specific PCC. The generation reference point may therefore be one PCC while the consumption of power may be at a different PCC.	6.4.6.4	AI198-AI208; AI592-AI593; AO133-AO141; AO478-AO479;
Automatic Generation Control (AGC)	The balancing authority [typically an independent system operator (ISO) or a regional transmission organization RTO)] sends commands every few seconds (typically 4 s) to a DER to set its active power level. Although typically associated with bulk power generators, aggregations of DER (usually storage systems) may also support this function.	6.4.7	AI209-AI226; AO142-AO154; BI91; BO39;
Active Power Smoothing	The active power at a specific reference point (e.g., at the PCC) is smoothed by a DER absorbing or producing additional watts.	6.4.8	AI227-AI241; AO155-AO167;
Frequency-Watt Curve	Active power is modified based on frequency. Functionally, it is identical to the main Frequency-Watt function, except that this “curve” version permits more complex frequency-watt combinations of independent and dependent variables, for instance, to change watts more rapidly if frequency is changing more rapidly.	6.4.9	AI257-AI276; AO181-AO198; BI88-BI89; BO36-BO37;
Dynamic Volt-Watt	Active power is modified based on the voltage at the reference point. It is similar to the main Volt-Watt Function, except the active power output is based on a moving average of the voltage.	6.4.10	AI102-AI114; AO48-AO56;
Reactive power functions		6.5	
Constant Vars	Reactive power is set at a constant value, either as a percentage of maximum reactive power or as absolute vars.	6.5.1	AI277-AI283; AO199-AO205; BI115; BO47; AI621; AO511;
Constant Power Factor	Power factor is set to a fixed value.	6.5.2	AI284-AI289; AO206-AO211;
Volt-Var	Reactive power is modified based on the voltage at the reference point.	6.5.3	AI290-AI301; AO212-AO220; BI93; BO41;
Watt-Var	Reactive power is modified based on the active power at the reference point.	6.5.4	AI302-AI311; AO221-AO228;

Function	Brief description	Document clause	DNP3 points range
Power Factor Correction	The DER modifies the power factor of individual phases at the DER's PoC in order to achieve the desired average power factor at the reference point of applicability (RPA).	6.5.5	AI312-AI320; AO229-AO236;
Dynamic Reactive Current Support	Defines the requirements for DER to support the grid during short periods of abnormally high or low voltage levels by feeding reactive current to the grid until the voltage either returns within its normal range or the DER is forced to disconnect.	6.5.6	AI83-AI101; AO32-AO47;
Equipment data		6.6	
Equipment data from meters (HM)	The DER optionally reports power and voltage measured by one or more optional signal meters other than the system meter.	6.6	Starting at 5000 AI HM0-HM36; AO HM0-HM11; BI HM0-HM12;
Equipment data from DER units (HDU)	The DER optionally reports nameplate and operational performance information associated with each individual unit of the DER.	6.6	Starting at 10 000 AI HDU0-HDU13; BI HDU0-HDU3;
Equipment data from inverters (HI)	The DER optionally reports nameplate and performance information associated with inverters.	6.6	Starting at 15 000 AI HI0-HI32; AO HI0-HI11; BI HI0-HI34;
Equipment data from battery banks (HB)	The DER optionally reports nameplate and performance information associated with battery banks.	6.6	Starting at 20 000 AI HBO-HB26; AO HBO-HB3; BI HBO-HB53;
Curves			
Defining curves	Use of curves for defining piecewise linear x-y coordinates for functions requiring the correlations between independent and dependent variables.	6.1.3	AI328-AI532; AO244-AO448; BI107;
System meter			
System monitoring/metering	The DER reports basic power and voltage measurements at the RPA from a designated system meter.	6.2.1 and 6.2.2	AI533-AI568; AO449-AO460;
Scheduling			
Scheduling of functions	The controlling station remotely configures particular DER functions to execute at specified intervals.	6.1.4	AI3000-AI3411; AO3000-AO3409; BI3000-BI3008; BO3000-BO3008;
Priority of functions	This subclause describes which functions will have priority controlling the outputs of the DER if more than one function is active.	7.3	Each function and schedule has AI and AO data points
Backward compatible scheduling	Original scheduling structure in DNP3 Application Note, supported for backward compatibility	A.2	AI2000-AI2211; AO2000-AO2208; BI2000-BI2007; BO2000-BO2007;
Experimental functions		Annex B	
Volt-watt advanced functionality	Volt-watt advanced function could include one or more of the following capabilities: applicable to low voltage, immediate response upon passing the voltage high or low threshold, hysteresis, deadband around thresholds, or ramping.	B.2	Exp_AI+0-Exp_AI+22; Exp_AO+0-Exp_AO+20 Exp_BI+0-Exp_BI+1; Exp_BO+0;

Function	Brief description	Document clause	DNP3 points range
Synthetic inertia	Active power is modified based on frequency. In this case, the purpose is to use inverter-based systems to counter frequency changes and slow those changes down, thus providing artificial inertia. This synthetic inertia function is not specifically focused on returning the frequency toward its nominal value, but rather on providing transient stability.	B.3	Exp_AI+50-Exp_AI+61; Exp_AO+50-Exp_AO+61; Exp_BI+10-Exp_BI+11; Exp_BO+10;
Communications configuration			
Configuration of equipment data points	Configuration of DER meters, inverters, units, and batteries.	1.5	Spreadsheet Key Tab
Starting data point indexes	Indexes for the starting DNP3 points for each category.	1.5	AI65000

1.7 Mapping of IEEE 1547 interoperability requirements to IEEE 1815.2 profile

Table 2 identifies a subset of DER points from this profile that correspond to the interoperability information specified as mandatory for DER communications in IEEE Std 1547-2018.

NOTE—IEEE Std 1547.1™-2020 [B18] identifies the use of curves for some functions since IEEE Std 1547-2018 defines those functions using equations that can be mapped to curves. However, implementers have objected to using the curves process defined in the DNP3 AN2018-01 [B4] as being unnecessarily complex. Therefore, IEEE Std 1815.2 has defined simpler alternative methods for implementing functions that avoid the use of curves. But this means that implementations using those alternative methods would no longer comply with IEEE Std 1547.1-2020. Until IEEE Std 1547.1-2020 is updated, implementations may not be compliant with IEEE Std 1547.1-2020, or they may use the curve methods for certification but switch to the simpler method for actual implementations.¹⁷

Table 2—Mapping of IEEE 1547 interoperability requirements to the IEEE 1815.2 DNP3 profile

Category	Information	Unit(s)	Output(s)	Input(s)
Monitored information	Active power	watt	n/a	AI537
	Reactive power	var	n/a	AI541
	Voltage	volt	n/a	AI547-AI553
	Current	ampere	n/a	AI554-AI556
	Frequency	hertz	n/a	AI536
	Operational state /connection status	on/off/others...	n/a	BI10-BI24
	Alarm status	alarm/no-alarm	n/a	BI0-BI9
	Operational state of charge	percent	n/a	AI48

¹⁷ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

Category	Information	Unit(s)	Output(s)	Input(s)
Nameplate information (energy)	Active power rating at unity power factor	watt	n/a	AI4
	Active power rating at specified over-excited power factor	watt	n/a	AI6-AI7
	Specified over-excited power factor	unitless	n/a	AI8
	Active power rating at the specified under-excited power factor	watt	n/a	AI9-AI10
	Specified under-excited power factor	unitless	n/a	AI11
	Reactive power injected maximum rating	var	n/a	AI12
	Reactive power absorbed maximum rating	var	n/a	AI13
	Active power charge maximum rating	watt	n/a	AI5
	Apparent power charge maximum rating	voltampere	n/a	AI15
	Storage actual capacity	watthour	n/a	AI16
Nameplate information (rms)	AC voltage nominal rating	rms volt	n/a	AI29-AI30
	AC voltage maximum rating	rms volt	n/a	AI3
	AC voltage minimum rating	rms volt	n/a	AI2
	AC current maximum rating	rms ampere	n/a	AI19-AI20
Nameplate information (other)	Supported control functions	List of yes/no	n/a	BI31-BI51
	Normal operating performance category	A/B	n/a	AI22
	Abnormal operating performance category	I/II/III	n/a	AI23
	Reactive susceptance that remains connected	siemens	n/a	AI21
	Manufacturer	text	n/a	Refer to 5.6.6
	Model	text	n/a	Refer to 5.6.6
	Serial number	text	n/a	Refer to 5.6.6
	Version	text	n/a	Refer to 5.6.6
Operational settings	Maximum active power	watt	n/a	AI32
	Maximum reactive injection power	var	n/a	AI34
	Maximum reactive absorption power	var	n/a	AI35
Enter service	Permit service	enabled/disabled	BO3	BI16
	ES voltage high	percent nominal	AO6	AI50
	ES voltage low	percent nominal	AO7	AI51
	ES frequency high	hertz	AO8	AI52
	ES frequency low	hertz	AO9	AI53
	ES delay	seconds	AO10	AI54
	ES randomized delay	seconds	AO11	AI55
	ES ramp rate	seconds	AO12	AI56
Active Power Limit function	Limit active power enable	on/off	BO17	BI69
	Maximum active power	watt	AO87-AO88	AI148-AI149

