



MESA-ESS Specification
DRAFT
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1. Introduction

1.1 Scope and Purpose

The MESA-ESS specification defines the communication requirements for utility-scale energy storage systems (ESS), including ESS configuration management, ESS operational states, and a profile of the IEEE 1815 (DNP3) standard based on the IEC 61850-7-420 information model for advanced DER functions. These advanced DER include all of the functions defined in IEEE 1547:2018, California’s Utility DER Electric Rule 21 Interconnection, and the European ENTSO-E DER interconnection requirements (2016), as well as additional functions of particular interest to ESS. This specification references the DNP3 Application Note AN2018-001 which is based on a DNP3 Mapping Spreadsheet, which directly maps the IEC 61850 data objects for basic and advanced DER functions to DNP3 data objects.

The purpose of this MESA-ESS specification is to support the use of communication standards, promote interoperability, and minimize the amount of non-recurring engineering that is required to integrate ESS into utility operations using DNP3. It is expected that profiles of other communication standards will also be developed for different types and purposes of ESS (see Section 2). It is also expected that the IEC 61850-DNP3 profile will become an IEC document in the future.

For more information on MESA, please visit the MESA web site: <http://www.mesastandards.org>

1.2 References

The documents in Table 1 are either referenced in this document or provide additional information that may be useful when reading this document.

Table 1: Referenced Specifications and Standards

Document	Description
DNP3 Application Note: 2018 (AN2018)	DNP3 Profile for Advanced Distributed Energy Resource (DER) Systems
IEC/CD 61850-7-420: 2018	Communication networks and systems for power utility automation – Part 7-420: Basic communication structure - Distributed energy resources logical nodes (<i>currently available as a Committee Draft (CD)</i>)
IEEE 1547:2018	IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
California Rule 21	http://www.cpuc.ca.gov/Rule21/
IEEE 1815	IEEE Standard for Electric Power Systems Communications—Distributed Network Protocol (DNP3)
IEEE 1815.1	IEEE Standard for Exchanging Information between networks Implementing IEC 61850 and IEEE Std 1815™ (Distributed Network Protocol - DNP3)
EPRI 3002008217	Common Functions for Smart Inverters, Version 4

1.3 Process Used for Mapping IEC 61850-7-420 information model to DNP3 Data Points

After determining that the DNP3 AN2013-001 did not meet all of the requirements for MESA-ESS, in 2017 a collaborative effort between MESA and EPRI was initiated to develop an updated version, DNP3 AN2018: DNP3 Profile for Advanced Distributed Energy Resource (DER) Systems. At the same time, IEC 61850-7-420, the information model for DER, was being updated to reflect the new DER “grid code” requirements from California’s Rule 21, IEEE 1547:2018, and Europe’s ENTSO-e requirements. It was determined that not only should the DNP3 Application Note be updated to reflect ESS requirements, but that it should also include the new DER “grid code” requirements.

The basic procedure for developing the DNP3 AN2018 consisted of the following steps:

- The functional requirements for each DER “grid code” were defined (over the years 2013-2018) in the updates to California Rule 21 and in the revision of IEEE 1547.
- As the grid code functional requirements were defined and refined, the data exchange requirements were determined by the MESA-EPRI team and the IEC TC57 WG17 which is responsible for updating IEC 61850-7-420. These data objects were updated in the Enterprise Architect model of IEC 61850-7-420.
- The MESA-EPRI team created a DNP3 spreadsheet which was used to map each relevant data object from the IEC 61850-7-420 model to a DNP3 data point.
- Since both the IEEE 1547 and the IEC 61850-7-420 standards were being updated “simultaneously”, there were many iterations to ensure the functional requirements were clear, the information model was valid, and the mapping to DNP3 data points was correct.
- When IEEE 1547:2018 was released in April 2018, the IEC 61850-7-420 was also submitted to the IEC as a Committee Draft (this is the normal process for creating a standard). At the same time, the update to the DNP3 AN2018 was started, using the DNP3 spreadsheet.

1.4 Scope Constraints

Although the MESA-ESS specification can be used by any type or size of DER, including photovoltaic systems, any type of energy storage system, and combined PV plus storage, this profile is focused initially on utility-scale battery energy storage systems, so battery-specific terminology is sometimes used.

Some ESS requirements are discussed which may or may not involve the use of DNP3. For instance, although DNP3 is used to monitor operational states, the permissions associated with those states may be implemented manually or through some other protocol. It is also expected that some implementations may use DNP3 to collect historical data (as opposed to SCADA data), while other implementations may choose to use other protocols.

1.5 Terminology

The terms in Table 2 are used throughout this document.

Table 2: Terminology

Term	Definition
Battery Bank	A collection of battery cells which can be used to store energy. Connected to a single inverter. 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)	An integrated electronic management system for monitoring, measurement, reporting, and protection of a battery storage bank at cell-, module-, and bank-levels.
Distributed Energy Resource (DER)	<p>generation, storage, and controllable load connected at the low or medium voltage distribution level.</p> <p>Note 1: DER may include associated protection, control, and monitoring capabilities, and may consist of aggregated DER units.</p> <p>Note 2: DER may interact with the area and/or local electric power systems (EPS) by providing energy through the EPSs, by adapting their behaviour based on EPS conditions, and/or by providing other EPS-related services for regulatory, contractual, or market reasons.</p>
DER System	One or more DER units that have a common DER controller (e.g. PV unit plus energy storage unit with a single controller, multiple energy storage units with a single controller)
DER Unit	A physical DER entity of one single type (e.g. photovoltaic unit, energy storage unit, or controllable load).
Distribution System Operator (DSO)	Utility managing the distribution power system
DNP3	Protocol standardized in IEEE 1815 and used by most US utility SCADA systems for monitoring and controlling substation equipment
Electrical Connection Point (ECP)	The point of electrical connection between a DER system and any electric power system (EPS)
Electric Power System (EPS)	The facilities that deliver electric power to a load or from generation
EPS, Area	The electric power system (EPS) that serves Local EPSs
EPS, Local	An EPS contained entirely within a single premises or group of premises
Energy Storage System (ESS)	A system that can store energy and release that energy as electricity
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
Independent System Operator (ISO)	Utility managing the balancing of generation and load within a control area by reflecting the bulk power market while still meeting the power system reliability requirements

Term	Definition
Inverter	<p>Device that converts DC electricity into AC electricity, equipment that converts direct current from the array field to alternating current, the electric equipment used to convert electrical power into a form or forms of electrical power suitable for subsequent use by the electric system.</p> <p>For battery storage systems, it is typically 4-quadrant and is usually connected to a single battery bank.</p>
Referenced ECP	<p>The ECP that a DER's function references as the source of power system measurements. Usually this is either the ESS's ECP or the PCC, but other ECPs may be referenced.</p>
Regional Transmission Operator (RTO)	<p>Utility managing the transmission power system</p>
Supervisory Control and Data Acquisition (SCADA)	<p>System used by utilities and other facilities for controlling and monitoring power system equipment</p>
Transmission System Operator (TSO)	<p>Utility managing the transmission power system</p>

2. Information Management for ESS Configurations

2.1 Economic Drivers for ESS Functions

There are many economic drivers for implementing and interfacing Energy Storage Systems. Based on work by the “More Than Smart” efforts, more specific discussions in the Sandia “*Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide*” document¹, and discussion with the MESA members, an assessment of the ESS functions identified in this document is shown in Figure 1.

¹ <http://www.sandia.gov/ess/publications/SAND2010-0815.pdf>

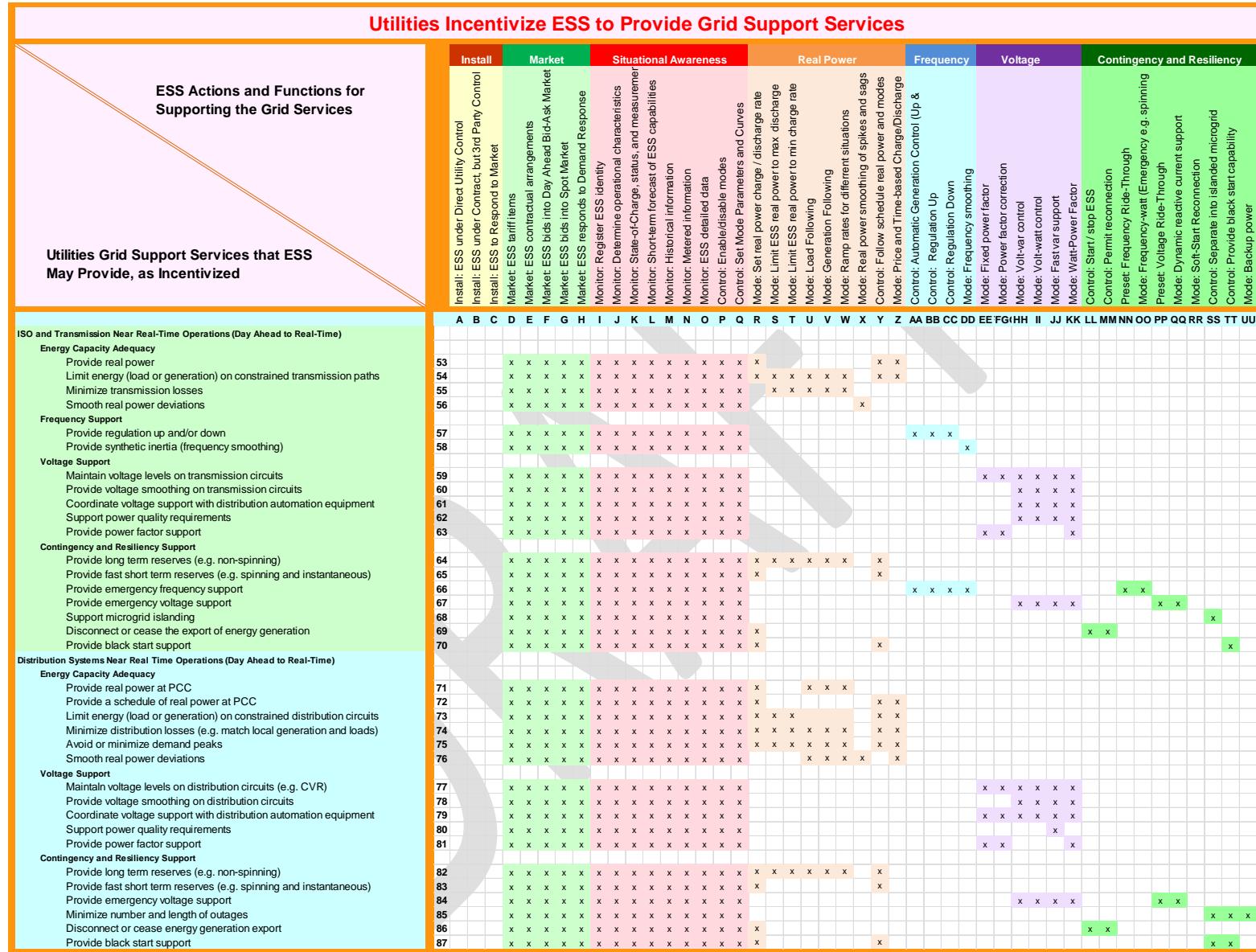


Figure 1: Economic Drivers: Near-Real-Time Energy Services Mapped to ESS Actions and Functions

