5-23-2022

Developing an Energy Service Interface Specification

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by

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A thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Science
in
Electrical and Computer Engineering

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Portland State University
2022

Abstract

Developing an Energy Service Interface (ESI) specification requires engaging a community of stakeholders including grid operators, Information and Communication Technology implementors, integrators, and finally standards bodies who will define an interface that respects and boundaries of ownership and roles of responsibility in order to activate millions of Distributed Energy Resource for the provision of grid services. By applying Interoperability Maturity Model Criteria and ESI principles to common grid-DER service use cases, the Grid Modernization Lab Consortium team will engage subject matter experts to develop a specification, with an eventual goal of informing development of ESI compliant profiles or standards. The ESI Specification is intended to specify the characteristics, attributes, or qualities that need to be addressed in ESI compliant standards or profiles. This includes addressing interoperability criteria and the service-performance style of the interface.

Dedication

Dedicated to Dr. Robert Bass III, who has been an exceptional mentor to this Author, and invaluable partner/advisor to the Grid Modernization Lab Consortium (GMLC) Team

Acknowledgements

This research was supported by the Grid Modernization Initiative of the U.S. Department of Energy (DOE) as part of the Grid Modernization Lab Consortium, a strategic partnership between DOE and the National Laboratories to bring together leading experts, technologies, and resources to collaborate on the goal of modernizing the nation's grid. This author acknowledges the help and guidance received from the DOE manager, Christopher Irwin, in developing the plan for this project and encouraging outreach to relevant stakeholders.

Thanks to the GMLC Team, which includes many partners from LBNL, NREL, PNNL, Argon, and Oakridge. In particular, this author would like to emphasize the contributions of David Narang and Steve Widergren, who have had a critical role in the development of the Interoperability Maturity Model and Energy Service Interface (ESI) Standards Development Organization engagement process, Jingjing Liu who aided in the development of common grid service definitions, and Rich Brown who is the overall project lead for GMLC 2.5.2, ESI. And finally, thanks to members of the Smart Electric Power Alliance ESI Task Force and Portland State University Power Group for their contributions and feedback.

PNNL-32806

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Acronyms

CPUC California Public Utility Commission

CSIP Common Smart Inverter Profile

CTS Common Transactive Services

DER Distributed Energy Resource

DERMS Distributed Energy Resource Management System

DRLC Demand Response Load Control

DTM Distributed Trust Model

EGoT Energy Grid of Things

ESC Ecosystem Steering Committee

ESI Energy Service Interface

EV electric vehicle

FERC Federal Energy Regulatory Commission

GMLC Grid Modernization Lab Consortium

GSP Grid Service Provider

HVAC heating, ventilation, and air conditioning

ICAID Industry Connections Activity Initiation Document

ICT Information and Communication Technology

IMM Interoperability Maturity Model

LBNL Lawrence Berkeley National Laboratory

NAESB North American Energy Standards Board

NERC North American Electric Reliability Corporation

NREL National Renewable Energy Laboratory

PAR Project Authorization Request

PNNL Pacific Northwest National Laboratory

PSU Portland State University

SDO Standards Development Organization

SEPA Smart Electric Power Alliance

SME Subject Matter Expert

SPC Service Provisioning Customer

1 Introduction

1.1 Problem Statement

Integrating Distributed Energy Resource (DER) requires customization and is not aligned across jurisdictions. This causes integration to be labor intensive and expensive, creating a barrier to large scale adoption of DER to provide grid services.

1.1.1 Value of Distributed Energy Resources

DER come in many forms, from water heaters and heating, ventilation, and air conditioning (HVAC), to electric vehicles (EVs) and solar panels, and do not exclude traditional types of generation such as diesel generators. The context of "DER" for this paper is typically referring to those things that have some form of intelligence or controls. Also, it should be considered feasible that loads and generation that may not currently have the communication capability or intelligence required could be developed or retrofitted to have this capability. For example, a thermostat being connected to the internet was rare 15 years ago but is now a common HVAC accessory.

These DER are not typically procured to provide support to the grid, however, the ability to benefit financially or at least recuperate a portion of their capital expense could certainly influence the DER owner's decision to participate in grid-DER service programs, and perhaps to invest in DER capacity. Also, DER are often not fully utilized by the owner. For example, an EV may only be used for a short daily commute, leaving many kWh worth of energy that could be used to reduce the amount consumed from the grid during peak energy use periods.

1.1.2 Promoting Widespread Adoption

As grid operators aspire to a future of reduced fossil fuel consumption and focus on electrification, utilities and other stakeholders look to harness the collective capabilities of DER to defer costly infrastructure improvements and increase the resilience of the electric grid. Regulators are following suit in order to facilitate the changes. The Federal Energy Regulatory Commission (FERC) Order 2222 [1] directs utilities and other grid operators to submit plans regarding how DER will be managed and, in particular, how they will participate in energy markets. This includes discussion of topics such as presenting aggregated DER to markets and avoiding double counting for the same service.

Grid operators need to entice aggregations of DER willing to participate in order to provide a meaningful contribution to the grid and participate in these markets. Consider again that the primary role of DER is to benefit the owner. The service-oriented nature of the Energy Service Interface (ESI) allows the prosumer to maximize the personal benefit of their DER; both for comfort and monetary benefits. Additionally, focusing on performance-based grid-DER services rather than a specific objective or direct control allows abstraction from the happenings within the DER Facility, which is under the purview of the DER Facility owner/operator, or the need for insight into a specific DER.

1.1.3 Standards and Interoperability

The Grid Modernization Lab Consortium 2.5.2 project plan contains a series of tasks to advance the development of Information and Communication Technology standards; specifically from the Statement of Work, “the concept and requirements of ESI to the point of launching related interface standards and guides, that can be implemented in communication protocols and business process definitions,” e.g grid-DER service agreements.

This author’s prior GMLC project, 1.2.2 Interoperability, determined that the lack of a standards consistent with the ESI concept is a major barrier to enabling interoperability between the electric system and customer sites that contain DER[2]. Creating ESI inspired standards, guides, and related material will help reduce DER integration costs and grid operating costs, improve reliability, reduce carbon and improve sustainability.

This work is in progress with approximately 1 year remaining. The process developed by the author with the support of the GMLC team is currently being circulated with the various standards organizations including IEEE Std 2030.5 and OpenADR Subject Matter Experts (SMEs) to aid in refinement of the tools, identify preliminary topics to address, and ultimately, develop a specification for presentation to one or more Standards Development Organization (SDO).

2 Background

2.1 The ESI Concept

An Energy Service Interface (ESI) is defined as "a bi-directional, service-oriented, logical interface that supports the secure communication of information between entities inside and entities outside of a customer boundary to facilitate various energy interactions between electrical loads, storage, and generation within customer facilities and external entities." [3] The service-oriented qualification separates what is expected (a service) from how that service is performed. For example, a net load reduction request could be accomplished by a variety of DER, with the resources used changing between and within such requests. The external party does not need to know how the DER Facility manages its DER equipment if the requested service satisfies the terms of the service agreement.

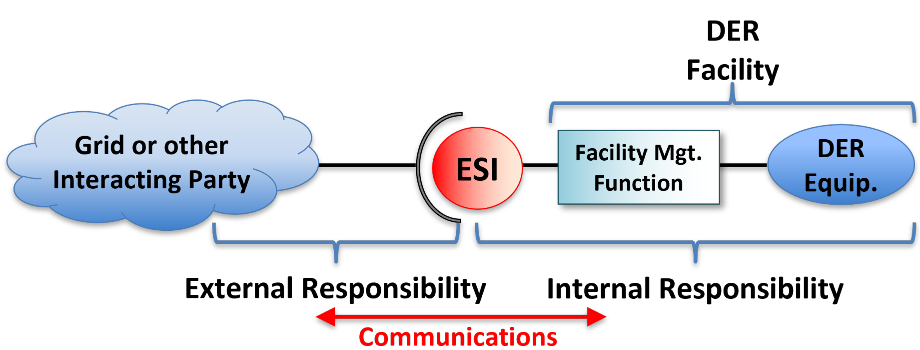

Figure 2.1: GMLC 1.2.2 Energy Service Interface Concept Diagram [4]

In the context of the ESI, an electricity customer site that includes DER is referred to as a DER Facility. The grid architecture concept of layered decomposition hierarchically disaggregates a complex problem into a series of simpler subproblems with clear and relatively simple interfaces between them. These subproblems are solved locally with interaction links to larger coordination domains and internally to subdomains. A DER Facility is such a subdomain. In other words, the DER Facility concept allows us to focus on the boundary between a grid-DER service requester and DER Facility, the grid-DER service provider, rather than the one or many DER and the interactions that are under the purview of the Facility Management Function.