Category	Information	Unit(s)	Output(s)	Input(s)
Constant Power Factor function	Constant power factor enable	on/off	BO28	BI80
	Constant power factor	unitless	AO210-AO211	AI288-AI289
	Constant power factor excitation	over/under	BO10-BO11	BI29-BI30
Volt-Var function	Voltage-reactive power (volt-var) enable	on/off	BO29	BI81
	V _{Ref} (Reference voltage)	volt	AO0-AO1	AI29-AI30
	Autonomous V _{Ref} adjustment enable	on/off	BO41	BI93
	V _{Ref} adjustment time constant	seconds	AO220	AI300
	V/Q gradients: voltage data points (V1, V2, V3, V4)	volt	AO484, AO486, AO488, AO490	AI594, AI596, AI598, AI600
	V/Q gradients: reactive power data points (Q1, Q2, Q3, Q4)	var	AO485, AO487, AO489, AO491	AI595, AI597, AI599, AI601
	V/Q curve points (x,y) (if curves are used)	volt, var	AO217, AO244-AO448	AI297, AI328-AI532
	Open loop response time	seconds	AO218-AO219	AI298-AI299
Watt-Var function	Active power-reactive power (watt-var) enable	on/off	BO30	BI82
	P/Q gradients: active power data points (P1, P2, P3, P4)	watt	AO492, AO494, AO496, AO498	AI602, AI604, AI606, AI608
	P/Q gradients: reactive power data points (Q1, Q2, Q3, Q4)	var	AO493, AO495, AO497, AO499	AI603, AI605, AI607, AI609
	P/Q curve points (x,y) (if curves are used)	watt, var	AO226, AO244-AO448	AI308, AI328-AI532
Constant Var function	Constant reactive power enable	on/off	BO27	BI79
	Constant reactive power as percentage or absolute vars	Selection	BO47	BI115
	Constant reactive power value	As a percentage of var	AO203	AI281
	Constant reactive power value	As absolute var	AO511	AI621
Volt-Watt function	Voltage-active power (volt-watt) enable	on/off	BO25	BI77
	V/P gradients: active power values for P1, P2, P3, and P4	volt	AO500, AO502, AO504, AO506	AI610, AI612, AI614, AI616
	V/P gradients: voltage values for V1, V2, V3, and V4	watt	AO501, AO503, AO505, AO507	AI611, AI613, AI615, AI617
	V/P curve points (x,y) (if curves are used)	volt, watt	AO173, AO244-AO448	AI248, AI328-AI532

Category	Information	Unit(s)	Output(s)	Input(s)
	Open loop response time	seconds	AO175- AO176	AI251-AI252
Voltage trip	HV trip curve points (x,y)	seconds, volt	AO23, AO244- AO448	AI73, AI328-AI532
	LV trip curve points (x,y)	seconds, volt	AO24, AO244- AO448	AI74, AI328-AI532
Momentary cessation	HV momentary cessation curve points (x,y)	seconds, volt	AO25, AO244- AO448	AI75, AI328-AI532
	LV momentary cessation curve points (x,y)	seconds, volt	AO26, AO244- AO448	AI76, AI328-AI532
Frequency trip	HF trip curve points (x,y)	seconds, hertz	AO28, AO244- AO448	AI79, AI328-AI532
	LF trip curve points (x,y)	seconds, hertz	AO29, AO244- AO448	AI80, AI328-AI532
Frequency droop (frequency- watt)	Over-frequency droop deadband DB_{OF}	hertz	AO62- AO63	AI121-AI122
	Under-frequency droop deadband DB_{UF}	hertz	AO66- AO67	AI125-AI126
	Over-frequency droop gradient	watts per hertz	AO480	AI590
	Under-frequency droop gradient	watts per hertz	AO481	AI591
	Open loop response time	seconds	AO72- AO73	AI131-AI132

1.8 Cybersecurity for DERs

Cybersecurity for DERs is extremely important. However, it is not in scope for this document, so this document defers to IEEE Std 1815 for the DNP3 security requirements and defers to IEEE Std 1547.3™ [B19] for the broader cybersecurity recommendations for the DER environment.

1.9 DNP3 level of the profile

The outstation described in this profile shall be conformant to DNP3 Level 2 (DNP3-L2) or higher as defined in IEEE Std 1815. Implementors are free to add additional features beyond DNP3-L2 by agreement between the providers of the controlling station and the outstation.

Some features described in this profile require capabilities beyond Subset Level 2 interoperability. As an example, scheduling (see 6.1.4) requires the use of Group 40 and 41 (analog output status and analog output control) with 32-bit variations, which are not available in Subset Level 2. Such features are deemed optional.

If an outstation supports features that go beyond DNP3-L2, it shall be possible to disable them for compatibility with DNP3-L2 controlling stations.

Time shall be transmitted in Universal Time Coordinated (UTC) and, as necessary, converted to desired or local time in human-machine interfaces (HMIs).

1.10 DNP3 terminology

CAUTION

This subclause includes terms considered disrespectful or offensive. They are included for historical context only and shall no longer be used to refer to this standard.

The reader of this profile is expected to be familiar with DNP3 and understand DERs. It is useful, but not required, for the reader to be familiar with IEC 61850-7-420.

Readers who are not familiar with DNP3 or IEC 61850 but are (for instance) reading this profile to become familiar with DER functionality should note that this profile uses the following terminology convention common to supervisory control and data acquisition (SCADA) systems:

- a) The controlling station is the side of the DNP3 communications link that gathers data and operates controls. Up to IEEE Std 1815-2012, the controlling station was known as the *master*. This term will be deprecated in the future revisions of IEEE Std 1815.
- b) The outstation is the side of a DNP3 communications link that reports data and receives controls.
- c) A data point is the smallest unit of data transferred by the protocol.
- d) An input point is any data transmitted toward the controlling station, in this case, from the outstation (e.g., plant management system or DER) to the controlling station (e.g., power utility or some other entity controlling the DER). Analog input points are termed “AI”, and binary input points are termed “BI”.
- e) An output point is any data transmitted toward the outstation, in this case, from the controlling station (e.g., power utility or other controlling entity) to the outstation (e.g., plant management system or DER). Analog output points are termed “AO”, and binary output points are termed “BO”.

These terms apply only to the data communications and are distinct from the power input to the DER and output from the DER.

1.11 Jurisdiction requirements

The interoperability and communications requirements of specific DER deployments may be subject to utility interconnection tariffs, utility handbooks, contracts, or other regulatory- or program-related vehicles.

1.12 Conformance certification

Interoperability issues between different sources of equipment implementing the same standard such as IEEE Std 1815 or IEEE Std 1815.2 are common in our industry. This is especially true when a new standard or profile is adopted or when new suppliers may not be familiar with the protocol and the profile standard. Therefore, it is strongly recommended that utilities request that their suppliers have their implementations of IEEE Std 1815 and IEEE Std 1815.2 independently conformance certified.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEC 61850-7-3 Ed. 2.1 2020, Communication networks and systems for power utility automation—Part 7-3: Basic communication structure—Common data classes.¹⁸

IEC 61850-7-420 Ed. 2.0 2021, Communication networks and systems for power utility automation—Part 7-420: Basic communication structure—Distributed energy resources logical nodes.¹⁹

IEEE Std 1547™-2018, IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.²⁰

IEEE Std 1815™-2012, IEEE Standard for Electric Power Systems Communications—Distributed Network Protocol (DNP3).^{21, 22}

IEEE Std 1815.1™-2015, IEEE Standard for Exchanging Information Between Networks Implementing IEC 61850 and IEEE 1815 (DNP3).²³

IEEE Std 2800™-2022, IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems.²⁴

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.²⁵

area electric power system: An electric power system (EPS) that serves local EPSs. Note that, typically, an area EPS has primary access to public rights-of-way and priority crossing of property boundaries and is subject to regulatory oversight.

battery bank: A collection of battery cells that can be used to store energy in electrochemical form.

NOTE—They are configured as strings often connected in parallel and are connected to one or more inverters. A bank may be a shipping container full of lithium-ion battery modules, or it may be a redox flow battery string.

battery management system (BMS): A system that implements controls on batteries in order to obtain safe operation, it also balances the energy of batteries and monitors the status thereof.

bulk power system (BPS): Any electric generation resources, transmission lines, interconnections with neighboring systems, and associated equipment.

¹⁸ IEC publications are available from the International Electrotechnical Commission (<https://www.iec.ch>) and the American National Standards Institute (<https://www.ansi.org/>).

¹⁹ This document is the IEC specification for standard data models to be used for DERs. It incorporates all of the functions defined in IEEE Std 1547-2018 and includes many additional functions, in particular, those required or useful for energy storage systems (ESSs).

²⁰ The technical specifications for, and testing of, the interconnection and interoperability between utility electric power systems (EPSs) and distributed energy resources (DERs) are the focus of this standard.

²¹ The IEEE standards or products referred to in Clause 2 are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.

²² IEEE publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

²³ This is a specification for mapping data between IEC 61850 and DNP3 networks and for configuring a gateway between such networks. This standard was developed through the assistance of the National Institute of Standards and Technology (NIST) and the Smart Grid Interoperability Panel (SGIP) under the label Priority Action Plan Twelve (PAP12).

²⁴ Uniform technical minimum requirements for the interconnection, capability, and lifetime performance of inverter-based resources interconnecting with transmission and sub-transmission systems are established in this standard.

²⁵ *IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

cease to energize: Cessation of active power delivery under steady-state and transient conditions and limitation of reactive power exchange.

NOTE 1—It may lead to momentary cessation or trip.