2.2 Overview of DER Hierarchical Configurations

Direct control of Distributed Energy Resources (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. In addition, these DER systems can greatly assist in meeting these utility requirements effectively and efficiently, thus 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, pre-established settings, and DER owner preferences. DER systems can also be active participants in power system operations and must be coordinated with other DER systems and distribution equipment. In addition, the DSOs must interact with transmission system operators (TSOs), also known as regional transmission organizations (RTOs) and/or independent system operators (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 either through operational actions or market actions.

This hierarchical approach can be described as hybrid combinations of five (5) levels across multiple domains, as illustrated in the five-level hierarchical DER system architecture shown in Figure 2 and described below. The circled numbers identify the various logical information exchanges.



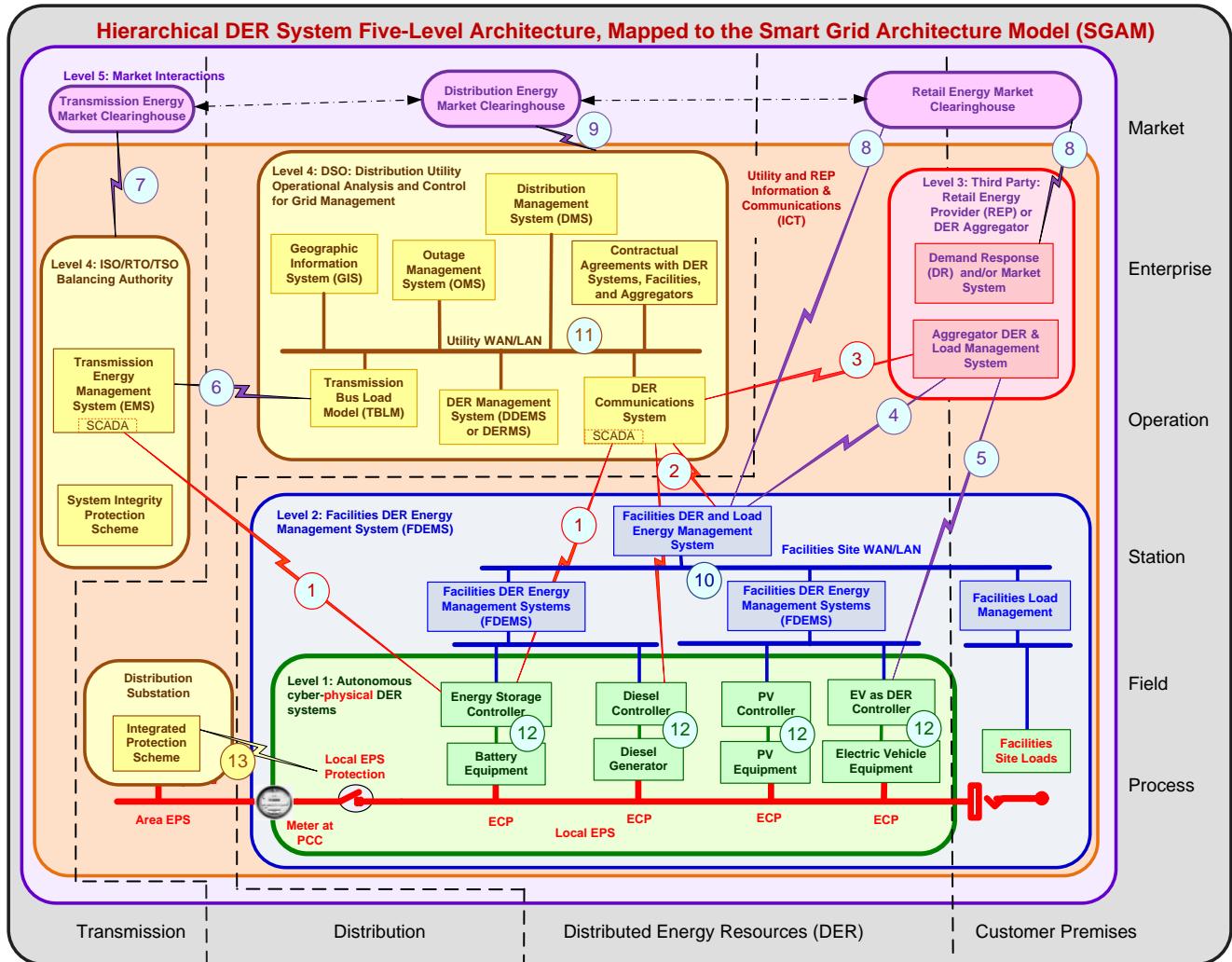


Figure 2: Hierarchical management of information exchanges for DER systems

1. **Level 1 DER Systems** (green in the Figure) is the lowest level and 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 Point of Common Coupling (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. In other words, these DER systems will be 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, pre-set parameter, and commands issued by utilities and aggregators.
2. **Level 2 Facility DER Management** (blue in the Figure) is the next higher level in which a facility DER management system (FDEMS) manages the operation of the Level 1 DER systems. This FDEMS 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 FDEMS to handle DER systems located at utility sites such as substations or power plant sites. For utilities, FDEMS 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.

3. **Level 3 Third Parties: Retail Energy Provider or Aggregators** (red in the Figure) shows market-based aggregators and retail energy providers (REP) who request or even command DER systems (either through the facility's FDEMS 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. Aggregator DER commands would likely be price-based either to minimize customer costs or to respond to utility requirements for safety and reliability purposes. The combination of third parties (this level) and facilities (level 2) may have varying configurations, responsibilities, and operational scenarios but, overall, still fundamentally provide the same services.
4. **Level 4 Utility Operational Grid Management** (yellow in the Figure) applies to utility applications that are needed to determine what requests or commands should be issued to which DER systems. Distribution System Operators (DSOs) must 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. This utility assessment involves many utility control center systems, orchestrated by the Distribution Management System (DMS) and including the DER database and management systems (DERMS), Geographical Information Systems (GIS), Transmission Bus Load Model (TBLM), Outage Management Systems (OMS), and Demand Response (DR) systems. Transmission System Operators (TSOs), regional transmission operators (RTOs), or independent system operators (ISOs) may interact directly with larger DER systems and/or may request services for the bulk power system from aggregated DER systems through the DSO or through the REP/Aggregators. Once the utility has determined that modified requests or commands should be issued, it will send these either directly to a DER system, indirectly through the FDEMS, or indirectly through the REP/Aggregator.
5. **Level 5 Market Operations** (purple in the Figure) is the highest level, and it involves 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.

2.3 ESS Structures and Configurations

Energy storage systems come in many shapes and sizes. A simple ESS may consist of a single battery, a power conversion system, and one or two meters as shown in Figure 3. More complex energy systems might include multiple inverters and battery pairs, and they may utilize additional meters to ensure the proper monitoring and control of the ESS. Figure 4Error! Reference source not found. provides an example of a more complex energy storage system.