On the external, interacting party side of the ESI, there may be more than one entity involved in the interactions across the ESI. There will likely be more than one DER in almost every facility, though they are hidden behind the Facility Management Function. The Facility Management Function is implemented by some entity that is (logically) internal to the building. It may pass on grid signals from the ESI to individual DER, or may make functional control decisions that incorporate grid signal information in sending other sorts of commands or requests to DER

2.1.1 ESI Principles

Principles from the ESI concept include the following.

- The Facility Management Function does not expose the identity or other details of individual DER, but rather only the collective capability of all DER in the DER

Facility for a particular grid-DER service.

- Boundaries of responsibility on either side of the ESI are clear and protected by the style of the interface.
- This approach embraces a distributed, decision-making coordination framework that emphasizes modularity and loose coupling of the interacting system components.
- The ESI is universally applicable to all types of DER if they qualify to address the agreed upon grid-DER service.

Some advantages of this approach follow:

- Makes for a simpler interface specification. Fewer rules and information need to be agreed to or exchanged. Test procedures are simpler. Integration effort is reduced.
- Supports adaptation to new DER technologies or advances in existing technologies.
- Avoids specialized interfaces based on DER technology type.
- Enables scalable coordination frameworks.
- Is sensitive to information privacy concerns.
- Reduces the cybersecurity threat space by eliminating remote, direct control of equipment and reducing the flow of private information.

Multiple types of agreements between participants may need to be covered in an ESI specification to achieve interoperability. Examples include an interconnection agreement, a grid-DER service agreement, and a billing-payment agreement.

2.2 Performance-Based Grid Services

Markets evolved independently but also divergently, often based on the more or less focused objective of the service requester. For example, the term “demand response” is some sort of change in energy production, often through direct load control [5]. This terminology allows for considerable confusion when negotiating or perhaps operating across jurisdictions [6].

The current approaches for DER to interact with the grid operator typically involve direct load control, akin to telling a DER what it is to do, such as changing a set point on an HVAC system or turning a water heater off [7]. A service-oriented approach would not require the grid operator to have access “into” the DER; rather, one would request that some agreed upon performance expectation be met [8]. In other words, the interaction only needs to communicate *what* is needed and not *how* it is provided [9].

This approach of defining grid services in terms of the performance requirement of the service being requested allows a more broad and commonly understood list of just six grid services, as demonstrated in Figure 2.2. Some of the services are still nascent in terms of grid-DER services, but common in wholesale markets. It is expected that DER will eventually participate in those markets as well to some extent. This is particularly true with energy storage and other inverter-based resources which tend to be very responsive.

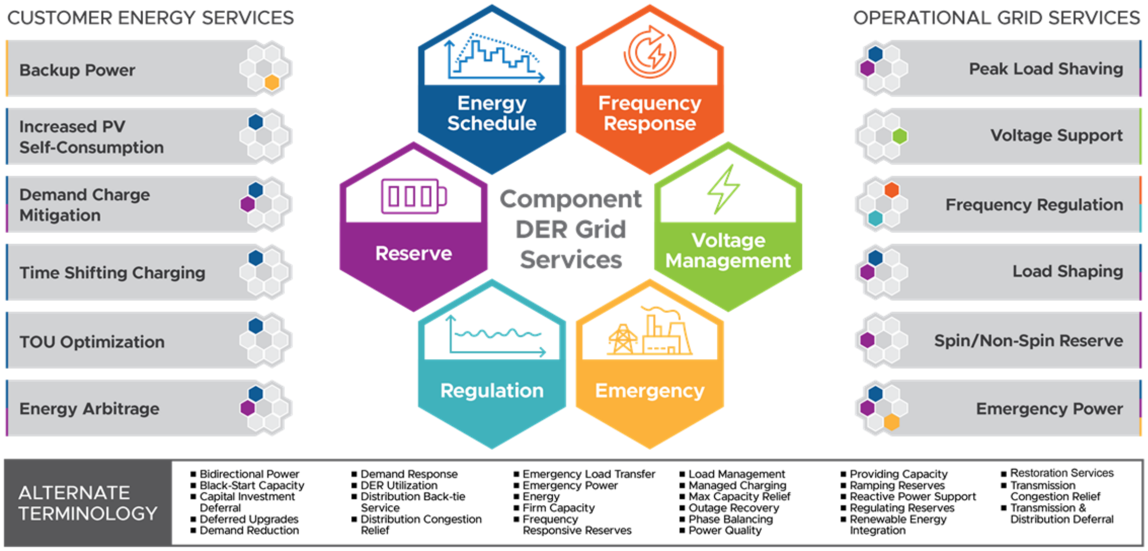

Figure 2.2: Common Grid Service and Traditional Grid Objectives

2.3 Grid-DER services

This related task of this author includes developing proposed "Common Grid Services Definitions" for presentation to North American Energy Standards Board (NAESB) which will inform their ongoing work to better define services for the increasing participation of DER. In the upcoming report, a set of grid-DER services are proposed as distinct categories of services with clear performance expectations and characteristics. These grid-DER services can be provided by a DER Facility through the ESI under a service agreement with an entity that represents the grid-DER service requester (such as a grid operator or utility). Such grid-DER services drive the business requirements of the ESI as they are the reason for the interaction. The terms of the agreement need to be clearly understood between the interacting parties (i.e., a grid-DER service requester and a grid-DER service provider). The exact performance expectations and characteristics of a grid-DER service is determined by the service requester's business requirements, which reflect the operational objectives.

2.3.1 Electrical Attributes

Real and reactive power capacity: Many grid services involve the resources producing or consuming power from the grid. To qualify for a grid service program, one or an aggregate of resources may need to provide their real and reactive power capacity. Note, from the grid service requester point of view, reducing load is equivalent to increasing generation or discharging energy storage. Some grid services require resources to provide reactive power instead of or in addition to real power.

Location: Though not necessarily an "electrical attribute," strictly speaking, location is a physical property of the overall electrical system and directly tied to the impact of loads and generation on the grid. This can be more or less impactful depending on the grid-DER service's performance requirements. FERC Order 2222 states that the "locational requirements for distributed energy resources to participate in a distributed energy resource aggregation that are as geographically broad as technically feasible."

2.3.2 Timing Attributes

The timing of the service attribute describes those parameters associated with when the service is delivered and the speed of delivery.

Delivery schedule: A service delivery schedule is the period over which the grid-DER service is needed. Its specification includes things like when the service starts and when it ends. This can also be calculated by a start time and a duration of operation that determines the end time. In the case of on-call services, such as reserves, the timing attributes start from when the service is called, based on the service agreement.

Response time: Response time is the allowable elapsed time between the moment when the grid service is to start and the moment when the desired behavior meets the defined threshold for a given grid-DER service. Response time requirements can determine the qualification of resources for providing each service. Expected response times range from milliseconds to hours depending on the grid-DER service agreement. Some grid-DER services require such rapid response (nearly instantaneous) that autonomous behavior is required, such as those defined through volt/watt and frequency/watt curves.

Grid-DER Service	**Response Times**	**Duration of Service**	**Measurement Requirements**
Energy Schedule Service	Minutes	Minutes-Days	±kWh Duration/Schedule
Reserve Service	Seconds-Minutes	Minutes-Hours	±kWh Duration/Schedule (Reserve and Operational Schedules)
Regulation Service	Seconds	Continuous	±kWh Duration/Schedule
Emergency Service	Seconds-Hours	Minutes-Hours	±kWh, ±kVAr Duration/Schedule
Voltage Management Service	Milliseconds-Hours	Seconds-Hours	PF, ±kWh, ±kVAr Duration/Schedule
Frequency Response Service	Milliseconds	Seconds	±kWh Duration/Schedule

Table 2.1: Grid-DER Services and the Associated Timing Requirements

2.3.3 Energy Schedule Service

An energy schedule service requests a planned import or export of energy from an electrical service point over a specified scheduled period.

Performance Expectations

Electrical Attributes: An energy schedule service specifies the quantity of electric energy over the performance period. The agreement can specify a fixed quantity of energy with the price paid for that quantity, or it may leave the amount of energy open, but specify the price of energy over the performance period. The price for a fixed quantity of energy may also be the result of a price-quantity negotiation (electric energy market)

Timing Attributes: the period of performance describes the start time and end time of power import or export. This can also be specified with a start time and a duration. The service agreement specifies the time by which the schedule needs to be put in place and the periodicity of the scheduling agreement (e.g., daily, hourly, 5-minute periods).

Performance Measurement

The energy schedule service agreement needs to specify how performance is measured. For distribution customers, this is usually done with revenue-grade interval meters capable of recording energy usage at intervals that match the timing attributes of the service agreement. For DER facilities such as buildings that may aggregate energy production and usage, this can be a customer site meter. For specific equipment agreements, sub-metering may be specified to isolate measuring performance.

Example Service Requester Operational Objectives

Grid operators procure energy in this manner to manage peak system load and balance energy use with production. This service can also be used to manage distribution equipment limitations such as those that may be caused by electric vehicles charging.