NOTE 2—It does not necessarily imply, nor exclude, disconnection, isolation, or a trip.

NOTE 3—Limited reactive power exchange may continue as specified (e.g., through filter banks).

NOTE 4—Energy storage systems are allowed to continue charging but are also allowed to cease from actively charging when the maximum state of charge (maximum stored energy) has been achieved.

controlling station: Any entity that issues requests to gather data or perform controls using Distributed Network Protocol (DNP3).

cyber-physical system: A system that integrates computation with physical processes, in a network manner, whose behavior is defined by both cyber and physical parts of the system.

distributed energy resource (DER): A source of electric power that is not directly connected to a bulk power system. DER includes both generators and energy storage technologies capable of exporting active power to an EPS. An interconnection system or a supplemental DER device that is necessary for compliance with this standard is part of a DER.

electric power system (EPS): Facilities that deliver electric power to a load. *See also:* **area electric power system; local electric power system.**

NOTE—This may include generation units.

energy storage system (ESS): A system that is capable of absorbing energy, storing it, and dispatching the energy back into the power system.

enter service: Begin operation of the DER with an energized area EPS.

gateway: A network entity (software or hardware) that interfaces between networks that use different protocols or are of different, potentially incompatible technology.

intentional island: A planned electrical island that is capable of being energized by one or more local EPSs. These (1) have DER(s) and load, (2) have the ability to disconnect from and to parallel with the area EPS, (3) include one or more local EPS(s), and (4) are intentionally planned.

interconnection system (ICS): The collection of all interconnection and interoperability equipment and functions, taken as a group, used to interconnect a DER to an area EPS. (IEEE Std 1547-2018)

interoperability: The capability of two or more networks, systems, devices, applications, or components to externally exchange and readily use information securely and effectively.

inverter: A machine, device, or system that changes direct-current power to alternating-current power. (IEEE Std 1547-2018)

inverter-based resource unit (IBR unit): An individual inverter device or a grouping of multiple inverters connected together at a single point of connection (PoC).

NOTE 1—Can be type tested by a verification entity to verify performance at the PoC.

NOTE 2—An IBR unit may include a unit transformer.

NOTE 3—For type III wind turbine generators, the wind turbine itself, the doubly-fed generator, the rotor-circuit inverter, and the three-winding unit transformer, if present, make up an IBR unit.

NOTE 4—A string inverter or set of string inverters that are type tested by a verification entity at a single PoC is regarded as an IBR unit for the purpose of this standard. A set of string inverters not type tested as a group is not regarded as one IBR unit.

island: A condition in which a portion of an area EPS is energized solely by one or more local EPSs through the associated PCCs while that portion of the area EPS is electrically separated from the rest of the area EPS on all phases to which the DER is connected. When an island exists, the DER energizing the island may be said to be “islanding.”

load: Devices and processes in a local EPS that use electrical energy for utilization, exclusive of devices or processes that store energy but can return some or all of the energy to the local EPS or area EPS in the future.

local electric power system (EPS): An EPS contained entirely within a single premises or group of premises.

momentary cessation: Temporarily cease to energize an EPS, while connected to the area EPS, in response to a disturbance of the applicable voltages or the system frequency, with the capability of immediate Restore Output of operation when the applicable voltages and the system frequency return to within defined ranges.

NOTE—Momentary cessation is part of the ride-through functions.

nameplate ratings: Nominal voltage (V), current (A), maximum active power (kW), apparent power (kVA), and reactive power (kvar) at which a DER is capable of sustained operation. (IEEE Std 1547-2018)

NOTE—For local EPSs with multiple DER units, the aggregate DER nameplate rating is equal to the sum of all DER nameplate ratings in the local EPS, not including aggregate capacity-limiting mechanisms such as coincidence factors and plant controller limits that may be applicable for specific cases.

normal operating performance category: The grouping for a set of requirements that specify technical capabilities and settings for DER under normal operating conditions, i.e., inside the continuous operation region.

open loop response time: The duration from a step change in control signal input (reference value or system quantity) until the output changes by 90% of its final change, before any overshoot.

outstation: Any entity that responds to requests and/or controls from a controlling station using DNP3.

point of common coupling (PCC): The point of connection between the area and the local EPS.

point of distributed energy resources connection (point of DER connection—PoC): The point where a DER unit is electrically connected in a local EPS and meets the requirements of this standard exclusive of any load present in the respective part of the local EPS. (IEEE Std 1547-2018)

reference point of applicability (RPA): The location where the interconnection and interoperability performance requirements specified in this standard apply. (IEEE Std 1547-2018)

return to service: Enter service following recovery from a trip.

ride-through: Ability to withstand voltage or frequency disturbances inside defined limits and to continue operating as specified.

trip: Inhibition of immediate return to service, which may involve disconnection.

3.2 Acronyms and abbreviations

AI	analog input
AO	analog output
BI	binary input
BO	binary output
CDC	common data class
DER	distributed energy resource
DSO	distribution system operator
DNP3	Distributed Network Protocol
ECP	electrical connection point
EPS	electric power system
ESS	energy storage system
FCR	frequency containment reserve
FDERMS	facility DER management system
HMI	human-machine interface
HVRT	high voltage ride-through
IBR	inverter-based resource
ICS	interconnection system
IEC	International Electrotechnical Commission
IoT	internet of things
ISO	independent system operator
ISO/IEC	International Standards Organization/International Electrotechnical Commission
LN	logical node
LVRT	low voltage ride-through
MMS	manufacturing messaging specification
OCPP	open charge point protocol
OpenADR	open automated demand response
PCC	point of common coupling
PoC	point of connection
PV	photovoltaics
RBAC	role-based access control
RPA	reference point of applicability
RTO	regional transmission organization
SGAM	smart grid architecture model
SOC	state of charge
TSO	transmission system operator
UTC	Universal Time Coordinated

4. DER concepts and context

4.1 Overview of DER hierarchical configurations

This clause describes the expected architecture of DERs and identifies to which interfaces this standard is expected to apply. Direct control of DER by distribution system operators (DSOs) is neither technically feasible nor contractually acceptable for the thousands, if not millions, of DER systems interconnected with the distribution power system. At the same time, utilities are responsible for meeting the reliability and electrical requirements within their distribution systems and therefore require information on the locations, capabilities, and operational status of these DER systems, both initially at interconnection and eventually in a high DER future, throughout the life of the DER. In addition, these DER systems can significantly assist in meeting utility requirements effectively and efficiently, thereby making them proactive stakeholders in managing the electric power system.

Information exchange is critical to accommodate these complex and dynamic power system requirements, and management of these information exchanges needs to be organized and interoperable. Specifically, a hierarchical approach is necessary for the various stakeholders (utilities, aggregators, facilities, markets, and DER systems) to exchange information. At the local level, DER systems generally manage their own generation and storage activities autonomously based on local conditions, preestablished settings, and DER owner preferences. DER systems can also be active participants in power system operations and should be coordinated with other DER systems and distribution equipment. In addition, the DSOs should interact with transmission system operators (TSOs), also known as “RTOs” and/or “ISOs,” for reliability and market purposes. In some regions, retail energy providers, aggregators, or other energy service providers are responsible for managing groups of DER systems through either operational actions or market actions.

This hierarchical approach can be described as hybrid combinations of five levels across multiple domains, as illustrated in the five-level hierarchical DER system architecture shown in Figure 1 and described after. The circled numbers identify the various logical information exchanges and are explained in Table 3.

Table 3—Protocol alternatives for DER systems

Protocol	Domain	#	Data format	Availability	Latency (low = fast)	Cybersecurity
IEEE Std 1815 (DNP3) (IEEE Std 1815.2 for DER)	Widely used by utilities for SCADA interactions with field devices	1, 2	Simple data structures	High	Low latency	In IEEE Std 1815. Based on IEC 62351-5 [B15]
IEC 61850-8-1 (MMS) [B14]	SCADA communication to field devices	1	IEC 61850-7-x over BER	High	Low-to-medium latency	In IEC 62351 standards
IEC 61850-8-1 (GOOSE) [B14]	Protective relaying and substation status signals	12, 13	ASN.1/BER	Very high	Very low latency	In IEC 62351 standards
Modbus (SunSpec Alliance mappings)	Widely used between DER components	12	Simple data structures	High	Low latency	None in Modbus but may use bump-in-the-wire
IEC 61850-8-2 (61850 IoT)	Interactions with DER systems	2, 3, 10	IEC 61850-7-x over XMPP	High	Low-to-medium latency	In IEC 62351 standards
IEEE Std 2030.5™-2023 (SEP2) [B21]	Originally home area networks, now being expanded to utility interactions with DER systems	2, 3, 10	XML, using XSD structures using RESTful HTTP	Medium	Medium latency	In IEEE Std 2030.5-2023 [B21]
OCPP	Electric vehicle financial interactions	4	JSON or SOAP	High	Medium latency	TLS1.2 or later
ISO/IEC 15118-20 [B22]	Electric vehicle charging and discharging	14	Simple data structures	High	Low latency	In ISO/IEC 15118-20
SAE series for EVs	Electric vehicle charging and discharging	14	IEEE Std 2030.5 [B21] and others	High	Low latency	SAE J2931/7 [B25]
OpenADR (IEC 62746-10-1 [B16])	Market Demand Response	8	XML-based	Low	Medium latency	TLS 1.2
Proprietary	Vendor-specific	4a, 15	Proprietary, XML, JSON	Medium	Medium latency	Unknown

NOTE—Numbers in column three refer to the circled numbers in Figure 1.