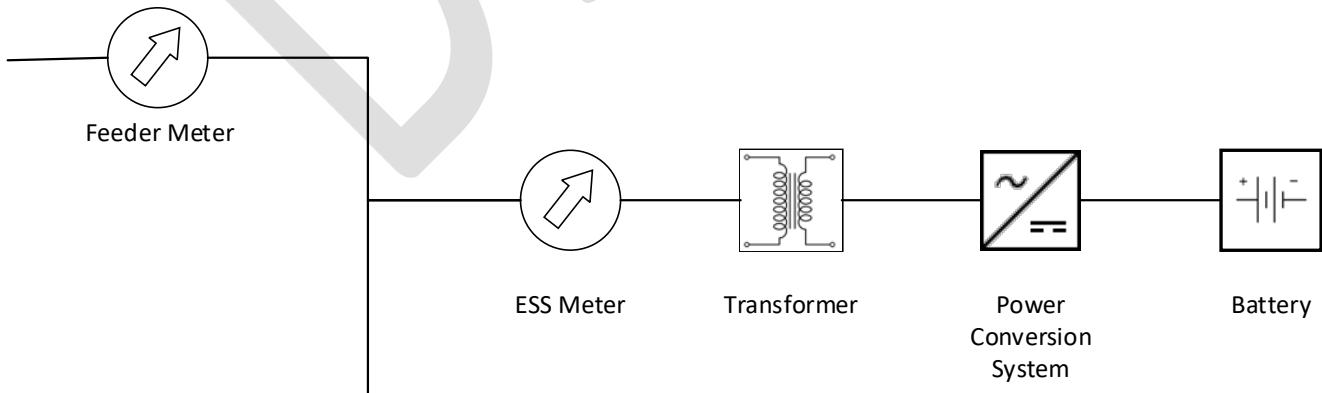


Figure 3: A simple energy storage system

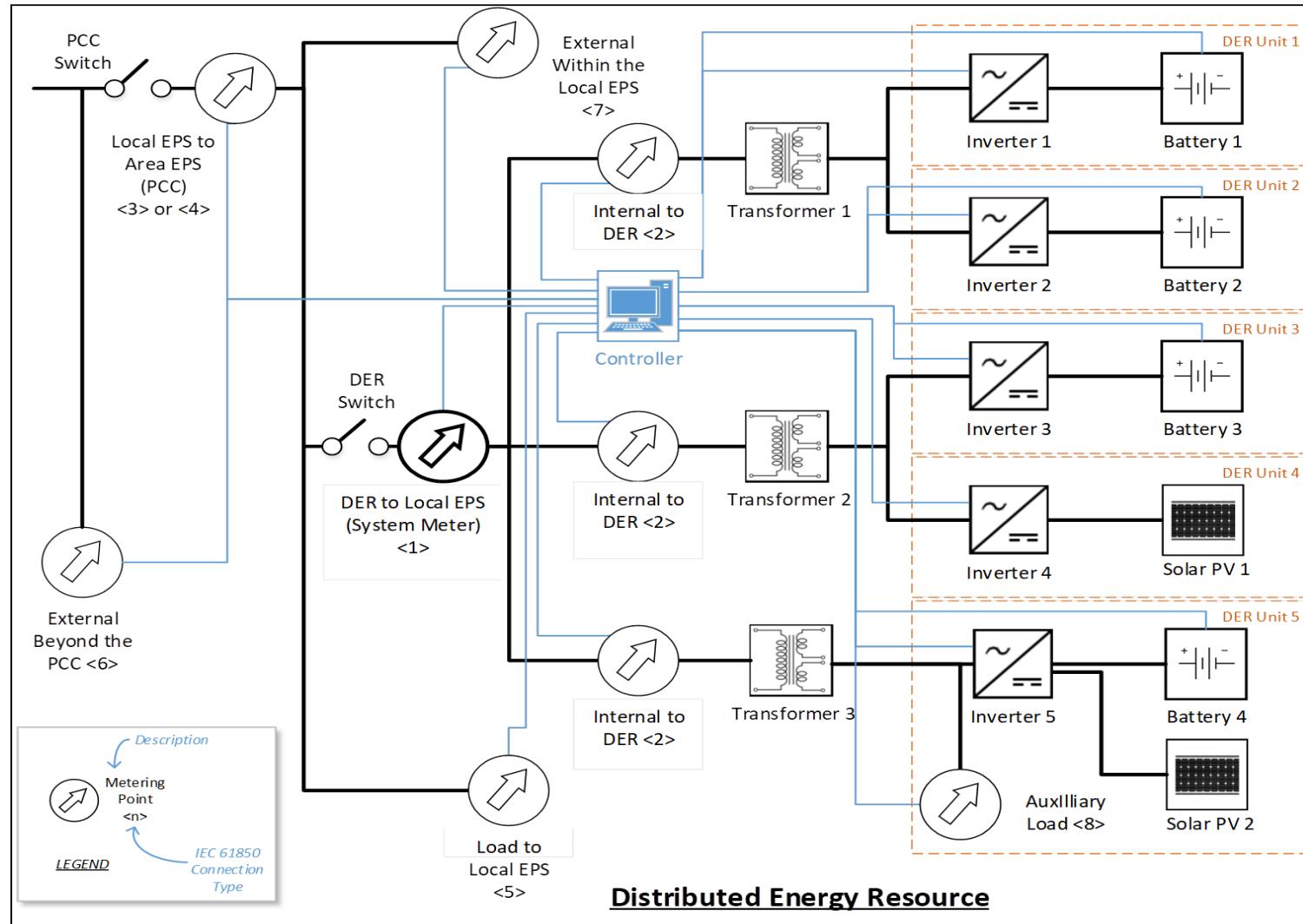


Figure 4: A more complex energy storage system

The MESA-ESS specification has been designed to support these different ESS configurations. In particular, MESA-ESS recognizes that energy storage systems typically consist of one or more inverters connected to a like number of energy storage components (e.g. battery banks). A MESA-ESS compatible ESS may have one or more inverter and battery bank pairs.

To ensure maximum utilization of more complex energy storage systems, the MESA-ESS specification provides monitoring and control points which 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 ESS shown in **Error! Reference source not found.**, it is possible to place Inverter 3 and Battery 3 into maintenance mode and continue to use the rest of the system normally.

MESA-ESS also recognizes that energy storage systems typically use multiple power meters to ensure the safe and effective operation of an ESS. These meters typically fall into one of the following categories:

- ESS Meters, such as Meter 1 and Meter 2, monitor the output of the ESS itself. Aside from providing key measurements to the operator, these meters may be used in conjunction with feedback loops to ensure consistent power output from the ESS.
- Feeder Meters and other power meters at electrical connection points provide valuable operational data. It is often desirable to use the data from these meters to drive the behavior of the operational modes provided by the ESS.
- Auxiliary power meters measure the auxiliary power needed to operate the inverters, batteries, chillers, HVAC systems, etc. within the ESS.

2.4 ESS Actual and Usable Capacity

The definition of the capacity of an ESS depends upon what is important to different types of users. For instance, the vendor of an ESS is concerned about the actual capacity of the ESS, 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 ESS capacity and the usable ESS capacity. The actual ESS capacity is the nameplate information, possibly modified over time if the ESS characteristics change. The usable ESS capacity is what users are permitted to have access to, which is based on the decisions of ESS manufacturers or ESS owner/operators.

In addition to usable capacities, ESS 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 either for 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.

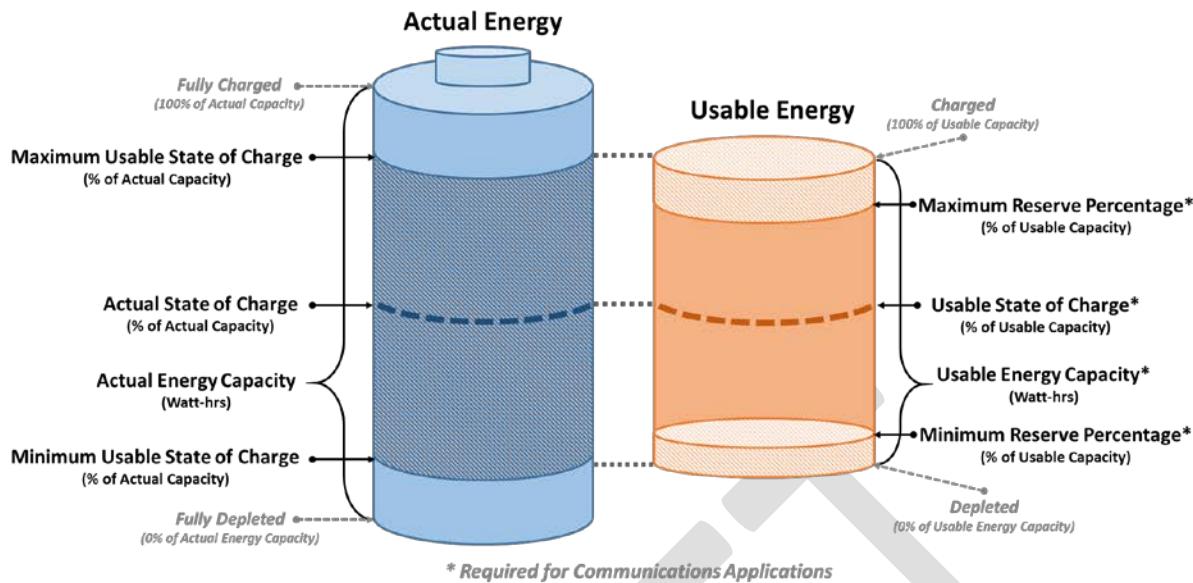


Figure 5: ESS State of Charge: Difference between Actual Capacity and Usable Capacity

2.5 Protocol Alternatives for Information Exchanges with ESS Systems

IEC 61850-7-420 has been developed as the data model for interactions of DER systems, but can use different communication protocols to transport the data. A number of protocol alternatives exist that are based on or mapped from this IEC 61850 information model. These protocols generally have specific purposes and characteristics, although there are overlapping areas across them (see Table 3). The numbers represent the circled numbers in Figure 2.

Table 3: Protocol Alternatives for DER Systems

Protocol	Domain	#	Data Format	Availability	Latency	Cyber Security
IEC 61850-8-1 (GOOSE)	Protective relaying and substation status signals	12, 13	MMS	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	XML/XER, using XSDs	High	Low to Medium latency	In IEC 62351 standards
IEEE 1815 (DNP3)	Widely used by utilities for SCADA interactions with field devices	1	Simple data structures	High	Low latency	In IEEE 1815 standard but not widely implemented
IEEE 2030.5 (SEP2)	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 2030.5 standard

Some existing protocols, such as OpenADR and BACnet, may be mapped to appropriate portions of the IEC 61850 Information Model in the future, while other alternatives are under development, such as the Open Field Message Bus (OpenFMB) framework.

Figure 6 illustrates where the protocol alternatives might be used.