Origin of Service Definition

Wholesale markets negotiate scheduled blocks of energy. These are done in many forms including bilateral agreements between energy suppliers and energy users. They are also done in centrally-managed markets, such as those run by independent market operators. In the wholesale situation, the price and quantity of energy delivery over the performance period is negotiated ahead of time with information provided to an independent system operator for ensuring reliable system operation. The agreements, commonly referred to as a tariff which has received regulatory approval, also stipulate the penalties or fees for non-performance (over or under production and consumption).

2.3.4 Reserve Service

A reserve service specifies a quantity of energy or power operationally available during a predefined period. Reserved assets would be engaged as needed during this period.

Performance Expectations

Electrical Attributes: A reserve service specifies the quantity of available electric energy or power which could be called upon. The agreement can specify a quantity of energy or power that will be available to be called upon with the price paid for the quantity reserved and/or called upon. The agreement can also specify the responsiveness required of the service, e.g., ramp rate

Timing Attributes: The reservation period describes the start time and end time when the agreed upon quantity of energy will be available to be called upon. The period of performance describes the start time and end time of power import or export. The period of performance can differ from the reservation period. Either of these can also be specified with a start time and a duration. The service agreement specifies the time by which the reserve schedules need to be put in place and the periodicity of the scheduling agreement (e.g., daily, hourly, 30-minute periods) as well as the response time capabilities required to participate in the service.

Performance Measurement

The reserve service agreement will specify how performance is measured. Often in the case of reserves, responses are compared to requests for verification of the service. For distribution customers, this could be done with interval meters capable of recording energy usage at intervals that match the timing attributes of the service agreement. For DER facilities such as buildings that may aggregate energy production and usage, this can be a customer site meter. For specific equipment agreements, sub-metering may be specified to isolate measuring performance.

Example Service Requester Operational Objectives

Depending on the capability of the resource and the market it participates in, reserves can have several names such as synchronized reserves, non-synchronized reserves, day ahead scheduling reserves, Contingency reserves, ramping reserves, or operating reserves.

Origin of Service Definition

Power system operators use spinning and non-spinning reserves in order to maintain reliable supply of energy to the loads being served. Wholesale markets negotiate scheduled blocks of energy reserves to support this need. These are done in centrally-managed markets, such as those run by independent market operators. In the wholesale situation the price and quantity of power or energy available over the reservation-commitment period will be negotiated ahead of time with information provided to an independent system operator for ensuring reliable system operation. The agreements also stipulate the penalties or fees for non-performance.

2.3.5 Regulation Service

A regulation service increases or decreases real power import or export from an electrical service point over a specified scheduled period against a predefined real-power base point following a service requester's signal. The signal interval is one to several seconds and the associated performance period is of a significantly shorter duration than the typical energy scheduling service performance period.

Performance Expectations

Electrical Attributes: The service performance expected is a change in real power from a reference level. The regulation service is often delivered by commitment periods –for example, a commitment period is typically an hour in the real-time market. The service provider's performance is measured for each commitment period. The service provider will specify an upper and/or lower bound for the change in power level (e.g. in MW) expected over the commitment period. Another electrical attribute that may be specified in the agreement is the amount of instructed up and down movement within a period of service. This is often expressed as "mileage" and is the sum of the instructed up and down real power level changes.

Timing Attributes: While the grid operator's instruction signal is continuous, each service provider can choose which commitment period(s) it will participate in. The service agreement specifies the time by which the service provider's commitment (e.g. a bid) for a given commitment period needs to be put in place consistent with the market rules (e.g., 5-minutes before each hour in the real-time market). For operations timing attributes, the resources' real power import or export is to be adjusted immediately following the instruction signal at each step. The signal interval is typically of a regular periodicity (e.g., every 2 or 4 seconds).

Performance Measurement

The regulation service agreement needs to specify how real power import or export will be measured by power measuring equipment in order to determine performance. For distribution system customers, aggregation may be needed in order to qualify for providing the regulation service and warrant the expense of the required measuring equipment. Where practical, the real power import or export is measured at a time interval that aligns with the regulation signal or multiples of the regulation signal intervals. The real power measurement is provided to the service requester to determine the service provider's performance and compensation, based on the market clearing price for regulation services, for the regulation service provided during a given settlement period.

Example Service Requester Operational Objectives

The frequency regulation (or "regulation") service is used to balance small fluctuations in supply and demand in real time [10]. In the frequency control continuum [11], regulation service falls under the "secondary control" category i.e. once frequency drop has been arrested by primary control (in seconds), regulation service corrects the deviation (1-10 minutes) to the target value.

Origin of Service Definition

Historically, regulation service has been provided by generator units. It is common for generators to provide regulation service in conjunction with energy service and other ancillary services. However, single, large-load and aggregated demand-side resources are also allowed to participate in the regulation service in some markets [12] in the recent decade or so. This includes participation in PJM markets for RegA and RegD, and CAISO [13].

2.3.6 Emergency Service

This service uses the capability of resources to start without an outside electrical supply or automatically remain operating at reduced levels during an electric grid emergency. This service could include procedures that are used to help prevent outages or restore power following blackouts and could be an automated or signaled response.

Performance Expectations

Electrical Attributes: The emergency service agreement specifies the quantity of available electric energy or level of power which could be generated or deferred during an outage recovery period. The agreement can also specify the responsiveness required of the service, e.g. ramp rate.

Timing Attributes: The emergency service agreement specifies the response time capabilities required to participate in the service as defined in the service agreement.

Performance Measurement

This service could be considered critical and a coordinated control scheme might depend on all committed resources' participation. The service agreement will specify how performance is measured. The responses of the resource could be compared to requests for verification of the service. For distribution customers, this could be done with interval meters capable of recording energy usage at intervals that match the timing attributes of the service agreement. For DER facilities such as buildings that may aggregate energy production and usage, this can be a customer site meter. For specific equipment interconnection agreements, sub-metering may be specified to isolate measuring performance.

Example Service Requester Operational Objectives

Operational objectives of an emergency service include black start service, islanding, and emergency response service.

Origin of Service Definition

Though this is perhaps a more nascent service, there are currently several market operators with services such as this. In these markets, a Black Start Facility can restore its operation with on-site generation rather than relying on grid support. Other markets, such as NY-ISO[14], have programs where participants have mandatory curtailment notices, which are sent a day or two hours ahead.

2.3.7 Voltage Management Service

A voltage management service requests a response to provide voltage support (raise or lower) within a specified upper and lower voltage range at an electrical service point over a specified scheduled period.

Performance Expectations

Electrical Attributes: This service includes specification of a target voltage or upper and lower voltage levels at the electric service point over a performance period. The agreement can specify a single target or an upper and lower range of grid voltage magnitude or RMS value at the service point. The electric attributes may include the power factor of the DER Facility at the service point and/or injected or absorbed reactive power quantity from the DER.

Timing Attributes: The period of performance describes the start time and end time of the service. This can also be specified with a start time and a duration. The service agreement specifies the time by which the voltage management needs to be put in place and the periodicity of scheduling the agreement (e.g., daily, hourly, 15-minute periods).

Performance Measurement

The voltage management service agreement needs to specify how performance is measured. For distribution customers, this may be done with grid voltage magnitude or RMS measuring devices capable of recording voltage or power factor (real and reactive power) quantities at intervals that match the timing attributes of the service agreement. For DER facilities such as buildings that may aggregate energy production and usage, this can be a customer site voltage or real/reactive power meter. For specific equipment agreements, sub-metering may be specified to isolate measuring performance.

Example Service Requester Operational Objectives

The traditional objectives that relate to this service include maintaining voltage profile along a distribution circuit, mitigating voltage spikes, managing voltage sags and swells and providing Conservation Voltage Regulation (CVR). These issues may come from high voltage situations caused by neighborhood roof-top solar, low voltage situations caused by excessive electric vehicle charging, and high or low voltage profiles from circuit sectionalizing.

Origin of Service Definition

In the bulk power system, due to the highly inductive nature of transmission line, the frequency and voltage control can be decoupled such that the voltage is associated with the reactive power and the frequency can be controlled by the real power. Besides basic services (generating capacity energy supply, and power delivery), FERC In 1995 defined reactive power and voltage control as one of the six ancillary services[15]. In the distribution system, voltage management is done by changing transformer tap settings or manipulating capacitor banks. The state-of-the-art is to manage inverter equipment power factors with fixed settings or dynamically configurable settings that can be updated through secure, administrative communications.

2.3.8 Frequency Response Service

This service is based on the definition given by NERC as "the response of resources and load to arrest local changes in frequency," with the caveat that DER will provide this service rather than large transmission-connected generators [11].

Performance Expectations

Electrical Attributes: Note that frequency is a bulk power system level issue, and therefore will likely require a substantial amount of DER participation for meaningful effect. The level of participation needed will vary due to a number of factors including location, loading, time, and the amount of response needed.