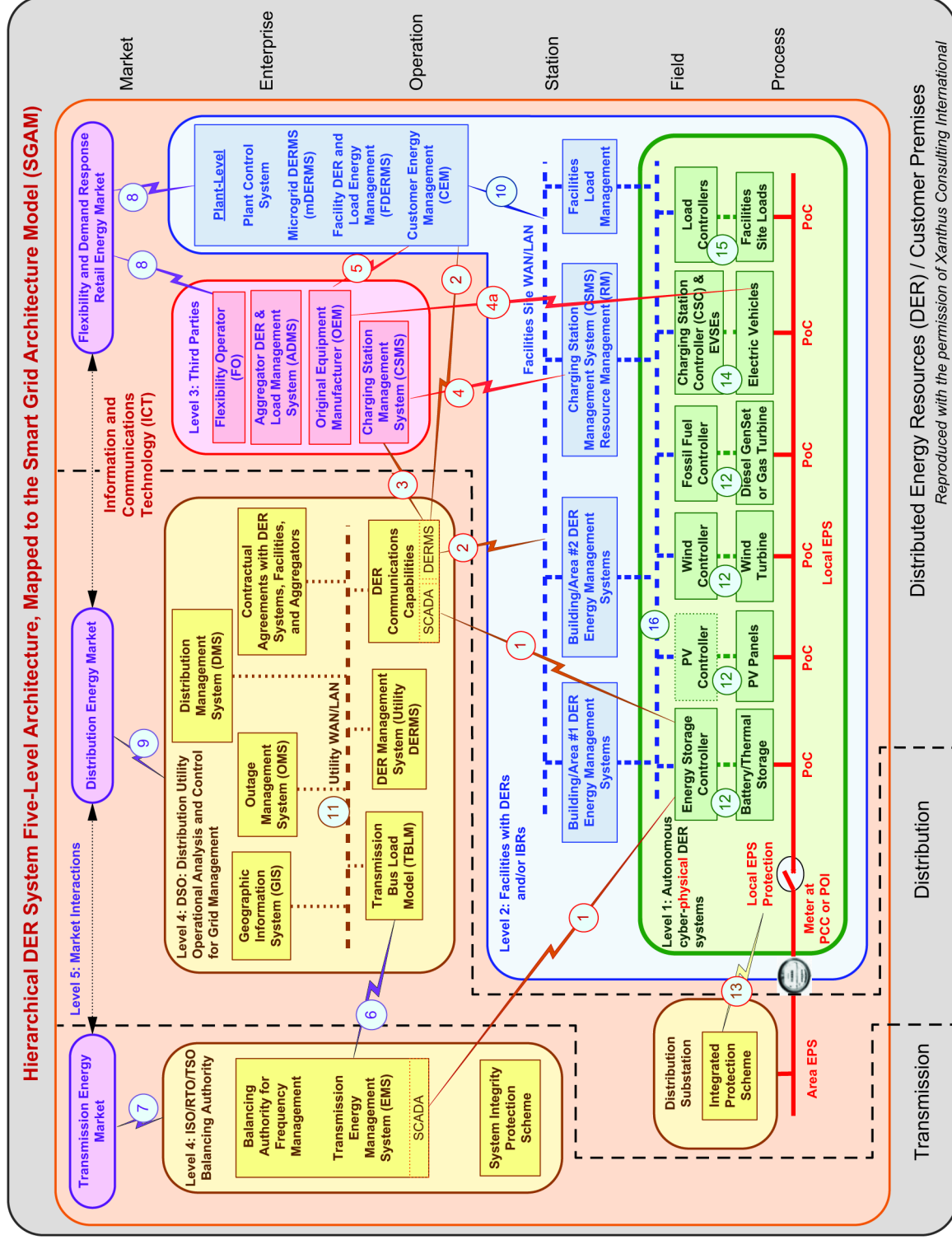


Figure 1—Hierarchical management of information exchanges for DER systems

- a) **Level 1 DER Systems** (green in Figure 1) includes the actual cyber-physical DER systems themselves. These DER systems will be interconnected to local grids at electrical connection points (ECPs) and to the utility grid through the PCC (the ECP and the PCC may be the same if the DER is directly grid-connected). These DER systems will usually be operated autonomously running based on local conditions, such as photovoltaic systems operating when the sun is shining, wind turbines operating when the wind is blowing, electric vehicles charging when plugged in by the owner, and diesel generators operating when started up by the customer. This autonomous operation can be modified by DER owner preferences, preset parameter, and commands issued by utilities and aggregators.
- b) **Level 2 Facility DER Management** (blue in Figure 1) is the next higher level in which a facility DER management system (FDERMS) manages the operation of the Level 1 DER systems. This FDERMS may be managing one or two DER systems in a residential home, but more likely will be managing multiple DER systems in commercial and industrial sites, such as university campuses and shopping malls. Utilities may also use a FDERMS to handle DER systems located at utility sites such as substations or power plant sites. For utilities, FDERMS are viewed as field systems and shown at the station level of the SGAM; however, from a facility's point of view, they may be seen as enterprises in their own right, and they could then be shown at the enterprise and operations levels.
- c) **Level 3 Third Parties: Retail Energy Provider or Aggregators** (red in Figure 1) shows market-based aggregators and retail energy providers (REPs) who request or even command DER systems (either through the facility's FDERMS or via aggregator-provided direct communication links) to take specific actions, such as turning on or off, setting or limiting output, providing ancillary services (e.g., volt-var control), and other grid management functions.
- d) **Level 4 Utility Operational Grid Management** (yellow in Figure 1) applies to utility applications that are needed to determine what requests or commands should be issued to which DER systems. DSOs should monitor the distribution power system and assess if efficiency or reliability of the power system can be improved by having DER systems modify their operation. When a utility has determined that modified requests or commands should be issued, it will send these directly to a DER system using a protocol such as DNP3, indirectly through the FDERMS, or indirectly through the REP/Aggregator.
- e) **Level 5 Market Operations** (purple in Figure 1) are the highest level and involve the larger energy environment where markets influence which DER systems will provide what services. The TSO markets are typically bid/offer transaction energy markets between individual DER owner/operators and the TSO. At the distribution level, the markets are not yet well formed, and over time as they evolve, they may be based on individual contracts, special tariffs, demand response signaling, and/or bid/offer transaction energy markets.

4.2 DER structures and configurations

4.2.1 DER definition

DER is defined in IEC 61850-7-420 as an energy resource comprising generation and/or storage and/or controllable load connected at the low- or medium-voltage distribution level. On the other hand, IEEE Std 1547-2018 does not explicitly include controllable load. IEEE Std 2800, which focuses on transmission-connected resources, does not use the term “DER” but instead defines the term “IBR” as an individual inverter device or a grouping of multiple inverters connected together at a single point of interconnection (POI). The point of measurement (POM) is the electrical location where measurements are taken.

However, all of the definitions included the assumption that a “DER” or an “IBR” can be composed of one or more “Units” with the boundary between these units defined as their PoCs. Therefore, the definition of a specific DER can vary depending on the perspective of the entity viewing or using the DER.

For the purposes of this communication standard, the terms “DER” and “IBR” are seen as equivalent and are used interchangeably since both DER and IBR may use this profile regardless of voltage levels (e.g., transmission or distribution voltage levels).

4.2.2 DER architectural assumptions

DERs come in many different configurations. A simple DER may consist of a single battery, a power conversion system, and one or two meters, as shown in Figure 2. More complex DER systems might include multiple inverters with pairs of photovoltaic (PV) devices and batteries, controllable loads, and/or buildings within a site containing various DER systems. Such a DER site would utilize additional meters to help ensure the proper monitoring and control of the DER systems.

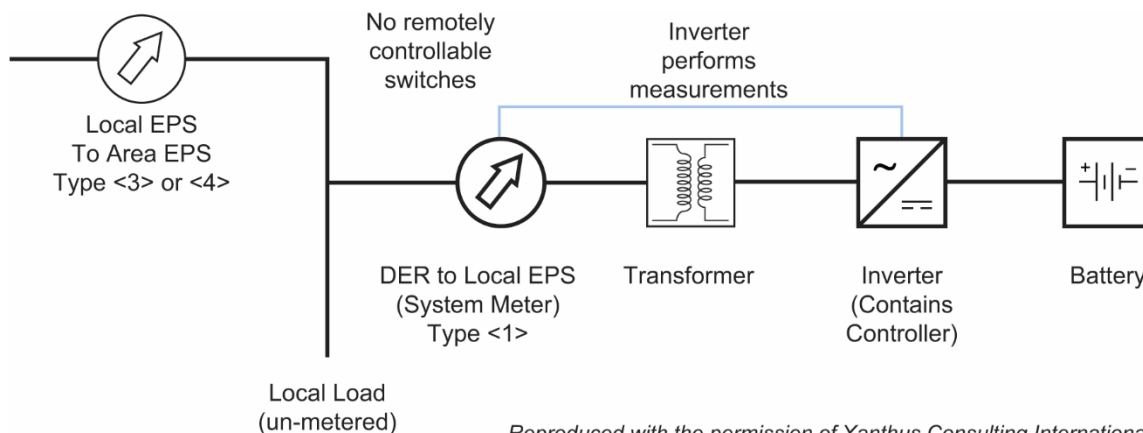


Figure 2—Simple DER

The DER profile makes several assumptions about the structure of the DER. Many of these assumptions and terms are derived from those used by IEEE Std 1547-2018 and IEC 61850-7-420:2021. These architectural assumptions include the following:

- a) **The DER model is a nested (hierarchical) model** [i.e., a DER is composed of one or more DERs (see Figure 3)].