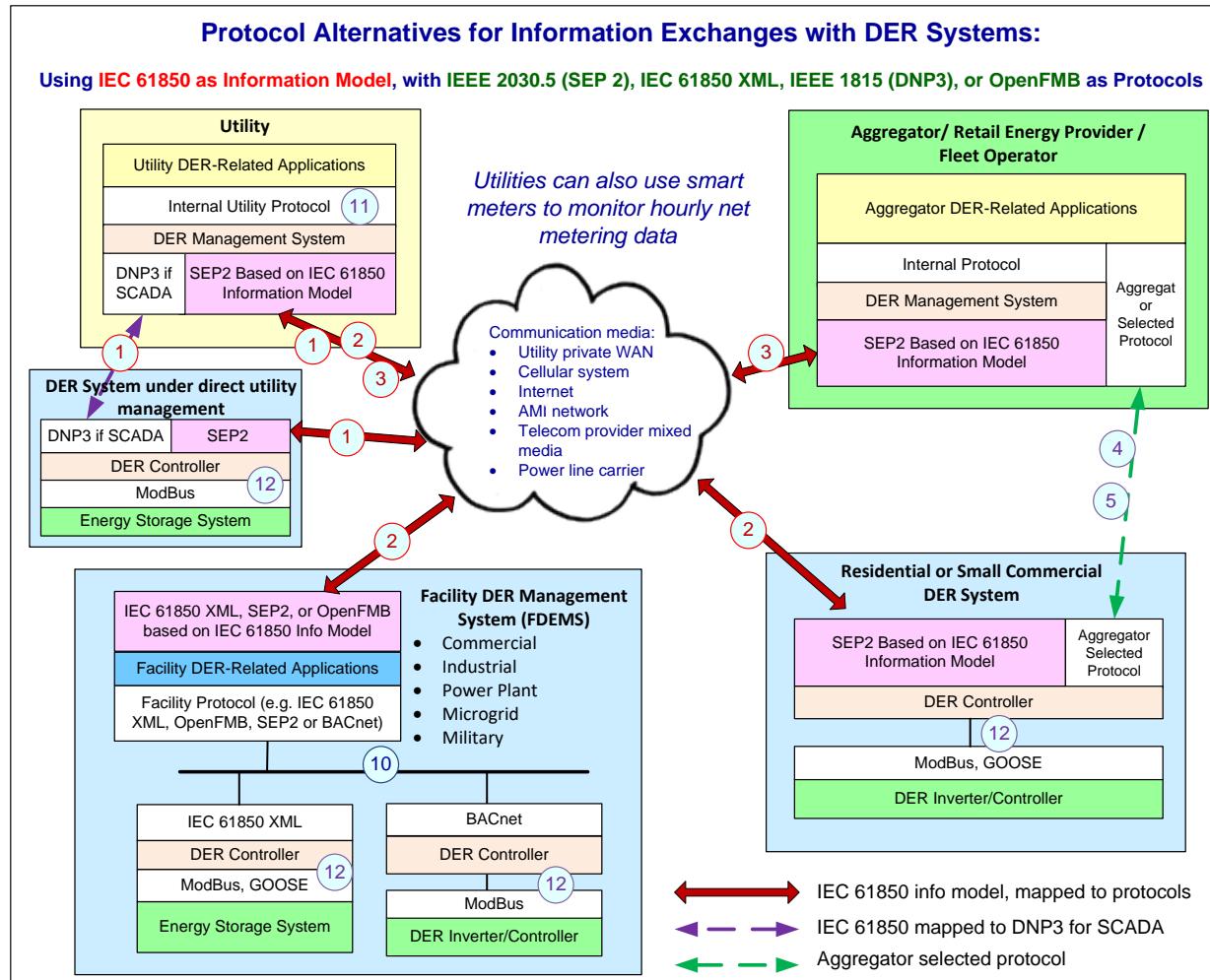


Figure 6: Protocol Alternatives for Information Exchanges with DER Systems, Including ESS

2.6 ECP and PCC Concepts

The electrical connection point (ECP) of a DER system defines its point of electrical connection to any electric power system (EPS). Usually, there is a switch, a circuit breaker, and/or a meter at this point of connection.

ECPs can be hierarchical. Each DER system has an ECP connecting it to its local power system. Groups of DER systems have an ECP where they interconnect to the power system at a specific site or plant. A group of DER systems plus any non-controllable loads have an ECP (termed the point of common coupling (PCC)) where they are interconnected to the utility power system.

In a simple DER configuration, there is one ECP between a single DER system and the utility power system. However, as shown in Figure 7, there may be more ECPs in a more complex DER plant installation. In this figure, ECPs exist between:

- Each single DER system and the local EPS

- Groups of DER systems and the local EPS
- Multiple groups of DER systems and the utility area EPS at the PCC
- An external ECP and the area EPS

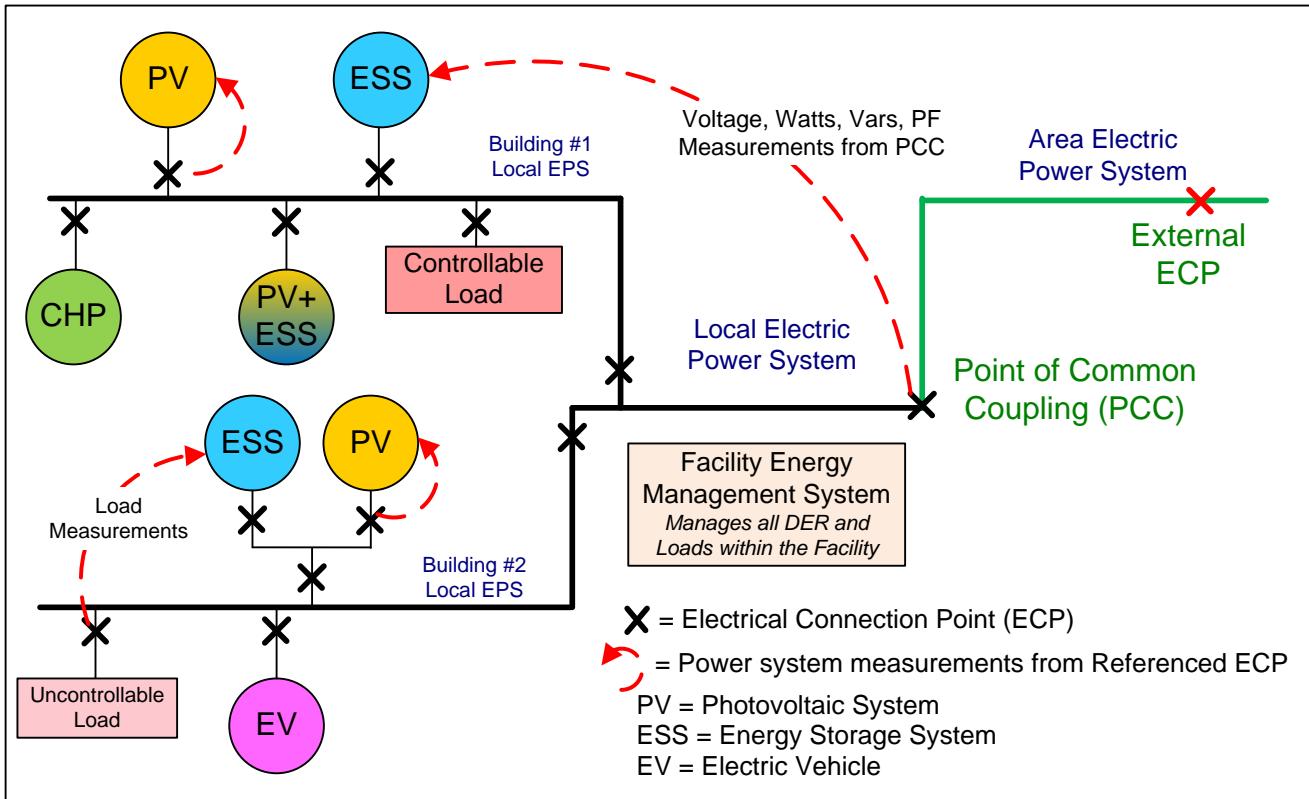


Figure 7: Concept of DER systems (colored circles), electrical connection points (ECP), and the Referenced ECP

The importance of the ECP concept lies in the fact that DER systems may need to use measurements or other information from ECPs that they are not necessarily directly connected to. For instance, if a DER system is providing peak power limiting, it must receive power measurements from the relevant remote ECP (e.g. the PCC as usually required by utilities). Or if an ESS is counteracting generation fluctuations from an external solar plant, it must receive those measurements from that external ECP.

In some deployments, one specific ECP is configured at installation time to be used for all functions. However, in other deployments, different functions may be able to use different ECPs, depending upon the operational requirements. In those cases, the ECP to be used must be identified as part of each function's settings. Therefore, for each function where different ECPs may be indicated, the data object "Referenced ECP" is used to identify the desired ECP.

2.7 Signal Meters

Many of the functions in this profile operate autonomously using data provided by a meter or some other sensor at a Referenced ECP. For example, the Frequency-Watt operational mode described in Section **Error! Reference source not found.** adjusts the Active Power output of the ESS based on frequency values read from a meter. In this specification, meters which provide signal data which is used by an autonomous function are referred to as "signal meters."

Each meter that is part of the energy storage system or that will be used by one of the ESS operational modes should be assigned a unique identifier (a positive integer). When a function is configured, a signal meter identifier will be specified, which identifies the meter that will provide values to the function.

2.8 Relationship to Other MESA Communication Specifications

As can be seen in Figure 8, MESA-ESS may be combined with MESA-Device communication specifications in the construction of a MESA-compliant energy storage system. Where MESA-ESS is a specification for the DNP3 interface to an energy storage system as a whole, the MESA-Device interfaces (MESA-PCS [1], MESA-Storage [2] and MESA-Meter [3]) provide standardization for the Modbus interfaces that are exposed by many of these devices.

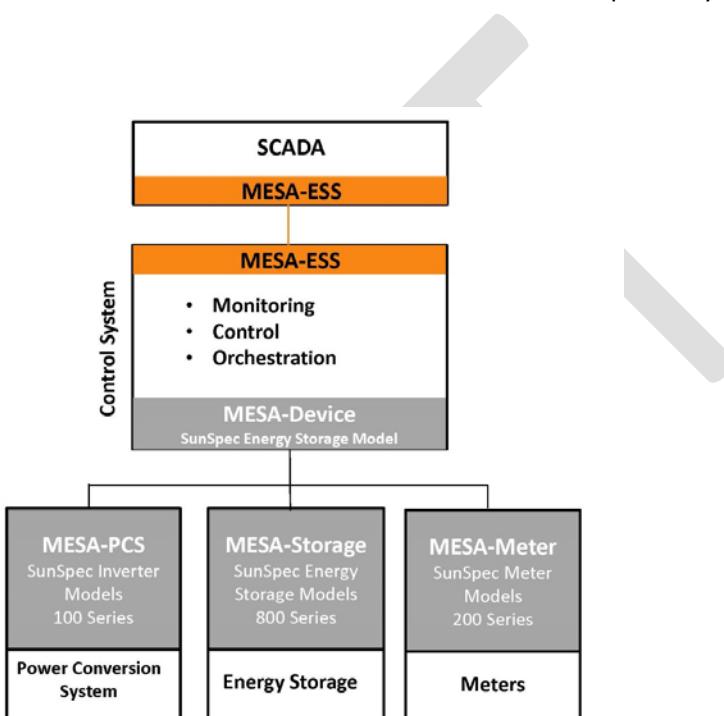


Figure 8: Conceptual Diagram of MESA-ESS

While MESA-ESS and MESA-Device have been designed to work well together, the use of MESA-ESS does not mandate the use of MESA-Device. An ESS that implements MESA-ESS alone still provides significant value to the asset owner.