Timing Attributes: The period of performance describes the start time and end time of power import or export. This can also be specified with a start time and a duration. The service agreement specifies the time by which the schedule needs to be put in place and the periodicity of the scheduling agreement (e.g., daily, hourly, 5-minute periods).

Performance Measurement

NERC uses a number of systems to monitor frequency events, including FNet (Frequency monitoring Network), CERTS - Electric Power Group (EPG) Resource Adequacy Tool Intelligent Alarms ("RA tool"), CERTS - EPG Frequency Monitoring and Analysis Tool ("FMA tool"). Balancing authorities also have additional tools for monitoring their control area, for example, PJM's Automatic Generation Control (AGC) program runs every two seconds and calculates Area Control Error (ACE), Area Regulation (AR) and economic dispatch. It is likely that aggregated resources will be required to meet these same measurement requirements.

Example Service Requester Operational Objectives

Fast frequency response and primary frequency response fall into this category of grid service.

Origin of Service Definition

This service has traditionally been provided by highly coupled generation units. Energy storage has been demonstrated to provide this in studies such as those at Portland General Electric's Salem Smart Power Center [16].

2.4 Life-cycle Phases

The ESI specification will provide examples of the types of interactions and information exchange between the service requester and service provider to support the grid-DER services. The ESI specification will include example interaction use cases that cover the various phases of a grid-DER service interaction lifecycle seen in Figure 2.3:

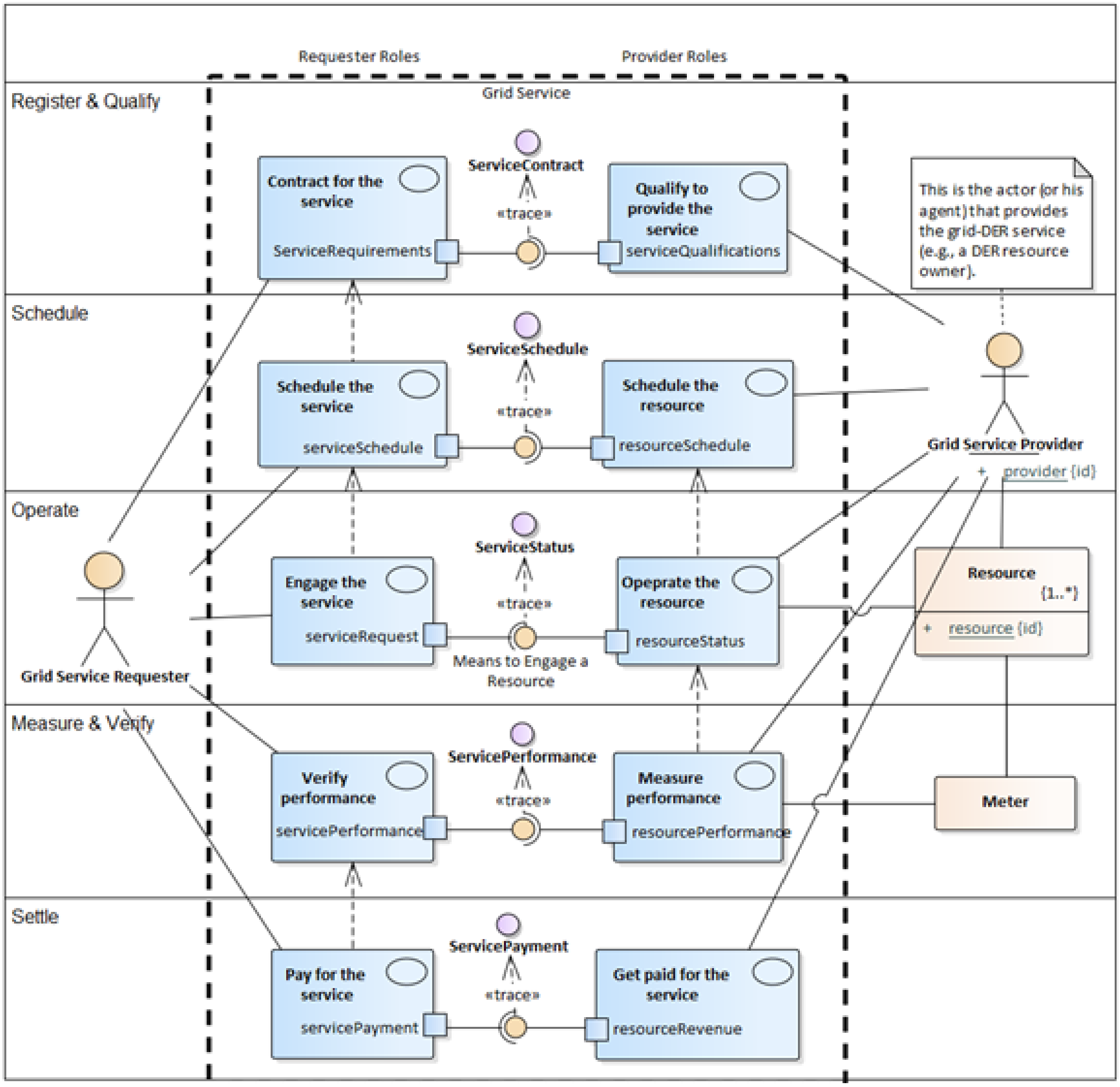

Figure 2.3: The lifecycle phases cover the major interactions that are needed for energy service transactions.

These interactions may be realized by designing multiple Information and Communication Technology (ICT) interfaces. For example, a web-based user interface could be used for registration, an interface between a utility DER management system and a facility management system to address operational interactions, and a meter-reading interface for interval meter data exchange to verify that the performance expectation of the agreement was met. The major interaction use cases cover the following phases of a service agreement:

2.4.1 Register and qualify

This phase establishes a contractual understanding between the service requester and service provider. It establishes that the service provider is qualified to provide the grid-DER service. Features like resource discovery should also occur during this phase to aid in determining geospatial and performance characteristics. The grid-DER service agreement should identify the grid-DER service and define the incentives, penalties, and risks that the service provider may be subject to while providing a grid-DER service. Qualification should include the minimum performance requirements of the DER Facility that will be necessary in all of the life-cycle categories.

Agreements should also have a termination clause. It could be based on an expiration date and time or perhaps initiated by either actor. Termination executes dissolution of the agreement so further related interactions are halted. Commencing termination could trigger additional actions, such as an offer to extend the agreement or a change in terms.

2.4.2 Schedule

This interaction takes place prior to grid-DER services being provided. The grid-DER service requester will provide advance notice to allow the grid-DER service provider to plan for delivery of the service. The plan should include the performance expectation and the schedule for the period of service. This phase may also include the negotiation of pricing or incentives depending on the terms of the agreement. The Facility Management Function could require assets to prepare to provide a change in energy based on an operational signal as in the case of a reserve service activation request.

2.4.3 Operate

This interaction occurs in real time as the grid-DER service is being delivered. The grid-DER service provider actively controls its resource(s) to fulfill the performance expectation. Communications are based on the terms of the agreement but could include the status of the service. The agreement may or may not require ongoing communication between interacting parties during this phase.

2.4.4 Measure and Verify

This phase confirms that the performance of the service provider meets the terms of the agreement. Enough information should be measured and exchanged by the interacting parties to satisfy the performance expectation of the agreement. The actors will measure the provider's performance according to the terms of the agreement. The collected information is used to adjudicate settlement in the next phase.

2.4.5 Settle

This phase uses the information collected in the Measure and Verify Phase to reconcile the performance of the service provider based on the agreement. This interaction occurs upon completing the service period. For example, settlement may be performed periodically at the end of the billing period following verified performance. The conclusion of this interaction is settlement between the grid-DER service requester and service provider for the period of performance.

2.5 Objectives of Work - The Energy Service Interface Specification

The ESI specification aims to facilitate the advancement of ICT interface standards and guides for the interaction between the electric grid and facilities with responsive DER equipment that is consistent with the ESI concept above. The ESI specification provides a framework to investigate existing information and communications technology interface standards to understand those requirements adequately covered by existing standards as well as the requirements where there are shortcomings or areas of improvement for standards development.

The ESI specification, similar to a product development specification, provides guidance for the development of an ESI compliant standard, or perhaps more appropriately, an ESI compliant profile. An example of a profile is the Common Smart Inverter Profile (CSIP) [17], which provides specific implementation guidance relating to interactions between grid operators and grid-tied inverters using specific methods of IEEE Std 2030.5 [18]. The ESI specification, in contrast, will provide a guide for implementing an ESI compliant standard or profile.

The ESI specification defines the requirements that are to be addressed in ICT interface standards for enabling the integration of a facility with responsive DER to an electric system consistent with the ESI concept. For the purpose of this discussion, a DER Facility may be as simple as a single DER with a communicating controller or as complex as a micro-grid campus with several buildings and many DERs, as shown in Figure 2.4.