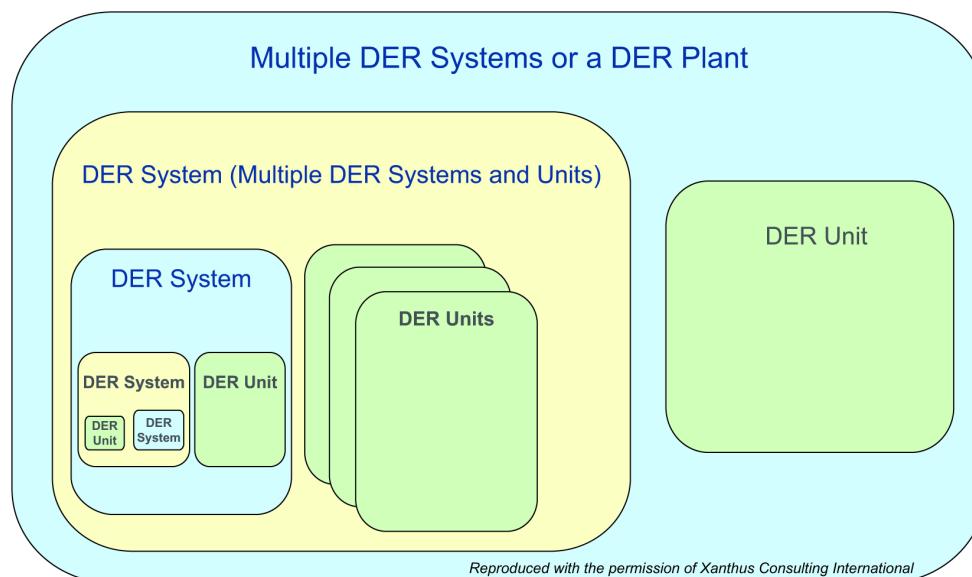


Figure 3—Nested composition of DER systems or DER plant

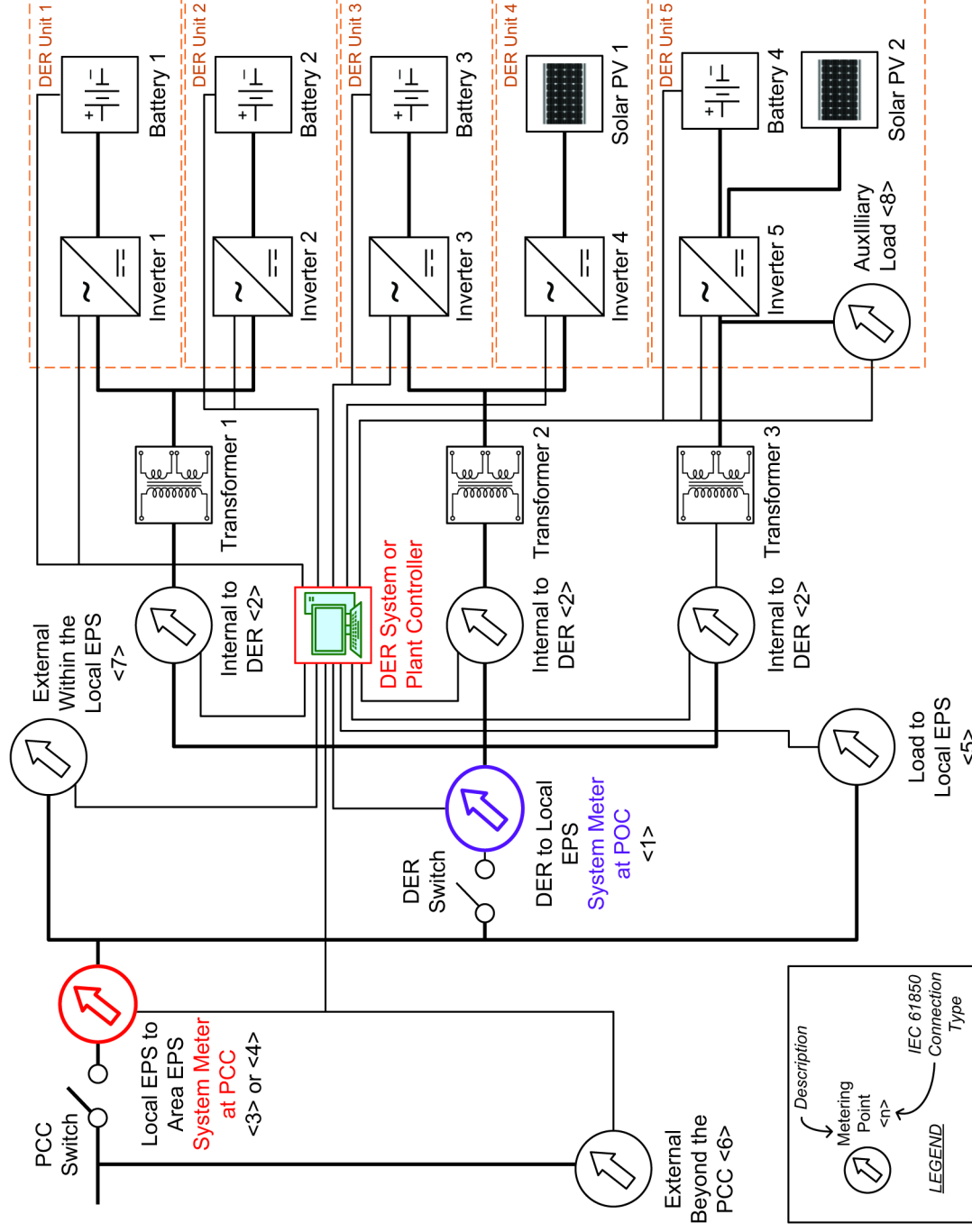
- b) **A DER may consist of generation, storage, load, or any combinations of these (mixed).** Noncontrollable load is not generally considered as DER but must be considered as a power system element. For example, when a DER requirement is to be met at the PCC or other ECP that includes loads behind it, the power management system or the DER controller may need to shed loads, modify loads, or compensate for loads.
- c) **This profile defines communications between a single DNP3 controlling station and a single outstation.** This outstation may be a single inverter controller or a plant controller. Some DERs include multiple processors and controllers. However, this profile assumes that the DNP3 communications take place with a single outstation that may act as a proxy or an aggregator for any other devices.
- d) The DER is part of a local EPS. The local EPS:
 - 1) Typically has a single connection to the area EPS (but may have more), which is normally the power utility distribution network. This is known as the “PCC.”
 - 2) May contain more than one DER unit, for example, at different buildings on a campus, together having a single PCC to the power utility. For the purposes of this profile, if a group of equipment has a separate controller acting as a DNP3 outstation that can adjust the input and output of the group, that group is considered a separate DER unit.
 - 3) May contain load, generation, and storage. Load that is located within the local EPS (i.e., is connected to the area EPS via the PCC) is known as “local load.”
- e) **The DER consists of the following entities**, each of which has its own block of input and output data points defined in this profile:
 - 1) A controller, as just described.
 - 2) At least one DER unit. There may be several DER units within the DER. A DER unit consists of:
 - i) An inverter that converts between ac and dc electricity. The assumption in this profile is that this is a “smart” inverter (i.e., capable of data communications and adjusting its operation in response to remote requests).
 - ii) At least one energy source. These sources may be storage devices, generation devices (e.g., PV panels or diesel motors), electric vehicles, or some combination. If the DER unit contains storage, the outstation may choose to report information associated with the storage using the block of points defined for a battery. No blocks of points defined in this profile are associated with any other specific type of energy source.
 - 3) At least one meter. Meters are categorized in IEC 61850 and in this profile by their location in and around the DER and provide status and measurements, as illustrated in Table 4 and Figure 4.
 - 4) An optional DER switch, also known as the “physical disconnect” switch, at the point where the entire DER connects to the local EPS (i.e., at the same point the system meter measures). Some DERs may not include this switch or may not permit it to be operated remotely.

Figure 4 provides an example of a DER system containing storage batteries and PV with different inverted configurations. Table 4 describes the meaning of the different connection types.

Table 4—IEC 61850 connection point types (DER meter types)

Number in diagram	Name	Details
<1>	DER to Local EPS	There is only one meter of this type in the DER. This is the system meter (ID = 0) for the DER, and the only metering point that is mandatory in this profile. Some specifications call this location the “DER PoC.” The system meter measures the input and output of <i>all</i> DER units at the point where they connect to the local EPS. The system meter points are grouped with the other system points describing the operation of the DER as a whole.
<2>	Internal to DER	This connection type may represent any meter within the DER that is not the system meter and does not specifically measure load. In Figure 4, this type of meter is shown measuring groups of DER units.
<3>	Local EPS with Load to Area EPS	This type of meter is at the PCC. A different IEC connection point type is assigned depending on whether the local EPS contains load.
<4>	Local EPS without Load to Area EPS	
<5>	Load to Local EPS	This type of meter measures only the local load.
<6>	External to DER beyond the PCC	This type of meter is sometimes called a “signal meter.” It measures a point outside the DER such as another DER in the local EPS or another generation source. This type of meter is used as input by some DER functions, for example, load following, generation following, or peak power limiting.
<7>	External to the DER within the Local EPS	
<8>	Auxiliary Load	This type of meter measures loads that are local to the DER itself, such as heaters, video cameras, or other security equipment.
<9>	Group of DERs to the Area EPS	This type of connection is not illustrated in Figure 4.