3. Operational State Model

3.1 Roles, Permissions, and ESS Operational States

There are multiple ways that an electric utility may control a grid-connected energy storage system and different utilities have different operating procedures and contractual arrangements. Therefore, the operating model must be flexible enough to include these differences, while still maintaining interoperability. One method for providing this flexibility is to establish different roles, which are assigned “permissions” for those actions they are allowed

to perform in the different operational states. Users are then assigned to one or more roles when they log into the ESS.

Figure 9 provides a generic overview of Role-Based Access Control (RBAC) based on the international standard IEC 62351-8. This overview shows a list of generic roles, the basic permissions that can be assigned, and how these permissions are modified by Areas of Responsibility (AoR) (equivalent to operational states).

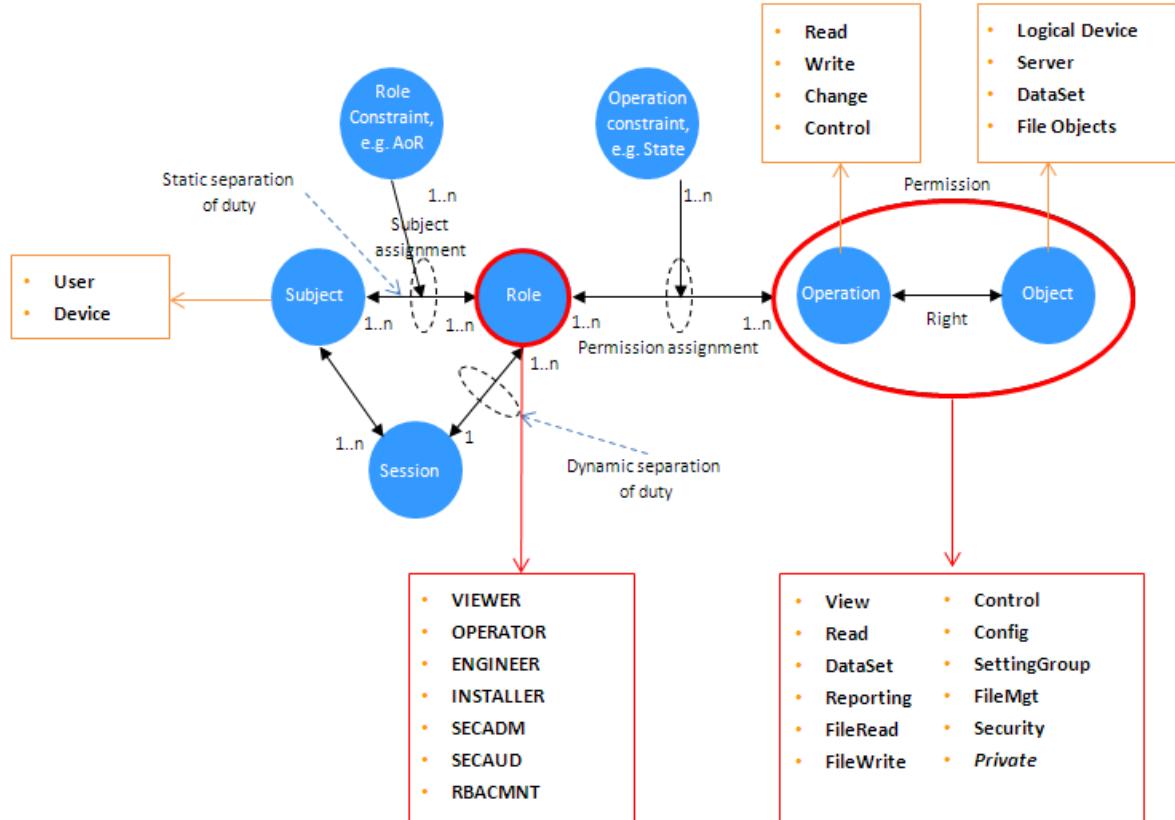


Figure 9: Roles, Permissions, and Operational States

3.2 Default Roles

For ESS user interactions, at least one of each of the roles in the list below is recommended to be implemented with additional roles permitted. Although different mechanisms may be used to assign users to roles, at a minimum, login credentials (e.g. unique username and password) shall be used during the assignment.

- Utility ESS operator
- Utility power scheduler
- Third party aggregator
- Facility ESS operator
- ESS maintenance personnel
- ESS vendor
- Guest viewer

Some role permissions may be different based on whether a user logs in locally or remotely – that situation may be handled by the ESS detecting whether the login is initiated locally or remotely, or may be handled by defining separate roles in which the local roles are only available at the local ESS HMI. For example, in some implementations, there could be two Facility ESS operator roles; one of which is remote, and the other is local. The local Facility ESS operator may be then given permission to perform tasks not allowed for the remote Facility ESS operator for safety reasons.

3.3 Operational States

To ensure the safety of the asset owner's personnel and to help in coordinating control of the ESS across operator roles, the ESS shall support the following mutually exclusive operational states:

- Normal Operations
- Lockout Operations
- Maintenance Operations

The following sections describe these Operational States in further detail.

3.3.1 Normal Operational State

In Normal Operational state, the ESS can respond to authorized commands from utility operators, facility operators, and third party aggregators, as determined by their roles and permissions.

In transitions to and from the Normal Operational state, all ESS settings and actions will remain as they were until modified by an authorized command.

3.3.2 Lockout Operational State

When the energy storage control system (the controller) is powered up for the first time, it should be set to Lockout Operational state. In this state, only authorized personnel with the appropriate permissions will be allowed to control the ESS. In general, a small subset of the ESS operators will be granted permission to control the ESS when it is in Lockout Operation. For example, a manufacturer might specify that only local, onsite operators will be able to control the ESS when it is in the Lockout Operational state.

See Section 3.4 for more information on Roles and Permissions and how they relate to Operational States.

3.3.3 Local or Maintenance Operational State

An engineer who is performing maintenance on site will use the local HMI to control the ESS. If this operator wishes to make maintenance-related changes to the ESS in any way, he or she may need to enable this Local/Maintenance Operational state. Once this occurs, remote users are locked out, as are any scheduled operations, helping to ensure the safety of the on-site personnel and the ESS itself. Upon completion of the maintenance work, the engineer returns the ESS to either Lockout Operational state or Normal Operational state.

It is important to note that the Local/Maintenance Operational state may also be used for system-wide maintenance operations, such as upgrading the ESS software or conducting tests on the ESS as a whole. MESA-ESS also supports maintenance on a subsystem within the ESS.

During normal operations, actions initiated by the controller and its operational modes affect all inverter and battery bank pairs that are under control. When maintenance is required on an inverter or battery bank, the

operator performing the maintenance must be able to safely work with the inverter and its batteries without interference from ongoing controller processes. Rather than shutting down the entire ESS to perform maintenance on a single inverter or battery, a given DER unit (i.e., an inverter and battery bank pair) may be placed into the maintenance operational state.

When a DER unit is in the maintenance operational state, the **DER Unit #N Is In Maintenance Operational State** Binary Input should return a value of 1 which indicates that the unit is not currently online. While the DER unit is in this state, the unit is removed from autonomous control, and the inverter no longer responds to actions initiated by operational modes. Any operational modes which are executed while the DER unit is in the maintenance operational state will only apply to other DER units which are not in the maintenance operational state. Additionally, the **System Available Apparent Power** and **State of Charge** Analog Inputs should both be updated automatically by the controller to indicate that the system is running at reduced capacity.

No facility is provided by the profile to allow an operator to place a DER unit into the maintenance operational state using DNP3. However, it is reasonable for a local HMI to provide this ability to the local operator.

Additionally, a local HMI may choose to provide functions which operate directly on the unit under maintenance such as:

- Stopping and starting the inverter.
- Disconnecting (opening connectors) and connecting (closing connectors) the battery bank.
- Charging and discharging the battery bank.

The exact behavior of the local HMI and the functionality that it provides for DER units in the maintenance operational state is not specified here as it is outside the scope of this document.

3.4 Default Permissions for Default Roles

Default assignments of permissions to roles are shown in Table 4, but these may be changed or expanded as necessary for different implementations. In order for different implementations to assign different permissions to different roles, each of these assigned permissions should be visible (able to be monitored and/or visible locally) and should be either preset upon installation and/or possibly modifiable after installation.

Table 4: Default Assignment of Permissions to Roles within Different ESS Operating States

Permissions	Roles	Utility ESS Operator	Utility Power Scheduler	Third-Party Aggregator	Facility ESS Operator	Maintenance Personnel	ESS Vendor	Guest Viewer
When ESS is in Normal Operational State								
• View current operational state	X	X	X	X	X	X	X	
• Set ESS to lockout operational state					X			
• Set ESS subsystem to maintenance/test mode					X	X		
• View roles and permissions	X	X	X	X	X	X	X	
• Modify roles and permissions					X		X	
• Monitor site-level ESS information					X	X	X	
• Monitor ESS status, modes, and measurements	X	X	X	X	X	X	X	X
• Monitor operational logs	X	X	X	X	X	X	X	
• Monitor security logs					X			
• Monitor historical data	X	X	X	X	X			
• Monitor configuration information					X	X	X	
• Update parameters of functional modes	X	X	X	X	X			
• Enable functional modes	X			X	X			
• Disable functional modes	X			X	X			
• Issue disconnect command from grid	X			X	X	X		
• Issue connect command to grid					X			
• Issue operational control command	X			X	X			
• Send schedule	X			X	X			
• Enable schedule	X			X	X			
• Disable schedule	X			X	X			
• Add item to operational log	X			X	X	X		
• Execute diagnostic tests						X		
• Issue test commands								
• Patch or update ESS software								
• Update security measures								
• Modify configurations								