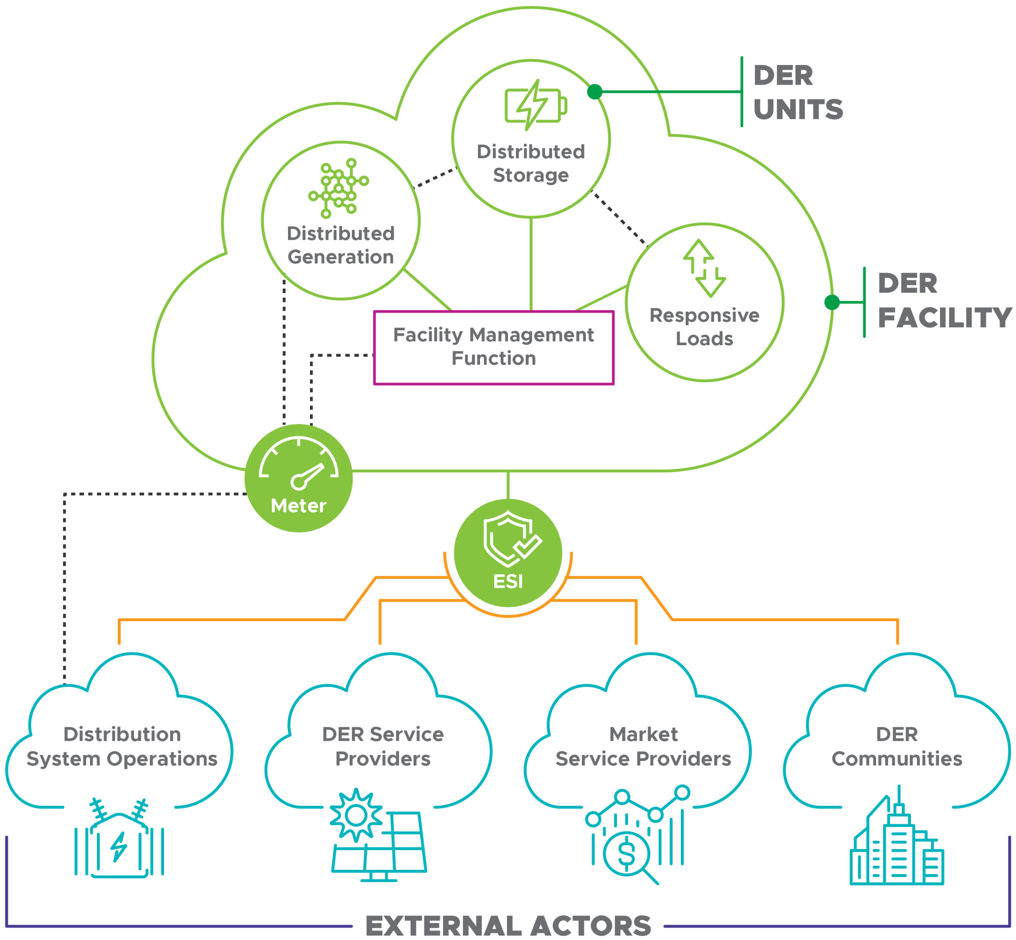

Figure 2.4: The DER Facility may be as few as one DER and its controller or a microgrid with many DER.

The ESI requirements specification is not a technical interface standard. Rather, the requirements in the specification can be used to check that existing, augmented, or new interface standards meet the interoperability requirements of the ESI concept. In this way, the ESI requirements specification can be used to guide standards advancement work in multiple standards development organizations.

The ESI specification considers the range of issues that need to be understood and agreed to for the interacting parties that implement the interface to successfully communicate and conduct business. That includes a set of business requirements related to grid-DER service agreements and supporting interoperability requirements related to categories and cross-cutting issues of the Interoperability Context-Setting Framework [19]. To address all the requirements, a set or profile of multiple technical standards are anticipated [20]. The ESI specification references the common grid-DER service agreements that are anticipated to be supported using this interface.

Lastly, the ESI specification facilitates the advancement of ICT interface standards and guides for the interaction between the electric grid and facilities with responsive DER equipment that is independent of the various DER device types. This specification provides a framework to investigate existing ICT interface standards to understand those requirements adequately covered by existing standards as well as the requirements where there are shortcomings or areas of improvement for standards development.

3 Methodology

3.1 Specification Development Overview

The three-year overall project plan is to; in year 1, develop an understanding of existing and future grid services in order to define a set of common, performance-based grid services and identify use cases of DER providing services at scale; in year 2, develop an ESI specification framework to simplify DER integration and support DER business models; an in year 3, finalize an ESI specification and accelerate industry agreement on ESI concept-inspired standardization through multiple suitable Standards Development Organizations, including an SDO for standardizing grid service definitions (NAESB). This particular document is focused on the ESI specification framework.

The intent of the ESI Specification is to guide the development or improvement of profiles and standards that would support service oriented grid interactions. It can be applied to any grid edge communication standard and support a variety of architectures. The ESI Specification includes the types of information that might be needed but not the specifics of any one standard. This is intentional, as the interactions required for the ESI may occur across multiple interfaces.

The development of the ESI specification involves the engagement of industry stakeholders and experts in the ICT aspects of integrating DER. This helps establish a growing community that shares consistent concepts, principles and terminology that can engage standards groups to consider new work or modifications to existing work related to advancing deployment using the ESI concept. The ESI requirements document is a tool for the GMLC 2.5.2 team to engage industry partners by describing the nature and purpose of an ESI specification and proposing the types of things it should cover. The following draws heavily from the currently unpublished ESI Requirements Document, which outlines outlines the contents expected in the ESI specification.

During the GMLC 1.2.2 Interoperability project, the GMLC team worked with SEPA to form the ESI Task Force. The ESI concept was refined and trialed at the SEPA Plug and Play Challenge, led by Pacific Northwest National Laboratory (PNNL)'s Steve Widergren. There, teams demonstrated their platforms for a rudimentary version of energy service interface with reasonable success. This GMLC/SEPA partnership continues as we develop a specification. The mix of stakeholders, which include utilities, standards developers, and integrators, provides the National Lab Team an opportunity to socialize the concepts of grid-DER services, the ESI lifecycle phases, and the Interoperability Maturity Model (IMM) criteria with SEPA's wide range of stakeholders before presenting to a SDOs [21].

Besides the various activities of the ESI Task Force, the Portland State University led Energy Grid of Things (EGoT) project is applying the principles of the ESI to IEEE Std 2030.5. The ongoing coordination and regular feedback from this exercise is providing valuable experience to inform the SDO engagement process as well. For example, the Portland State University (PSU) team, when considering that the IMM's privacy and security, developed a

Distributed Trust Model (DTM) which is designed to pass no information on what happens within theDER Facility, but evaluates message contents for "out-of-the-ordinary" behaviors to determine the trust-worthiness of the interaction. By not communicating the contents of the message, but only a "vector of trust", the DTM is able to comply with the ESI interoperability requirements for privacy while increasing the maturity level of the security criteria requirement. This mechanism also provides and example of how the ESI may apply to multiple interfaces.

3.1.1 Energy Service Interface Conceptual Requirements

Conceptual requirements for an ESI include the following:

1. The ESI applies to the electrical interaction of a DER Facility at the point where it connects to the electric system. It demarcates the areas of responsibility by parties on either side of the interface. The grid-side interacting party could be as small as a microgrid that manages two or more DER Facilities or it could be as large as a distribution system that is fed by a large, interconnected power system. The DER Facility could manage one DER or it could be a collection of many DER, such as found in a large, commercial building or a manufacturing facility.

2. The ESI supports at least one service agreement with an interacting party. An ESI service agreement specifies what a service provider will accomplish for a service requester and any compensation (monetary or otherwise) from the service requester

for performing that service. Common definitions of grid-DER services are provided in Task 1 of this project.

3. The ESI service agreement does not describe how the service is performed, but expectations of performance are described. It explains the qualifications of a service provider for entering into the agreement, if any. By being service-oriented, the ESI allows the service provider to replace or update DER without impacting the communication interactions of the ESI. That is, the grid-DER service agreement is agnostic to the types or assortment of DER that perform the service.

4. The grid-DER service agreement explains the way performance is measured and what is done for non-performance.

5. Information at the point of electrical connection between the DER Facility and the outside system is measured in an agreed upon manner (e.g., a measurement of electric energy flow in a period or derived measurement from other information) to determine performance expectations are met according to the service agreement. The point of electrical connection is important for coordinating the physical delivery aspects by the external party.

3.1.2 Business Requirements

In order to promote adoption of the ESI, the GMLC team will focus on the driving business requirements that are most prominent in the marketplace. In terms of both the currently available DER programs and current and most pressing needs of grid operators, the "Energy

Schedule Service" has been identified as a priority grid-DER service. Additionally, examples of its possible application are common today. The GMLC team uses energy scheduling as an example to illustrate the performance characteristics and related functional elements included in a grid-DER service. Under the Energy Schedule Service, the DER Facility is expected to consume or produce a specified amount of energy over a scheduled period of operation. Depending on the time period of the schedule, this service can be used to serve different operational objectives of a grid-DER service requester including, but not limited to, managing power generation for wholesale day-ahead and real-time energy services, managing transmission system peak load, and managing distribution system congestion.