Distributed Energy Resource



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Figure 4—DER system, containing battery storage, solar PV, and loads

The Standard DNP3 Profile was designed to support these different DER configurations. In addition to traditional one-unit, one-inverter configurations, the Standard DNP3 Profile recognizes that multiple devices may share one inverter. For instance, a DER may consist of one or more inverters connected to the same number of energy storage components (e.g., battery banks) or may have one inverter for a dc-connected PV plus storage unit. A DER compatible with the Standard DNP3 Profile may have one or more inverter and battery bank pairs.

To optimize maximum utilization of more complex energy storage systems, the Standard DNP3 Profile provides monitoring and control points that allow an inverter and battery pair to be taken offline for maintenance while the rest of the system continues to operate normally. For example, for the DER shown in Figure 4, it is possible to place Inverter 3 and Battery 3 into maintenance mode and continue to use the rest of the system normally.

4.3 Storage DER: Actual versus usable capacity

The definition of the capacity of a storage DER depends on what is important to different types of users. For instance, the manufacturer of a DER is concerned about the actual capacity of the DER, while an operator is only interested in what capacity is available to be used. Therefore, as illustrated in Figure 5, two types of capacities are envisioned: the actual DER capacity and the usable DER capacity. The actual DER capacity is the nameplate information, possibly modified over time if the DER characteristics change. The usable DER capacity is what users are permitted to have access to, which is based on the decisions of DER manufacturers or DER owner/operators.

In addition to usable capacities, DER owner/operators may choose to establish maximum and/or minimum reserve capacities (as a percentage of usable capacity) that would normally not be used but could be used for either emergency situations or other special circumstances.

State-of-charge (SOC) would be based on these capacity definitions, in which the “actual state of charge” is the percentage of actual capacity, while the “usable state of charge” is the percentage of usable capacity.

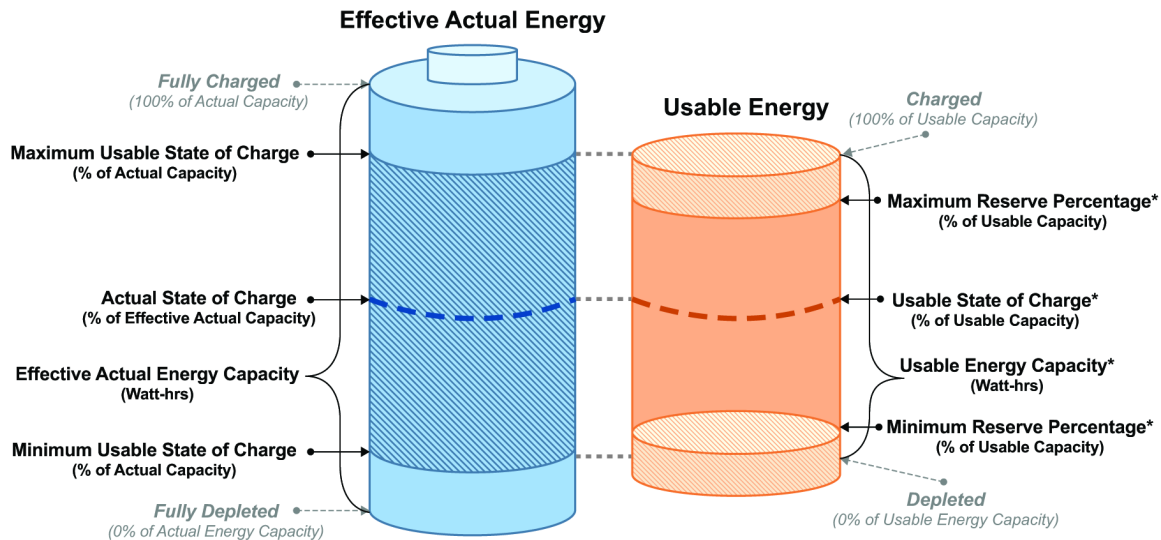


Figure 5—DER state of charge: Difference between actual capacity and usable capacity

4.4 Protocol alternatives for information exchanges with DER systems

4.4.1 Structure of information layers

Communications involve more than the traditional concept of communication protocols (e.g., bits and bytes going over a wire). The exchange of information involves multiple layers of interactions and business purposes down to the various media that could transport the information. As an example, the GridWise Architecture Council (GWAC) Stack and SGAM models are different; the GWAC stack has eight layers, while the IEC 63200 SGAM identifies six communication layers, but these two models were easily mapped to each other. As illustrated in Figure 6, the following are the primary information layers:

- a) **Business Objectives, Economic/Regulatory Policy, Business Layer:** This layer covers the business purposes for communications, including providing information for business decisions, meeting regulatory requirements, and requiring interoperability. This layer is not generally included in a communication protocol but is the driver for the design and capabilities of the rest of the layers.
- b) **Business Context and Procedures, Function Layer:** This layer addresses the functionality and use of the data within business contexts. This includes collections of settings, monitored information, commands, defaults, and timing, providing the information exchange requirements for the Voltage-Reactive Power function and sequences of steps with specific data exchanged in each for a DER to perform the Frequency Ride-Through function.
- c) **Semantic Understanding, Information Layer:** This layer provides the meaning of the data and acts as nouns in the sense of “the three-phase rms voltage measurement on Feeder A in Substation Z,” “the maximum active power rating of DER B right now,” or “the updated setting for reactive power for power plant Y.”
- d) **Syntactic Interoperability, Application Layer:** This layer provides the communication services and acts as verbs in the sense of getting, monitoring, controlling, and setting data values. It does not cover the meaning of the data, only the services.
- e) **Network Interoperability, Transport Layer:** This layer transports the information, usually in message packets, from one end to the other end. This may involve going through multiple nodes, gateways, routers, and so on.
- f) **Basic Connectivity, Component Layer:** This layer encompasses the physical media, such as wires, wireless, fiber optics, coaxial cable, local-area networks (LANs), and wide-area networks (WANs).

4.4.2 Four communication protocols identified in IEEE Std 1547-2018

There are many different communication protocols, information models, and cybersecurity standards for DER. Each has specific capabilities based on its origins and purposes, although some have expanded over time. The four core communication protocols and information models for DERs are illustrated in the four columns on the right-hand side of Figure 6.



4.4.3 Application of protocols in IEEE Std 1547-2018

Utility – DER Information Architecture, with Gateways for Security and Communications between Different Organizations

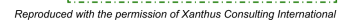


Figure 7—Utility-DER information architecture

4.5 IEC 61850-7-420 data model and naming conventions

Users of DNP3 may be familiar with the concept that the data reported to the controlling station is just a simplified view, or *model*, of what is actually happening at the remote site. There may be many complex interactions between devices that are simply summarized for the benefit of the controlling station. The collection of data reported and controlled by the DNP3 outstation is known as its *data model*. This terminology is not commonly used in the DNP3 documentation, but nonetheless each DNP3 outstation has a data model.

In DNP3, the data model is “flat.” Each data point is simply numbered, and there is no indication within the protocol itself of how one point relates to another. In IEC 61850 data models, each piece of data has a human-readable text *name* that uniquely identifies it. IEC 61850 names have a hierarchical structure, similar to a file system, so that each point of data has an implied relationship with the others.

IEC 61850 names consist of the hierarchy shown in Figure 8: *logical devices* that contain *logical nodes*, which contain *data objects*, which may contain several layers of *data attributes*. A logical node (LN) is a grouping of data associated with a particular electrical system function. Logical nodes are designated by four-character *class names*. If there is more than one logical node of the same class (performing the same function but on another part of the system), they are distinguished by one-or-two-character *instance numbers*.