Permissions	Roles	Utility ESS Operator	Utility Power Scheduler	Third-Party Aggregator	Facility ESS Operator	Maintenance Personnel	ESS Vendor	Guest Viewer
When ESS is in Lockout Operational State								
• View current operational state	X	X	X	X	X	X	X	
• Set ESS to normal operational state					X			
• Set ESS to subsystem maintenance/test mode					X	X		
• View roles and permissions					X	X	X	
• Modify roles and permissions					X		X	
• Monitor site-level ESS information					X	X	X	
• Monitor ESS status, modes, and measurements	X		X	X	X	X	X	X
• Monitor operational logs					X	X	X	
• Monitor security logs					X	X		
• Monitor historical data					X	X		
• Update parameters of functional modes					X			
• Enable functional modes					X			
• Disable functional modes					X			
• Issue disconnect command from grid	X		X	X	X	X		
• Issue connect command to grid					X			
• Issue operational control command					X			
• Send schedule					X			
• Enable schedule					X			
• Disable schedule					X			
• Add item to operational log					X	X		
• Execute diagnostic tests						X		
• Issue test commands								
• Patch or update ESS software								
• Update security measures								
• Modify configurations								

Permissions	Roles	Utility ESS Operator	Utility Power Scheduler	Third-Party Aggregator	Facility ESS Operator	Maintenance Personnel	ESS Vendor	Guest Viewer
When ESS (or subsystem) is in Maintenance/Test Operational State								
• View current operational state	X	X	X		X	X	X	
• Set ESS to normal operational state					X			
• Set ESS to lockout operational state					X	X		
• View roles and permissions					X	X	X	
• Modify roles and permissions					X		X	
• Monitor site-level ESS information					X	X	X	
• Monitor ESS status, modes, and measurements					X	X	X	X
• Monitor operational logs					X	X	X	
• Monitor security logs					X	X		
• Monitor historical data					X	X		
• Update parameters of functional modes					X	X	X	
• Enable functional modes								
• Disable functional modes					X			
• Issue disconnect command from grid					X			
• Issue connect command to grid								
• Issue operational control command								
• Send schedule								
• Enable schedule								
• Disable schedule								
• Add item to operational log					X	X		
• Execute diagnostic tests						X	X	
• Issue test commands						X	X	
• Patch or update ESS software						X	X	
• Update security measures						X	X	
• Modify configurations						X	X	

4. MESA-ESS DNP3 Interface

4.1 MESA-ESS DNP3 Profile Scope and Constraints

The MESA-ESS DNP3 profile has been designed to allow an energy storage system to be integrated into existing control and monitoring systems. In most installations, it will be most important to expose control and monitoring points to allow the ESS to be integrated into SCADA. For installations that support ESS scheduling, additional points exist in the profile to allow this functionality. Finally, in some installations it may be desirable to expose historical information through the DNP3 profile so that this data may be easily imported into an operational historian.

To support all of these scenarios, the points in the MESA-ESS DNP3 profile fall into one of five distinct categories: Configuration, SCADA, Scheduling, Historical, and Vendor Specific. These categories are described below in Table 5.

Table 5: MESA-ESS DNP3 Point Categories

Category	Description	Examples
Configuration	Configuration data which describe how a given energy storage asset has been configured and which features are enabled.	Power Factor Operating Quadrant, Supports Active Power Smoothing Mode, Reference Voltage
SCADA	Key operational points which allow the energy storage asset to be integrated into SCADA.	System Is In Lockout Mode, System Is Starting Up, System Has P1 Alarms, Charge/Discharge Active Power Target
Scheduling	Points which allow power scheduling personnel to effectively control the behavior of the energy storage system over a distinct time period.	Selected Schedule Is Enabled, Selected Schedule Priority, Selected Schedule Start Time
Historical	Detailed measurement and performance data which may be valuable to record in an operational historian	ESS Is Charging, Meter Active Power, Battery Bank State of Charge
Vendor Specific	Vendor specific data, including implementation-specific data that is not included in other categories	

4.2 MESA-ESS Implementation Levels

For many energy storage system installations, it will be necessary to implement the points in all point categories to ensure complete integration to existing systems. In other installations, only a subset of the points may be required. For example, if the asset owner does not maintain a historian, the points in the Historical category may be unnecessary.

To ensure broad compatibility across a variety of energy storage system controllers and installation types, the MESA-ESS specification includes the notion of “implementation levels.” These implementation levels allow an implementer to subset the DNP3 profile so that only required point categories are implemented. The levels of support are described in Table 6.

Table 6: MESA-ESS Implementation Levels

Level	Summary	Description
1	Configuration + SCADA Points Only	Only the points identified as Configuration or SCADA points are implemented by the MESA-ESS controller.
2	Configuration + SCADA + Scheduling Points	Only the points identified as Configuration, SCADA or Scheduling points are implemented by the MESA-ESS controller.
3	Configuration + SCADA + Scheduling + Historical Points	All points in the MESA-ESS profile are implemented by the controller

A MESA-compatible ESS controller which has decided to implement all three categories will be described as supporting MESA-ESS Level 3—the highest level of compatibility. Another MESA-compatible ESS controller may decide that integrating with SCADA is the only requirement, and, accordingly, only the Configuration and SCADA points will be implemented. This type of controller will be described as support MESA-ESS Level 1.

The points for Level 1 shall start at index 0 for all DNP3 point types. If Level 2 is implemented by the outstation, those points must start at the index which immediately follows the last Level 1 point in that point type. Similarly, if Level 3 is implemented, the first Level 3 point must be placed immediately following the last Level 2 point as shown in Figure 10. Vendor points are placed at the end of the points list after the last block of points from this profile.

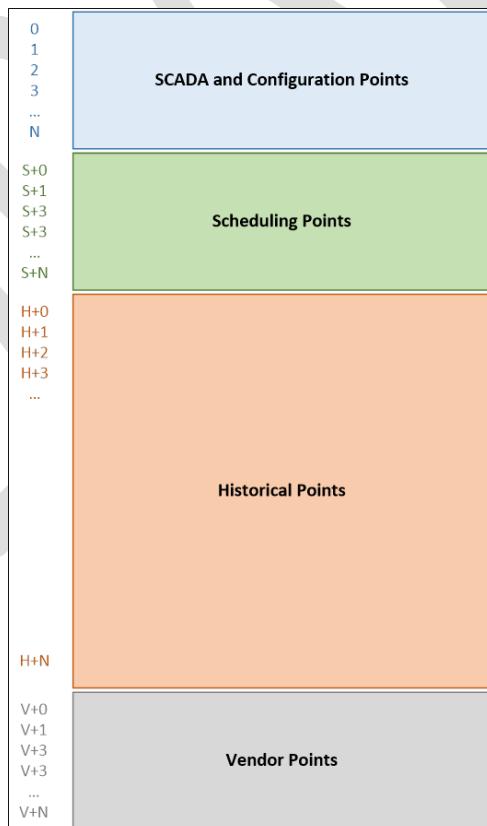


Figure 10: Indexing of DNP3 Categories

Note that in the figure above the points in the Vendor Points section are shown immediately following the points in the Historical Points section. While this is certainly a valid approach, this profile does not mandate that vendor specific points *immediately* follow the last point from the profile.

4.3 Repeating Blocks

Level 2 and Level 3 implementations must represent one or more repeating elements in the DNP3 point map. For example, Level 2 implementations will repeat three analog inputs for each schedule in the system as shown in the table below.

Table 7: Repeating Schedule Analog Inputs

Analog Input	Meaning
Schedule 1 Status	The status of the first stored schedule.
Schedule 1 Priority	The priority of the first stored schedule.
Schedule 1 Active Time Value	The active time value of the first stored schedule.
Schedule 2 Status	The status of the second stored schedule.
Schedule 2 Priority	The priority of the second stored schedule.
Schedule 2 Active Time Value	The active time value of the second stored schedule.
...	...
Schedule N Status	The status of the nth stored schedule.
Schedule N Priority	The priority of the nth stored schedule.
Schedule N Active Time Value	The active time value of the nth stored schedule.

For Level 3 implementers, blocks of analog inputs and analog outputs will be repeated for each meter, DER unit, inverter, and battery in the configured system as shown in Figure 11.

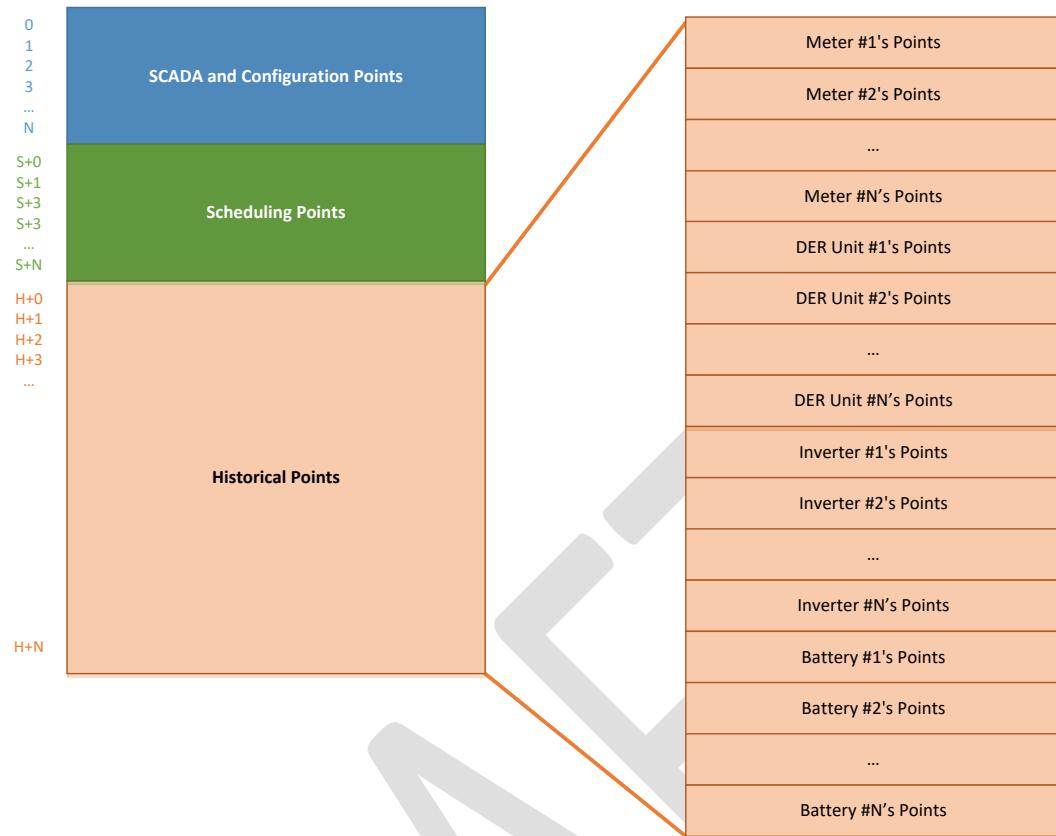


Figure 11: Level 3 Repeating Elements

Because the number of elements in these repeating blocks will vary by installation, the total length of the point lists for Level 2 and Level 3 implementations will also vary. However, Level 1 analog input points exist in the profile which can be used to deterministically calculate the total number of points in the profile. These points are shown in Table 8 below.