The Energy Schedule Service must specify the information needed so that grid-DER service requester performance expectations can be understood and agreed to by the grid-DER service provider. Different jurisdictions will have different service characteristics. The following items are representative of the types of items that would be specified:

- the scheduled time period of operation,
- the amount of energy to be produced or consumed, or the change in consumption during the scheduled period,
- the method for measuring the energy production or consumption during the scheduled period,
- the calculation of compensation to the service provider for the service (if any), and
- the time the scheduling for the period of operation needs to be established (in advance).

The Energy Schedule Service agreement may also include performance constraints, such as the minimum or maximum power production or consumption limits during the period of operation. Such items need to also consider how violations of the constraints would be determined and reconciled. Under the Energy Schedule Service, the scheduled time period of operation can be discrete periods or ongoing, i.e., a series of periods. Peak load management involving participation of flexible load resources is an example of scheduling energy consumption for a discrete period. A common approach is to request load reduction during a specific time window (e.g., 12-6 PM the following day). Dynamic pricing is an example of scheduling energy consumption for a series of time periods on an ongoing basis. For example, some existing day-ahead dynamic pricing programs post the hourly energy prices for the following day everyday so that customers can plan their next-day hourly energy consumption accordingly.

3.2 Illustrative Example

One of the tasks of the ESI project was to develop scenarios that could be used to relate to stakeholder interests. The following is one possible series of interactions relating to a to-be-published "scenarios" document. The illustrative example shows how the lifecycle phases, described in 2.3, and scenarios can be combined to demonstrate the type of service-oriented interactions an ESI might need to support. This particular example is based on a scenario for an Energy Scheduling Service. The intent of this scenario is to explore the interaction and interoperability requirements of an ESI standard or profile throughout the lifecycle of an Energy Schedule Service, with some relation to existing programs that DER facilities could participate in.

The example assumes that the DER Facility's performance qualifications are defined to an unambiguous level, and that the service requester and any associated grid-side entities have the means to support the coordination of the various DER Facilities. Examples of this include association of the service provider's performance characteristics, location on the electrical network, unique identifiers such as contract ID and service account of the DER Facility. Any interconnection agreements relating to mandated behaviors of DER covered by regulated codes are assumed to be understood and referenced by those establishing the grid-DER service agreements so that no conflicting requests will be made to the der Facility.

During the registration and qualification phase, a service provider and requester agree to the terms of a service agreement as determined in Figure 3.1. This registration phase would also associate any unique IDs and other information necessary for communications in later phases. In this example, rates and credits are part of the tariff approved by the regulatory authority and as such are defined in the terms of electrical service. The required qualifications of the DER Facility also need to be communicated to the grid-DER service requester to qualify the provider. For the example being discussed, there is no performance requirement, only the requirement that the DER Facility is able to read the prices from a published list at noon the day ahead and negotiate a rate for participation. There is no description of the penalty for non-performance besides non-payment. Other requirements required for the service include an interval meter appropriate to verify performance of the

DER Facility.

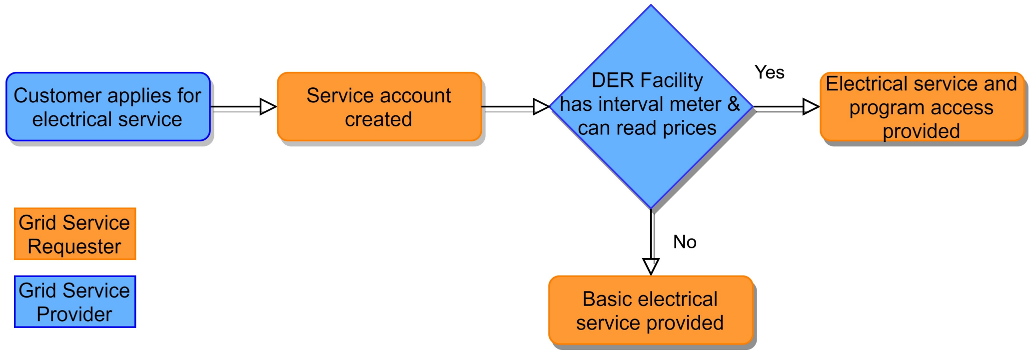

Figure 3.1: Example of the Registration Phase which includes qualification of the DER Facility to provide the grid-DER Service.

In this example, the scheduling phase, 3.2, occurs a day ahead starting at noon. At noon the DER Facility Management Function looks for requests and, in this case, reads a request for curtailment from 2 PM until 6 PM the next day. In this simple example, the DER Facility Management Function determines that it can modify the operating schedule of its equipment and reduce its load for the requested four-hour period by 50 kWh each hour. The control algorithm calculates the value of the curtailment to be $ .50 per kWh. This bid is communicated back to the service requester before 3 PM. In turn, the requester accepts the bid and communicates this acceptance to the DER Facility Management Function. The final step in this phase is when the DER Facility Management Function incorporates the updates to its operating schedule.

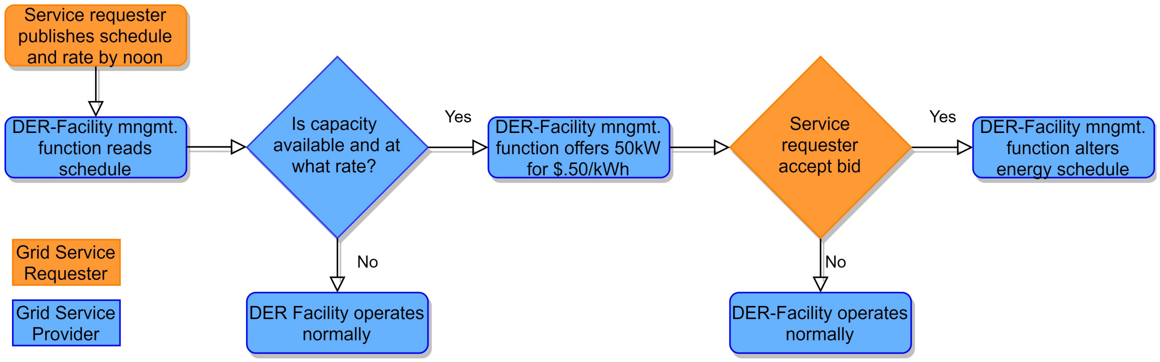

Figure 3.2: Example of the Schedule Phase which could include negotiation based on the grid-DER service agreement.

At 2 PM the following day the schedule is put into operation, the third lifecycle phase. Since the energy service agreement does not have communication requirements defined for this phase, the DER Facility Management Function simply employs the schedule that was calculated from the day before, Figure 3.3.

Figure 3.3: A simple example of the Operate Phase which may include a signal to operate

In the fourth lifecycle phase, measurement is performed by the communicating interval meter per the grid-DER service agreement, collecting energy-use data in 15-minute intervals and communicating it to the electrical service provider who, in this case, is also the service requester. The committed schedule is verified through comparison to a baseline average of the ten previous days by the back-office function of the requester, shown in 3.4. Any variation from the expected performance is resolved per the grid-DER service agreement. For this example, the service was deemed to be provided as expected.

Figure 3.4: The Measure and Verify Phase may use the service meter for performance verification as defined in the grid-DER service agreement

In the fifth phase, shown in 3.5, settlement occurs at the end of the billing cycle and, since the outcome was fulfilled, the payment for the service is applied to the monthly bill for the DER Facility. If settlement is performed on a monthly or other billing cycle, this phase could include multiple transactions of a similar nature based on the terms of the grid-DER service agreement.

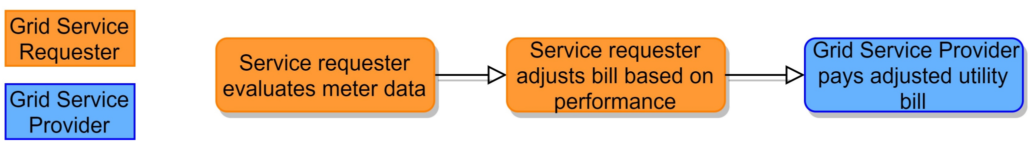

Figure 3.5: The Settle Phase uses the information from the previous phase to reconcile performance of the DER Facility.

3.3 Interoperability Maturity Model

The IMM is a tool that was developed to measure the effectiveness of methods for integrating the ICT aspects of intelligent devices and systems to coordinate their operation with the rest of the electric power system. The tool is focused on the evaluation of the interfaces used to integrate these devices and systems. By ranking the level of maturity for each criteria as shown in 3.6, the tool aids in identifying gaps between current and desired levels of interoperability. In the earlier GMLC 1.2.2 project, the IMM was applied to assess maturity of a communications interface standard, IEEE Std 2030.5 to develop a roadmap [2] for achieving ecosystem interoperability goals. In this project, the IMM has been adapted to apply to a potential ESI compliant standard or profile.