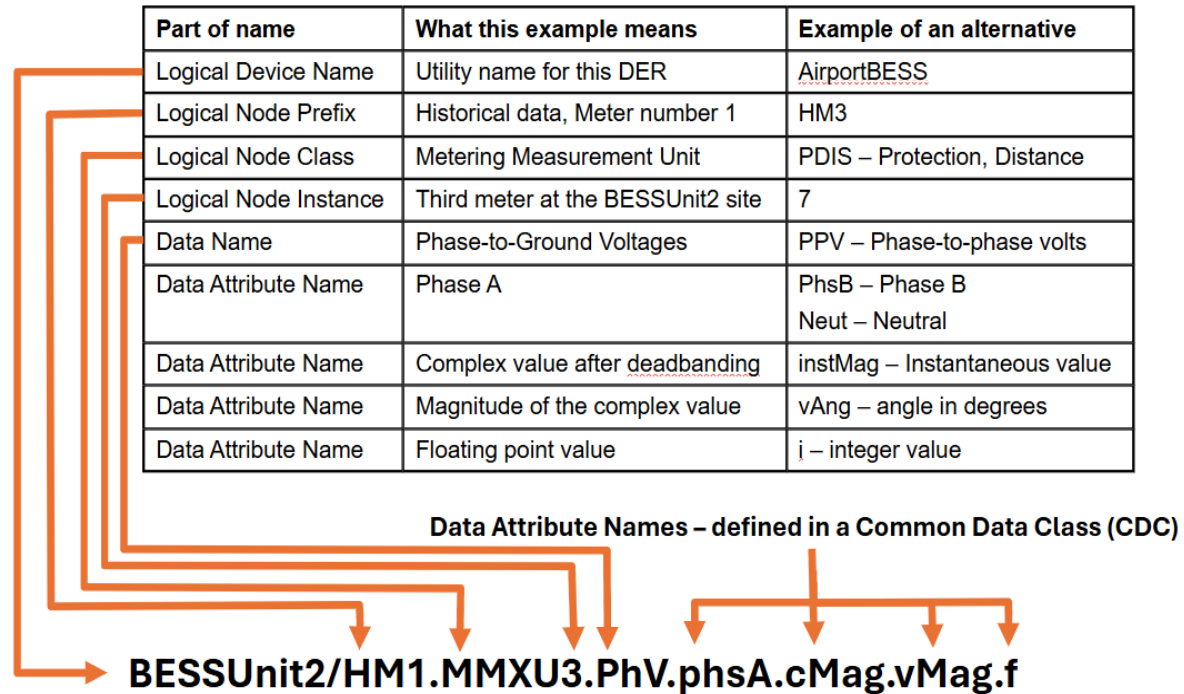


Figure 8—Example of an IEC 61850 name

5. DNP3 point constructs

5.1 Types of DNP3 points

This clause describes the points to be used by DNP3 outstations controlling a DER. The actual lists are contained in the associated IEEE 1815.2 Profile Companion Data Point Tables while the summary is included in Table 1.

Each type of DER component has a set or “block” of points associated with it based on whether the points are binary or analog, as well as on whether they represent inputs (to the controlling station) or outputs (from the controlling station). These are organized in different tabs in the IEEE 1815.2 Profile Companion Data Point Tables. In each block, the points are grouped into categories by their general purpose, as shown in Table 5. Figure 9 illustrates how the points are organized. For purposes of expansion, there are “gaps” between each category to allow additional DNP3 points to be added over time.

Table 5—Categories of points

Point category	Description
SCADA	The following points are associated with the controller. They define the following: a) The nameplate limits of the DER. b) The current physical configuration (structure) of the DER, including values that indicate the number of point blocks of meters, DER units, inverters, and batteries (equipment points) implemented by the outstation. c) The settings controlling all the DER functions as described in 6.1, 6.2, 6.3, 6.4, and 6.5. Refer to 6.1.1 and the NOTE that follows it regarding non-implemented functions. d) The current status of all the DER functions. e) The definition of curves for controlling DER operation, such as volt-var curves. Refer to 6.1.3. f) The measurements made by the system meter. The location of the system meter is illustrated in Figure 4. g) Extensions beyond the previous version of the profile (DNP3 AN2018-001 [B4]) are added at the end. NOTE—An outstation may claim to implement this DNP3 application note without implementing all the inverter functions.
Scheduling	Points that permit power scheduling personnel to effectively control the behavior of the DER over specific time periods. Schedules are implemented by the controller.
Equipment	Detailed measurement and performance data that may be valuable to record for operations of the equipment, but might not be useful to a system operator. These points are associated with the meters, DER units, inverters, and batteries in the DER.
Experimental Extensions	Points for new or extended or experimental functions that may not be the final set of points. Therefore, these experimental DNP3 point numbers may not be permanent.
Vendor-Specific	If an outstation reports additional data points, they shall be added after the last point index described in this specification that is appropriate to that DER’s implementation level, as illustrated in Figure 9. This capability permits an outstation to add to its outstation any proprietary or innovative functionality that is not part of this standard.
Start Indexes	Implementation of these points is optional and, if implemented, are not included in Class 0. See 1.4 for more details.

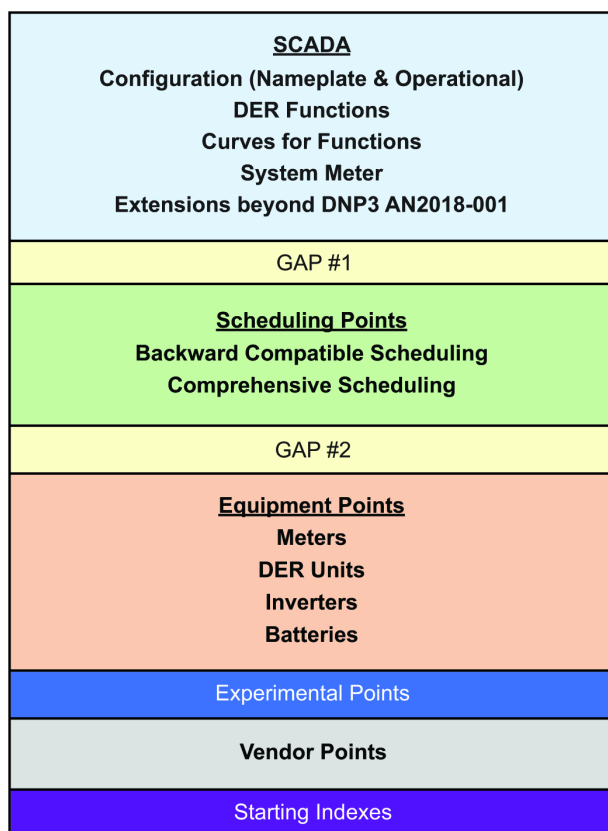


Figure 9—Categories of points

The naming of these point categories is somewhat arbitrary; since DNP3 is a SCADA protocol, any of these point categories can reasonably be considered “SCADA” points. However, the terminology is useful to describe which points are implemented in a given outstation.

The intent is that the system engineer configuring the controlling station can always know exactly which non-vendor-specific data points are implemented by the outstation, and in what order, based on the following:

- The DER Profile Version Number *MESA.VersNum* (DNP3 point AI0). This standard is currently version 1.1.
- The numbers of meters, DER units, inverters, and batteries as specified in the Key Tab of the IEEE 1815.2 Profile Companion Data Point Tables and captured in *MESA.NumMtr*, *MESA.NumInv*, *MESA.NumBat*, and *DSTO.InclDER*, respectively (DNP3 points AI24 through AI28).

The table formats and protocol parameters specified in this profile are taken from the DNP3 XML Device Profile [B6]. The subclause numbers in the “protocol options” tables are references within that document. When fields from the device profile are left blank, the value is left up to the implementer.

5.2 Method for numbering and indexing the DNP3 points

The SCADA and configuration (system) points have fixed absolute point numbers, with the starting indexes always starting at zero (0). However, the function, curves, schedule, equipment, and vendor points shall be relative to their starting index values and can be calculated from the starting index values in the Key Tab of the IEEE 1815.2 Profile Companion Data Point Tables or, if supported, dynamically from the starting index values starting at DNP3 Point AI65000.

In the Profile Companion Data Point Tables, an expression such as “HM + hmbi(m) + 2” means “Take the Starting Index of the equipment meter points, add the number of (equipment) binary input points per meter multiplied by the block number of this particular meter (where meter blocks are numbered starting at 0) and add two.” Note the expressions used may appear somewhat inconsistent (e.g., “equipment meters” vs. “DER units, equipment”), but the same expression is always used to refer to the same point.

5.3 Event classes

Event data is reported using class polling (or unsolicited reporting) in DNP3. This profile uses the criteria shown in Table 6 for assigning points to default DNP3 event classes.

Table 6—Default DNP3 event classes in his profile

Class	Criteria
1	Critical data. Alarms and other events requiring immediate action
2	Feedback
3	Measurements and configuration

If supported by the outstation, the operator/engineer may choose to change these defaults at runtime using the ASSIGN_CLASS function code from the controlling station. However, the outstation is not required to support ASSIGN_CLASS because it is not a DNP3-L2 function. The outstation may alternatively permit event classes to be assigned by preconfiguration or make them fixed.

5.4 Implementation table

Table 7 shows the minimum DNP3 objects and function codes that shall be supported by the controlling station and outstation implementing this profile. Devices may support objects and function codes beyond those listed in this table by agreement between the controlling station and outstation. This table represents the subset of Level 2 implementation used in this profile, as discussed in 1.9. As discussed in 5.6.4 and 5.6.5, floating-point analog inputs and outputs, as well as 32-bit analog outputs, are not part of the minimum requirements but are recommended enhancements. Objects that go beyond Level 2 implementation may also be required to implement all features presented in this standard. As always, for compliance with IEEE Std 1815, implementers are required to provide a device profile document precisely specifying the capabilities of their DNP3 implementation.