Table 8: Profile Information Analog Input Points

Analog Input Point	Description
DER Profile Version Number	Indicates what version of the profile has been implemented by the outstation.
DER Profile Implementation Level	Indicates whether the outstation has implemented Level 1, Level 2 or Level 3.
Number of System Schedules	The number of system schedules stored by the outstation.
Number of Meters	The number of meters that are monitored by the outstation.
Number of Inverters	The number of inverters that are monitored and controlled by the outstation.
Number of Batteries	The number of batteries that are monitored and controlled by the outstation.
Number of DER Units	The number of DER units which are connected to the outstation.

4.4 Profile Background

Unlike DNP3 AN2013-001, the MESA-ESS profile targets DNP3 Level 2. MESA partners and early adopters have indicated that a number of electric utilities that are exploring energy storage have infrastructural limitations which prevent the adoption of more advanced DNP3 features (e.g. Double-Bit Binary Inputs). While a MESA-compatible ESS controller may choose to offer more advanced functionality in some cases, these features are by no means required by MESA-ESS.

For reference, the following DNP3 Level 3 and 4 features are avoided by MESA-ESS:

- DNP3 Level 3 Features
 - Certain specific objects and variations
 - Group 0 (Device Attributes) read and write requests
 - The larger range of function codes specified by Level 3 and Level 4
 - Enabling and disabling of unsolicited responses by class
 - Dynamically reassigning data objects to classes (e.g., at runtime)
- DNP3 Level 4 Features
 - Self-address reservation
 - Double-bit binary input objects
 - The larger range of function codes specified by Level 4
 - Variations with time for frozen counters, frozen counter events, and analog input events
 - Floating-point variations for both analog inputs and analog outputs
 - Analog input reporting deadband
 - Event objects for binary and analog outputs
 - Device attributes
 - LAN time synchronization method

4.5 DNP3 Classes

MESA-ESS uses the criteria in Table 9 for assigning points to default classes.

Table 9: Criteria for Assigning Points to Default Classes

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

4.6 Curves and Schedules

A MESA-ESS compatible outstation will typically need to include support for curves (e.g. Volt-VAr curves) and schedules. These objects are similar in that they can be thought of as a two-dimensional graph. For example, a Volt-VAr curve specifies a voltage measurement on the X-axis and a VAr output requirement on the Y-axis. Similarly, a Charge/Discharge schedule is represented with time on the X-axis and power output on the Y-axis.

For the most part, curves and schedules are modeled as a series of points, where each point has an X-value and a Y-value. In DNP3, each of these characteristics maps to a single point in the profile. For a schedule with 100

points, the total number of DNP3 points will be $2 * 100 = 200$. Additionally, curves and schedules often have a few top-level properties which translate into a small number of additional DNP3 points per curve/schedule.

It is a design goal of MESA-ESS to allow multiple curves and schedules to be created, updated, and read through the profile. But in order to keep the DNP3 point lists manageable, the points for each curve/schedule are not repeated for every supported curve schedule. Instead, a “selector model” is used for these objects.

In the selector model, the DNP3 master must first indicate which curve or schedule should be read or updated. This is done by writing an index value to a selector analog output. For example, to view or update the 13th schedule in the set of schedules, the master begins by setting the Schedule to Edit Selector point to the value 13. When this occurs, the outstation updates the schedule points (BIs, BOs, AlIs, and AOIs) to reflect the value in schedule at index 13. In effect, the schedule points in the DNP3 profile act as a window into the full set of schedules. The same is true for curves.

More details on the selector model for curves and schedules are found in the DNP3 Technical Bulletin, Section 2.3.3.

4.7 Ramp Rates, Ramp Times, and Time Constants

Different functions may use ramp rates, ramp time, or time constants to modify or characterize the responses of the devices due to the function. Additional default ramp rates have been included to include ramp up and ramp down while generating and while charging.

More details on the use of these time-based parameters are found in the DNP3 Technical Bulletin, Section 2.3.4.

4.8 Mode Priorities

Each mode also has a priority field, allowing them to indicate which modes may have precedence over other modes if they might otherwise conflict (see Table 12). Lower numbers are higher priority than higher numbers, but there are no preset numbers for any mode.

4.9 Alarm Aggregation and Priorities

Each of the devices within an energy storage system may raise alarms when abnormalities occur. Additionally, the energy storage system itself may raise alarms under certain conditions (e.g., failure to communicate with a device). The Historical category of DNP3 points provides detailed alarm and warning information for the ESS and the devices that make up the ESS.

Because this detailed alarm information is generally not desired in SCADA, MESA-ESS exposes aggregate alarm information for the system as a whole. This aggregate data is provided in the following binary inputs:

Table 10: Aggregate Alarm Points

Binary Input	Description
CALH1.GrAlm	System Has P1 Alarms
CALH2.GrAlm	System Has P2 Alarms
CALH3.GrAlm	System Has P3 Alarms

As seen in Table 10, three aggregate alarm points are exposed in the DNP3 Profile, each with a different priority. How individual alarms are mapped to the different priorities is left to the implementer. One MESA-ESS controller may choose to map alarms to priorities based on severity (e.g., Fire Alarms are P1, Fan Warning is P3), while another may choose to map these priorities to roles (e.g., The Facility Operator will handle all P1 alarms, while the Remote Operator will handle all P2s and P3s).

5. ESS Functions

5.1 Table of ESS Functions

For the purposes of this specification, a *function* is a capability that is typically performed due to human intervention, and does not repeat unless it is requested again. A *mode* is automatic behavior which is pre-configured, enabled, and then operates either periodically or continuously.

Modes usually entail the DER system:

- Receiving some measurement either from a meter at the DER's ECP, from a meter at a remote ECP within the facility, from the PCC, or from an external ECP (termed the “Referenced ECP”), or
- Reacting to some event, and then responding to that measurement or event according the mode’s parameters.

The MESA-ESS profile supports the configuration and operation of the functions and modes shown in Table 11. The table also indicates where the functions and modes are described in the EPRI Common Functions report, IEC 61850-7-420, and the DNP3 Application Note 2018.

Implementations are not required to include all of the functions or modes since configuration data objects are used to indicate those supported. Each of these functions and modes can be invoked or enabled/disabled by authorized operators. In addition, some of these functions or modes may be controlled by a schedule.

Table 11: MESA-ESS functions and modes

#	Functions or Modes	Description	DNP3 App Note 2018	IEC 61850-7-420
	Support for functions and modes General information on supportive capabilities.	Support for Modes and Functions Mode Enabling Timing Parameters Multiplexed Generic Curves and Schedules Limiting Response: Ramp Rates, Ramp Times and Time Constants Use of Broadcasting Time Synchronization	Section 2.3.1 Section 2.3.2 Section 2.3.3 Section 2.3.4 Section 2.3.5 Section 2.4.7	Section 4.3 Section 4.4
	Interactive Functions		Section 2.4	
1.	Monitoring Function The ESS provides nameplate, configuration, status, measurements, and other requested data	Monitoring Use of Signal Meters Alarm Grouping and Reporting DER States Event/History Logging Function	Section 2.4.1 Section 2.4.2 Section 2.4.3 Section 2.4.6 Section 2.4.8	LN DGEN LN DSTO LN DBAT LN DRAT LN MMXU

#	Functions or Modes	Description	DNP3 App Note 2018	IEC 61850-7-420
2.	Disconnect/Connect Function Disconnect or connect the ESS from the grid at its ECP.	The disconnect command initiates the galvanic separation (usually via switches or breakers) of the ESS at its ECP. The connect command initiates the reconnection of the ESS at its ECP.	Section 2.4.4	LN DSTO or (for separate switch), LN CSWI, LN XCBR
3.	Cease to Energize and Return to Service Cease any current flow at the ECP or PCC Allow current flow at the ECP or PCC	“Cease to energize” is a different function from disconnect/connect. The purpose is to prevent the flow of current at the ECP or PCC. It may use the Active Power Limit mode with the Active Power output value set to zero. “Return to service” allows current flow at the ECP or PCC.	Section 2.4.5	LN DCTE
Emergency Modes				Section 2.5
4.	Low/High Voltage Ride-Through Mode The ESS rides through temporary fluctuations in voltage	The ESS follows the utility-specified voltage ride-through parameters to avoid tripping off unnecessarily. Although normally enabled by default, this ride-through mode may be updated, enabled, and disabled.	Section 2.5.1	LN DVRT
5.	Low/High Frequency Ride-Through Mode The ESS rides through temporary fluctuations in frequency	The ESS follows the utility-specified frequency ride-through parameters to avoid tripping off unnecessarily. Although normally enabled by default, this ride-through mode may be update, enabled, and disabled.	Section 2.5.2	LN DFRT
6.	Frequency-Watt Emergency Mode The ESS responds to large frequency excursions during H/LFRT events at a Referenced ECP by changing its charging or discharging rate	The ESS is provided with frequency-watt curves that define the changes in its watt output based on frequencies outside the normal range during H/LFRT events. When the emergency frequency-watt mode is enabled, the ESS monitors the frequency and adjusts its discharging or charging rate to follow the specified emergency frequency-watt curve parameters. New data points are provided multiple times per second.	Section 2.5.3	LN DWHZ
7.	Dynamic Reactive Current Support Mode The ESS reacts against rapid voltage changes (spikes and sags) to provide dynamic system stabilization	The ESS provides dynamic reactive current support in response to voltage spikes and sags, similar to acting as inertia against rapid changes. This mode may be focused on emergency situations or may be used during normal operations. When the dynamic reactive current support mode is enabled, the ESS monitors the voltage at the Referenced ECP and responds based on the parameters.	Section 2.5.4	LN DRGS