GridWise Architecture Council Interoperability Maturity Model	Maturity Characteristics			
Maturity Level Statements	Community / Governance	Documentation	Integration	Test / Certification
Level 5 Optimizing	Managed by a community quality improvement process	Adopts and open community standard	Integration metrics used for improvement of the standard	Test processes are regularly reviewed and improved
Level 4 Quantitatively Managed	Processes ensure currency and operation	References community standard w/o customization	Integration metrics are defined and measurements collected. Reference implementations exist	Community test processes demonstrate interoperability. Members claim interoperable performance
Level 3 Defined	Managed by community agreement	References community standard w/ some customization	Integration repeatable w/ predictable effort	Tests exist for community w/ certification. Members claim compliance to standard
Level 2 Managed	Managed by project agreement	Documented in a project specification	Integration is repeatable w/ customization expected	Testing to plan w/ results captured
Level 1 Initial	Management is ad hoc	Documentation is ad hoc	Integration is a unique experience	Testing is ad hoc

Figure 3.6: Levels of Interoperablity Maturity [22]

3.3.1 Interoperability Evaluation

Measuring interoperability maturity involves looking for evidence that practices (capability or integration) are being performed and, where they are not (to the level desired), creating a list of gaps so that the steps to reach the desired level of interoperability can be planned. As mentioned, assessing the degree of interoperability maturity requires evaluating the IMM criteria and grading them on a level of 1 to 5. The levels of maturity used in the IMM are based on the Capability Maturity Model Integration (CMMI) [23]. This is the same system that was used by GWAC for the Beta release of the IMM, which described the levels of maturity for different areas as shown in Figure 3.6.

The ESI Specification is to provide guidelines to SDOs and other stakeholders to evaluate interoperability and the ability to comply the ESI vision. The IMM was developed as a more general interoperability evaluation and, as such, does not inherently include those concepts core to the ESI principles. In an attempt to align with the principles, an effort was made to adapt the IMM in an ESI-centric fashion. The criteria were framed with how they might apply to the ESI, implementation assumptions, a possible review process, examples of questions used to gauge interoperability for the original roadmap effort, and notes that may not fit into any of those categories but are expected to be part of the discussion. This review was performed internal to the group initially and then provided as a limited distribution for stakeholders such as the Smart Electric Power Alliance (SEPA) ESI Task Force for review and comment. The following are the results of said review and will be presented to the targeted SME for more specific review of a given standard or profile.

3.3.2 General Capabilities

During the GMLC team review of the Interoperability Maturity Model review with SEPA's ESI Task Force, several general assumptions were identified. These include overarching assumptions, not an assumption or requirement of a specific criterion, and apply to the overall ESI or its implementation.

- In practice, an ESI may be implemented via a communications protocol and/or an implementation profile (examples of communications protocols are OpenADR or IEEE 2030.5 or Common Transactive Services [18, 24]. Within a broader standard, the ESI could be developed as an implementation profile such as the Common Smart Inverter Profile (CSIP).

- The ESI is implemented in the context of supporting contractual agreement(s) for grid services.
- DER Facility Management Function exists that manages individual DER at the facility.
- A shared list of DER Facility performance requirements that will be requested exists and can be accessed by the DER Facility and the grid service requesting entity.
- DER Interconnection agreement in place if required (e.g., between DER owner and local utility).
- The DER Facility performance requirements are defined and communicated by the service requester, and DER Facility performance capabilities are known and communicated by the service provider.
- Power system operators are coordinating with grid service request functions (e.g., ISO and local utility).

3.3.3 Configuration and Evolution

Criteria 1 through 8 address topics related to vocabularies, concepts, and definitions across multiple communities and companies. This means that all resources need to be unambiguously defined to avoid clashes between identification systems. This is important over time as new automation components enter and leave the system because resource identification is essential for discovery and configuration. This also provides the ability to upgrade (evolve) over time and to scale without affecting interoperability.

Criterion 1:
The ability of the interface to accommodate the integration with legacy components and systems is described along with an upgrade migration path.
Applied to the ESI:
The ESI compliant standard or profile is backward compatible and has an upgrade mechanism.
Implementation Assumptions:
The version of the supported specification is identified.
Review Process:
Evaluate standard's maturity to support this functionality.
Example questions:
Q1.1 -Is there a migration path for integration of legacy systems and components with new components? *Q1.2 -Is there documentation showing how new components are accommodated?*
Notes:
The integration ecosystem can provide version compatibility and upgrade path descriptions at the implementation profile level (e.g., consortium like SunSpec). Discussion includes the types of information that might need to be supported.

Criterion 2:
Interface capabilities can be revised over time (versioning) while accommodating connections to previous versions of the interface and without disrupting overall system operation (such as supporting a rolling upgrade process)
Applied to the ESI:
The ESI compliant standard or profile can be updated without disruption of system operation, which includes backwards compatibility.
Implementation Assumptions:
Assumes many devices operating in the system so that work on one does not impact the system from functioning. The standard includes a means for updating the ESI elements of the communications interface in a coordinated fashion. The ESI implementer or a proxy manages rolling upgrades.
Review Process:
Evaluate standard's maturity to support versioning, rolling upgrades, and backwards compatibility.
Example questions:
Q2.1 -Is there a documented process for revising an interface to extend its capabilities over time? *Q2.2 -Is there a documented process to ensure you can support multiple versions of interfaces, including previous versions?*

Criterion 3:
The way regional and jurisdictional differences are supported is described.
Applied to the ESI:
The ESI compliant standard or profile has configuration flexibility to address policy differences.
Implementation Assumptions:
Policies that are defined should be harmonized between actors.
Review Process:
Standard should not have policies that restrict use across jurisdictions.
Example questions:
Q3.1 -Describe regional and jurisdictional differences that exist within the ecosystem for the same interface. *Q3.2 -How is flexibility managed to account for jurisdictional and/or regional differences?*
Notes:
Business aspect needs to be addressed by service requestor. Profiles can be used to do the specialization. Applications can leverage the ESI to do the specialization.

Criterion 4:
Configuration methods to negotiate options or modes of operation including the support for user overrides are described.
Applied to the ESI:
The ESI compliant standard or profile supports modes of operation and user overrides.
Implementation Assumptions:
Modes include grid services or other modes of operation.Business process (messaging and their sequencing) need to support selecting options.
Review Process:
Methods and information model review ("methods" includes review of business process model (messages and sequencing)) of operating modes and overrides.
Example questions:
Q4.1 -Do your interfaces support user choice options? (for example, metric vs. imperial units; or report by exception vs. report at intervals) *Q4.2 -Do your interfaces support one or more modes of operation?* *Q4.3 -Do you have documentation explaining how user overrides and options are supported?*
Notes:
This may occur on either side of the interface.

Criterion 5:
The capability to scale the integration of many components or systems over time without disrupting overall system operation is supported.
Applied to the ESI:
The ESI compliant standard or profile is scalable without interruption to any interfacing actor.
Implementation Assumptions:
Scalability is also system architecture issue.
Review Process:
Review of coordination architecture, cybersecurity, public key management, ease of adding-removing components and other relevant aspects within the scope of the ESI as system size increases
Example questions:
Q5.1 -Please explain the limits of your ability to scale component integration? *Q5.2 -Can large-scale integration be achieved without disruption of service?*

Criterion 6:
The ability of overall system operation and quality of service to continue without disruption as interfacing actors (DER, utilities, aggregators) enter or leave the system is supported.
Applied to the ESI:
The ESI compliant standard or profile has methods for interfacing actors to enter or leave without disruption to the system.
Implementation Assumptions:
The grid operator will adjust appropriately to maintain quality of service as actors enter or leave the system. Systems that coordinate the operation of DER Facilities need to support their entering and leaving the system without overall disruption.
Review Process:
Review standard for methods on entering and leaving the system that don't require a system pause. This could include review of coordination architecture, public key management, and other relevant aspects within the scope of the ESI.
Example questions:
Q6.1 -Can your communications system operate without disruption as parties enter or leave the system?
Notes:
Coordinated with back office

Criterion 7:
Unambiguous resource identification and its management is described.
Applied to the ESI:
The ESI compliant standard or profile supports unambiguous identification of resources DER facilities referenced across the interface.
Implementation Assumptions:
An identity management feature exists for creating and maintaining uniqueness Archives for reconciliation and audit have lasting unique references to reliably process history
Review Process:
Review of standard where resource identification applies and how uniqueness is managed.
Example questions:
Q7.1 -Do all devices have a unique way to identify them? *Q7.2 -Is there a system in place to manage allocation of identifiers?* *Q7.3 -Do you have documentation describing the identifiers and how they are assigned, managed, and retired?*
Notes:
Implementation profiles may already specify how unique resource identifiers are created and managed including roles for third party management, such as a consortium or government agency. Information exchange requires unambiguous references to the interacting parties and associated information

Criterion 8:
Resource discovery methods for assisting with identification and integration between actors (such as access to information like owner, DER type, location, etc.) is supported.
Applied to the ESI:
The ESI compliant standard or profile has resource discovery methods to support integration of interacting actors.
Review Process:
Review resource discovery and announcement capabilities of the standard. For example, support for registries or access lists that methods can post to and query so that things can be discovered. Those things could be grid-DER service programs or a participant that is signing up for a program, etc.
Example questions:
Q8.1 -Does the system support the initial handshake for the discovery of new resources? *Q8.2 -Do the resource discovery methods support mutual understanding of device capability?* *Q8.3 -Are resource discovery methods supporting configuration documented?}*
Notes:
The discovery service will allow actors to associate information such as tariff or program, location, performance characteristics/requirements, and participation availability.