Table 7—DNP3 implementation table

DNP object group and variation			Request Controlling station may issue Outstation shall parse		Response Controlling station shall parse Outstation may issue	
Group num	Var num	Description	Function codes (dec)	Qualifier codes (hex)	Function codes (dec)	Qualifier codes (hex)
1	0	Binary Input—Any variation	1 (read)	06 (no range, or all)		
1	1	Binary Input—Packed format			129 (response)	00, 01 (start-stop)
1	2	Binary Input—With flags			129 (response)	00, 01 (start-stop)

DNP object group and variation			Request Controlling station may issue Outstation shall parse		Response Controlling station shall parse Outstation may issue	
Group num	Var num	Description	Function codes (dec)	Qualifier codes (hex)	Function codes (dec)	Qualifier codes (hex)
2	0	Binary Input Event— Any variation	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
2	2	Binary Input Event— With absolute time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
2	3	Binary Input Event— With relative time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) 130 (unsol. resp)	17, 28 (index)
10	0	Binary Output— Any variation	1 (read)	06 (no range, or all)		
10	2	Binary Output— Output status with flags			129 (response)	00, 01 (start- stop)
12	1	Binary Command— Control relay output block (CROB)	3 (select) 4 (operate) 5 (direct op) 6 (dir. op, no ack)	17, 28 (index)	129 (response)	echo of request
20	0	Counter— Any variation	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz. cl. noack)	06 (no range, or all)		
20	1	Counter— 32-bit with flag			129 (response)	00, 01 (start- stop)
21	0	Frozen Counter— Any variation	1 (read)	06 (no range, or all)		
21	1	Frozen Counter— 32-bit with flag			129 (response)	00, 01 (start- stop)

DNP object group and variation			Request Controlling station may issue Outstation shall parse		Response Controlling station shall parse Outstation may issue	
Group num	Var num	Description	Function codes (dec)	Qualifier codes (hex)	Function codes (dec)	Qualifier codes (hex)
21	9	Frozen Counter— 32-bit without flag			129 (response)	00, 01 (start-stop)
22	0	Counter Event— Any variation	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
30	0	Analog Input— Any variation	1 (read)	06 (no range, or all)		
30	1	Analog Input— 32-bit with flag			129 (response)	00, 01 (start-stop)
32	0	Analog Input Event— Any variation	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
32	1	Analog Input Event— 32-bit without time			129 (response) 130 (unsol. resp)	17, 28 (index)
40	0	Analog Output Status—Any variation	1 (read)	06 (no range, or all)		
40	2	Analog Output Status—16-bit with flag			129 (response)	00, 01 (start-stop)
41	2	Analog Output— 16-bit	3 (select) 4 (operate) 5 (direct op) 6 (dir. op, no ack)	17, 28 (index)	129 (response)	echo of request
50	1	Time and Date— Absolute time	2 (write)	07 (limited qty = 1)		
51	1	Time and Date CTO—Absolute time, synchronized			129 (response) 130 (unsol. resp)	07 (limited qty) (qty = 1)
51	2	Time and Date CTO—Absolute time, unsynchronized			129 (response) 130 (unsol. resp)	07 (limited qty) (qty = 1)

DNP object group and variation			Request Controlling station may issue Outstation shall parse		Response Controlling station shall parse Outstation may issue	
Group num	Var num	Description	Function codes (dec)	Qualifier codes (hex)	Function codes (dec)	Qualifier codes (hex)
52	1	Time Delay—Coarse			129 (response)	07 (limited qty) (qty = 1)
52	2	Time Delay—Fine			129 (response)	07 (limited qty) (qty = 1)
60	1	Class Objects— Class 0 data	1 (read)	06 (no range, or all)		
60	2	Class Objects— Class 1 data	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
60	3	Class Objects— Class 2 data	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
60	4	Class Objects— Class 3 data	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
80	1	Internal Indications— Packed format	2 (write)	00 (start-stop) index=7		
No Object (function code only)			23 (delay meas.)			

5.5 IEC 61850 mapping

In the IEEE 1815.2 Profile Companion Data Point Tables, the column headed “IEC61850UniqueString” has concatenated the Unique Names from IEC 61850 structures, as shown in Table 8.

Table 8—Meanings of the IEC 61850 columns

IEC 61850 structure	Meaning
Prefix	Prefix to support uniqueness
LN Inst	Logical node instance
Data Object	Data object within the logical node
CDC	Common data class of the data object
LN Class	Logical node class

IEC 61850 structure	Meaning
Unique String	This is the standardized IEC 61850 name of the point, including a prefix and/or an instance number if there are multiple data objects with the same name. The utility may add device names to this name to specify a particular location or instance.

The IEC 61850 Common Data Classes are defined in the IEC 61850-7-3 specification. Table 9 lists the names of those used in this profile.

Table 9—IEC 61850 common data classes referenced by this profile

CDC	Name
APC	Analog setpoint controllable
ASG	Analog setting
CSG	Curve setting
DPC	Double point controllable
ENG	Enumerated setting
ENS	Enumerated status
INC	Integer status controllable
ING	Integer setting
INS	Integer status
MV	Measured value
SPC	Single point controllable
SPS	Single point status
WYE	Wye-Connected 3-phase measurement

5.6 Data points in the IEEE 1815.2 Profile Companion Data Point Tables

5.6.1 Binary input (BI) tab in the IEEE 1815.2 Profile Companion Data Point Tables

The Binary Input (BI) tab in the IEEE 1815.2 Profile Companion Data Point Tables lists the binary input points (DER to controlling station) to be used in the DNP3 Profile for DERs. Table 10 specifies the minimum capabilities that shall be used by outstations when reporting these points. Note that these binary inputs are read/only values that represent the current state of the system. Some of these values can be changed using the corresponding binary output points listed in the Binary Output (BO) tab. The point numbers for the writeable values (BO) and the read/only (BI) values are not the same.

Table 10—Binary input protocol options

3.1 Single-bit binary inputs Static (Steady-State) Group Number: 1 Event Group Number: 2	Capabilities
3.1.1 Static variation reported when variation 0 requested or in response to class polls:	☐ Variation 1—Single-bit packed format ☒ Variation 2—Single-bit with flag ☐ Based on point index (add column to table in part 5)
3.1.2 Event variation reported when variation 0 requested or in response to class polls: <i>Note: The support for binary input events can be determined remotely using protocol object Group 0 Variation 237 if Device Attribute Objects are supported.</i>	☐ Variation 1—without time ☒ Variation 2—with absolute time ☒ Variation 3—with relative time ☐ Based on point index (add column to table in part 5)

3.1 Single-bit binary inputs Static (Steady-State) Group Number: 1 Event Group Number: 2	Capabilities
3.1.3 Event reporting mode: <i>When responding with event data and more than one event has occurred for a data point, an outstation may include all events or only the most recent event. All events must be checked to be compliant.</i>	☐ Only most recent ☒ All events ☐ Based on point index (add column to table in part 5)
3.1.4 Binary inputs included in Class 0 response:	☒ Always ☐ Never ☐ Only if the point is assigned to a class ☐ Based on point index (add column to table in part 5)

5.6.2 Binary output (BO) tab in the IEEE 1815.2 Profile Companion Data Point Tables

The BO tab in the IEEE 1815.2 Profile Companion Data Point Tables lists the binary output points (controlling station to DER) to be used in the DNP3 Profile for DERs.

Most of these binary output points have corresponding binary input points to provide feedback to the controlling station that the operation is completed. In addition to this feedback, it is recommended that the controlling station and outstation use binary output event objects. However, it shall be possible for the outstation to disable this capability because it is beyond a DNP3-L2 implementation.

Table 11 specifies in DNP3 Device Profile format the control operations that shall be supported for every binary output point (these columns are not shown in the IEEE 1815.2 Profile Companion Data Point Tables because of a lack of space and because they are the same for all binary output points).

Although all operation pairs (Pulse, Latch, Trip/Close) are permitted, the outstation shall behave as if all points were latched. Pulse time values in the control relay output block objects shall be ignored by the outstation. Note that all objects require select-before-operate functionality.

Table 11—Control operations supported

Supported control operations									
Select/Operate	Direct operate	Direct operate—No ack	Pulse on	Pulse off	Latch on	Latch off	Trip	Close	Count > 1
X	X	X	X	X	X	X	X	X	

Table 12 provides the minimum binary output status and control relay output block capabilities that shall be used by outstations when reporting these points.

Table 12—Binary output status and control relay output block

3.3 Binary Output Status and Control Relay Output Block Binary Output Status Group Number: 10 Binary Output Event Group Number: 11 CROB Group Number: 12 Binary Output Command Event Object Num: 13	Capabilities
3.3.1 Minimum pulse time allowed with Trip, Close, and Pulse On commands:	☒ Fixed at __0__ms ☐ Based on point index (add column to table in part 5)
3.3.2 Maximum pulse time allowed with Trip, Close, and Pulse On commands:	☒ Fixed at ____65 535__ms ☐ Based on point index (add column to table in part 5)
3.3.3 Binary output status included in Class 0 response:	☐ Always ☐ Never ☒ Only if the point is assigned to a class ☐ Based on point index (add column to table in part 5)
3.3.4 Reports output command event objects:	☒ Never ☐ Only upon a successful control ☐ Upon all control attempts
3.3.5 Static variation reported when variation 0 requested or in response to class polls:	☐ Variation 1—packed format ☒ Variation 2—output status with flags ☐ Based on point index (add column to table in part 5)
3.3.6 Event variation reported when variation 0 requested or in response to class polls: <i>Note: The support for binary output events can be determined remotely using protocol object Group 0 Variation 222.</i>	☐ Variation 1—status without time ☒ Variation 2—status with time ☐ Based on point index (add column to table in part 5)
3.3.7 Command event variation reported when variation 0 requested or in response to class polls:	☐ Variation 1—without time ☐ Variation 2—with absolute time ☐ Based on point index (add column to table in part 5)
3.3.8 Event reporting mode: <i>When responding with event data and more than one event has occurred for a data point, an outstation may include all events or only the most recent event.</i>	☐ Only most recent ☒ All events
3.3.9 Command event reporting mode: <i>When responding with event data and more than one event has occurred for a data point, an outstation may include all events or only the most recent event.</i>	☐ Only most recent ☐ All events