#	Functions or Modes	Description	DNP3 App Note 2018	IEC 61850-7-420
8.	Dynamic Volt-Watt Mode The ESS system dynamically absorbs or produces additional watts	The ESS system dynamically absorbs or produces additional watts in proportion to the instantaneous difference from a moving average of the measured voltage. This function utilizes the same basic concepts and settings as the Dynamic Reactive Current function, but uses active power as an output rather than reactive current.	Section 2.5.5	LN DVWD
	Active Power Modes		Section 2.6	
9.	Active Power Limit Mode Limits the discharging and/or charging level of the ESS based on the Referenced ECP	The discharging and/or charging of the ESS is limited at the Referenced ECP, indicated as absolute watt values. Separate parameters are provided for discharging or charging limits to permit these to be different.	Section 2.6.1	LN DAMG
10.	Charge/Discharge Mode Set the ESS to charge or discharge at the Referenced ECP	The ESS is set to a percentage of maximum charge or discharge rate at the Referenced EC). A positive value indicates discharge, and a negative value means charge.	Section 2.6.2	LN DCHD
11.	Coordinated Charge/Discharge Management Mode The ESS determines when and how fast to charge or discharge so long as it meets its target state of charge level obligation by the specified time	The ESS is provided with a target state of charge and a time by which that SOC is to be reached. This allows the ESS to determine when to charge or discharge based on price. The ESS takes into account not only the duration at maximum charging / discharging rate, but also other factors, such as, at high SOC, the maximum charging rate may not be able to be sustained, and vice versa, at low SOC, the maximum discharge rate may not be able to be sustained.	Section 2.6.3	LN DTCD
12.	Peak Power Limiting Mode The ESS limits the load at the Referenced ECP after it exceeds a threshold target power level	The Active Power output of the ESS limits the load at the Referenced ECP if it starts to exceed a target power level, thus limiting the power that needs to be imported from the grid. The discharging output is a percentage of the excess load over the target power level. The target power level is specified in percentage of maximum watts.	Section 2.6.4	LN DPKP
13.	Load Following Mode The ESS counteracts the load by a percentage at the Referenced ECP, after it starts to exceed a threshold target power level	The Active Power output of the ESS follows and counteracts the load at the Referenced ECP if it starts to exceed a target power level, thus resulting in a flat power profile. The discharging output is a percentage of the excess load over the target power level. The target power level is specified in percentage of maximum watts.	Section 2.6.4	LN DLFL

#	Functions or Modes	Description	DNP3 App Note 2018	IEC 61850-7-420
14.	Generation Following Mode The charging and/or discharging of the ESS counteracts generation power at the Referenced ECP.	The Active Power output of the ESS follows and counteracts the generation measured at the Referenced ECP if it starts to exceed a target power level. The charging and/or discharging output is a percentage of the excess generation watts over the target power level. The target power level is specified in percentage of maximum watts.	Section 2.6.4	LN DGFL
15.	Automatic Generation Control (AGC) Mode The ESS responds to raise and lower power level requests to provide frequency regulation support	When AGC mode is enabled, the ESS responds to signals to increase or decrease the rate of charging or discharging every 4 to 10 seconds, with the purpose of managing frequency.	Section 2.6.5	LN DAGC
16.	Active Power Smoothing Mode The ESS produces or absorbs Active Power in order to smooth the changes in the power level at the Referenced ECP.	The ESS follows the specified smoothing gradient which is a signed quantity that establishes the ratio of smoothing Active Power to the real-time delta-watts of the load or generation at the Referenced ECP. When the power smoothing mode is enabled, the ESS receives the watt measurements from a meter (or another source) at the Referenced ECP. New data points are provided multiple times per second.	Section 2.6.6	LN DWSM
17.	Volt-Watt Mode The ESS responds to changes in the voltage at the Referenced ECP by changing its charging or discharging rate	The ESS is provided with voltage-watt curves that define the changes in its watt output based on voltage deviations from nominal, as a means for countering those voltage deviations. When the volt-watt mode is enabled, the ESS receives the voltage measurement from a meter (or another source) at the Referenced ECP. The ESS adjusts its discharging or charging rate to follow the specified volt-watt curve parameters. New data points will be provided multiple times per second.	Section 2.6.7	LN DVWC
18.	Frequency-Watt Mode The ESS responds to changes in frequency at the Referenced ECP by changing its charging or discharging rate based on frequency deviations from nominal, as a means for countering those frequency deviations	The ESS is provided with frequency-watt curves that define the changes in its watt output based on frequency deviations from nominal, as a means for countering those frequency deviations and smoothing the frequency. When the frequency-watt mode is enabled, the ESS monitors the frequency and adjusts its discharging or charging rate to follow the specified frequency-watt curve parameters. New data points are provided multiple times per second.	Section 2.6.8	LN DFWS

#	Functions or Modes	Description	DNP3 App Note 2018	IEC 61850-7-420
	Reactive Power Modes		Section 2.7	
19.	Constant VAr Mode The ESS power factor is set to a fixed value.	The ESS VAr are set to the specified VAr, as a percentage of either the maximum reactive power or the available reactive power.	Section 2.7.1	LN DVAR
20.	Fixed Power Factor Mode The ESS power factor is set to a fixed value.	The ESS power factor is set to the specified power factor. A leading power factor is positive and a lagging power factor is negative, as defined by the IEEE sign convention.	Section 2.7.2	LN DPPF
21.	Volt-VAr Control Mode The ESS responds to changes in voltage at the Referenced ECP by supplying or absorbing vars in order to maintain the desired voltage level	The ESS is provided with voltage-VAr curves that define the vars for voltage levels. When the Volt-VAr Control Mode is enabled, the ESS receives the voltage measurements from a meter (or another source) at the Referenced ECP. The ESS responds by supplying or absorbing vars according to the specified Volt-VAr curve in order to maintain the desired voltage level. New data points are provided multiple times per second.	Section 2.7.3	LN DVVC
22.	Watt-VAr Mode The ESS responds to changes in power at the Referenced ECP by changing its power factor	The ESS is provided with watt-reactive curves that define the changes in its power factor based changes of power. When the Watt-Power Factor Mode is enabled, the ESS modifies its power factor setting in response to the power level at the Referenced ECP.	Section 2.7.4	LN FFWP
23.	Power Factor Correction Mode The ESS supplies or absorbs VAr to hold the power factor at the Referenced ECP	When the PF Correction mode is enabled, the ESS is provided with the target PF. The ESS supplies or absorbs vars in order to maintain the PF at the Referenced ECP within the target PF.	Section 2.7.5	LN DPFC
	Additional Capabilities			
24.	Pricing Signal Mode	The ESS uses the pricing signal for determining other actions. The details are not defined on how or when these other actions might be undertaken.	Section 2.8	(Not defined yet)
25.	Scheduling of Power Settings and Modes	The ESS follows the schedule which consists of a time offset (specified as a number of seconds) from the start of the schedule and is associated with: <ul style="list-style-type: none"> • a power system setting • the enabling/disabling of an operational mode • a price signal 	Section 2.9	LN FSCH LN FSCC

#	Functions or Modes	Description	DNP3 App Note 2018	IEC 61850-7-420
26.	Historical Information	Detailed measurement and performance data which may be valuable to record in an operational historian	Parts of Section 2.2.5 and Section 2.28	LN MMXU
27.	Microgrid Separation Control <i>{Not included}</i>	Process for normal separation, emergency separation, and reconnection	Section 2.11	LN DMIC (not defined yet)
28.	Provide Black Start Capability <i>{Not included}</i>	Ability to start without grid power and the ability to add significant load in segmented groups		(Not defined yet)
29.	Provide Backup Power <i>{Not included}</i>	Ability to provide power to local loads when not connected to the grid		(Not defined yet)

5.2 Compatibility, Coexistence, and Mutual Exclusivity of ESS Modes

Most modes are compatible with each other although some are mutually exclusive. A few could possibly co-exist, but the priority of one mode over the other must be established. For example, all emergency modes could be set with higher priority than modes that would operate during normal conditions. Active Power modes are compatible with reactive power and frequency modes. However, the AGC mode is mutually exclusive with most of the other Active Power modes, but may possibly co-exist with limiting Active Power charge/discharge rates if the latter is given higher priority.

The ESS cross-mode compatibility is shown in Table 12.

Table 12: Compatibility, possible coexistence, and mutually exclusive ESS modes

ESS Modes: Compatible (c), Possibly Coexist (P), or Mutually Exclusive (M)	Emergency				Real Power				Reactive Power							
	Voltage Ride-Through	Frequency Ride-Through	Dynamic reactive current support	Frequency-watt emergency	Limit real power discharge/charge rate	Peak Power Limiting	Load / generation following	Real power smoothing	Volt-watt control	AGC (utility sends Reg /down)	Charge-by management	Frequency-watt smoothing	Fixed power factor	Volt-var control	Watt-PF	Power factor correction
4 Voltage Ride-Through 5 Frequency Ride-Through 6 Dynamic reactive current support 19 Frequency-watt emergency 7 Limit real power discharge/charge rate 8 Peak Power Limiting 9 Load / generation following 10 Real power smoothing 11 Volt-watt control 12 AGC (utility sends Reg up and down commands) 13 Charge-by management 18 Frequency-watt smoothing 14 Fixed power factor 15 Volt-var control 16 Watt-PF 17 Power factor correction	c c c c c c c c c c c c c c c c	c c c c c c c c c c c c c c c c	c c c c c c c c c c c c c c c c	c c c c c c c c c c c c c c c c	P P P P P P M P P M P M M M M	c c c c c c c c c c c c c c c c	c c c c c c c c c c c c c c c c	c c c c c c c c c c c c c c c c	c c c c c c c c c c c c c c c c	c c c c c c c c c c c c c c c c	c c c c c c c c c c c c c c c c	c c c c c c c c c c c c c c c c	M M M M M M P P P P P P P P P	c c c c c c c c c c c c c c c c	P P P P P P P P P P P P P P P P	P P P P P P P P P P P P P P P P

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