3.3.4 Security and Safety

Criteria 9 through 12 are concerned with aligning security policies and maintaining a balance between minimizing exposure to threats while supporting performance and usability. This includes the capability to troubleshoot and debug problems that span disparate system boundaries, while placing the integrity and safe operation of the electric power system above the health of any single automation component.

Criterion 9:
The requirements and mechanisms for auditing and logging exchanges of information is described.
Applied to the ESI:
The ESI compliant standard or profile describes mechanisms for auditing and logging the exchange of information.
Implementation Assumptions:
Information that will be audited or logged is defined. Each contractual engagement has an energy services agreement in place. There may be different versions of the energy services agreement depending on needs of the contracting parties. Specific energy services agreements may implement a subset of the auditing & logging mechanisms described in the ESI implementing communications standard. Multiple interfaces might require auditing and logging i.e., metering
Review Process:
Standard review for auditing and logging capability and supported features
Example questions:
Q9.1 -Do you have the capability to log information exchanges? *Q9.2 -Do you have the capability to audit your information exchange logs?* *Q9.3 -Is there documentation describing the auditing and logging processes?*
Notes:
Any interaction across the interface may need to be logged. Alternatively, the agreement may require selective information is logged. Things like the size or length of the log need to be specified and what is done when size limits are reached. ESI implementations may have different auditing and logging requirements.

Criterion 10:
Privacy policies are defined, maintained, and aligned among the parties of interoperating systems.
Applied to the ESI:
The ESI compliant standard or profile describes privacy policy support mechanisms and how information is protected.
Implementation Assumptions:
There are jurisdictional considerations concerning privacy policies. The standard may need to accommodate flexibility to support different policies. The security policies are consistent for support of privacy protection policies.
Review Process:
Standard review for privacy policies and their support with related methods including auditing and logging capability. Work with \gls{sdo} representative to determine minimum requirements.
Example questions:
Q10.1 -Do you have a privacy policy? *Q10.2 -Is a community privacy policy part of your community governance agreement?* *Q10.3 -Do all of your information exchanges take place with partners who have a privacy policy?* *Q10.4 -What is your policy if partners do not have a privacy policy?* *Q10.5 -Do you have pro forma contractual language for your privacy policy?*
Notes:
Personally identifiable information (PII) may need protections, for example using a unique ID rather than name or PII. Anonymizing mechanisms for PII need to be described.

Criterion 11:
Security policies are defined, maintained, and aligned among the parties of interoperating system.
Applied to the ESI:
The ESI compliant standard or profile has mechanisms to support security policies.
Implementation Assumptions:
There are jurisdictional considerations concerning security policies. Example of a security policy is access control.
Review Process:
Standard review for security related features including message cryptography and access control capability. Work with SDO representative to determine minimum requirements and supported security features for example DER Access control.
Example questions:
Q11.1 -Do you have a security policy? *Q11.2 -Is there a community security policy?* *Q11.3 -Do any of your information exchanges take place with partners who do not have a security policy?* *Q11.4 -Is your security policy aligned with those of interoperating parties?*
Notes:
Policy would be defined, maintained, and aligned outside of the interface. The agreement between parties needs to include expectations for security of data management, but it also needs to stipulate things like cybersecurity messages and the management of those features to support security policies. Additional question: Is there anything detecting security breaches and what happens in such events?

Criterion 12:
Failure mode policies are described and aligned among the parties of the interoperating systems to support the safety and health of individuals and the overall system.
Applied to the ESI:
ESI compliant standard or profile describes failure modes.
Implementation Assumptions:
As a system architecture issue all participants should not negatively impact the components of the overall system, not just the ESI. This could also be defined on either side of the interface. Responses to failures are aligned among interoperating systems in the ESI agreement/contract
Review Process:
Review standard for methods to identify and announce failure modes.
Example questions:
Q12.1 -Do you have a failure mode policy? *Q12.2 -Is there a community failure mode policy?* *Q12.3 -Do any of your information exchanges take place with partners who do not have a failure mode policy?* *Q12.4 -Is your failure mode policy aligned with those of interoperating parties?*
Notes:
Safety and health of individual participants and the overall system will be managed on either side of the interface. Policies and failure mode responses are defined in the Energy Service Agreement

3.3.5 Operation and performance

Criteria 13 through 16 focus on synchronicity and quality of service, as well as operational concerns. Operational concerns may include concerns such as maintaining integrity and consistency during fault conditions that disrupt normal operations and ensuring that distributed processes can meet expected interaction performance and reliability requirements.

Criterion 13:
Performance and reliability requirements of the interface are defined.
Applied to the ESI:
Performance and reliability requirements of the ESI compliant standard or profile are defined.
Implementation Assumptions:
There exists a defined set of performance and reliability requirements and metrics.
Review Process:
Review standard for performance and reliability requirements.
Example questions:
Q13.1 -Are performance and reliability requirements defined for all interfaces? *Q13.2 -Which reliability requirements are specified by the entity or entities that govern your business processes?* *Q13.3 -Do your interfaces meet the performance requirements for all interfaces?}*
Notes:
Examples: The maximum response time for a party to respond to a message request is stated. The expected response times to deliver a service request are stated. Verification of performance and reliability requirements are explained.

Criterion 14:
The interface definition specifies the handling of errors in exchanged data.
Applied to the ESI:
The ESI compliant standard or profile specifies error handling.
Implementation Assumptions:
Things break and interactions do not always work as anticipated.
Review Process:
Review standard for methods of error handling (detection, identification, and announcement)
Example questions:
Q14.1 -Do your interfaces have documented error handling expectations? *Q14.2 -Does your process for building and revising interfaces include a step for creating or revising the error handling management documentation?*
Notes:
For ESI, 12 and 14 are closely related Some of this is technical and might be standardized, but other parts might be platform and use case dependent and defined for an implementation or elsewhere.

Criterion 15:
Time order dependency and sequencing (synchronization) for interactions is specified.
Applied to the ESI:
Time order dependency and sequencing for interactions is specified in the ESI compliant standard or profile
Review Process:
Review standard for time order dependency and sequencing requirements.
Example questions:
Q15.1 -Do community members have business objectives that require common time order dependency and sequencing definitions? *Q15.2 -Do business processes and procedures specify time order dependency and sequencing mechanisms to be supported by the interface(s)?* *Q15.3 -Do the interface(s) between community members support these time order dependency and sequencing mechanisms?* *Q15.4 -Does the communication architecture separate network protocols from time order and sequencing information?*

Criterion 16:
The interface definition specifies the mechanism for message transaction and state management.
Applied to the ESI:
The mechanism for message transaction and state management is specified in the ESI compliant standard or profile.
Review Process:
Review standard for state and transaction management methods
Example questions:
Q16.1 -Are the transactions and state management specified?
Notes:
Most internet-based schemes use REST approaches for managing state, but other approaches exist.

3.3.6 Organizational

Criteria 17 and 18 represent the pragmatic aspects of interoperability. They explore the policy and business drivers for interactions. Interoperability is driven by the need for businesses (or business automation components) to share information and requires agreement on the business process integration that is expected to take place across an interface.

Criterion 17:
Compatible business processes and procedures shall exist across interface boundaries.
Applied to the ESI:
The ESI compliant standard or profile supports the business interactions required throughout the lifecycle phases.
Implementation Assumptions:
Business processes and procedures relevant to the energy service agreement should be harmonized between actors.
Review Process:
Evaluate standard for requirements that support business processes.
Example questions:
Q17.1 -Does your interface use an information model that includes the context of the transaction? *Q17.2 -Are the business context information model and processes fully supported by the interfaces?*
Notes:
ESI implementations may have different business interaction requirements.

Criterion 18:
Where an interface is used to conduct business within a jurisdiction or across different jurisdictions, it complies with all required technical, economic, and regulatory policies.
Applied to the ESI:
The ESI recognizes technical, economic, and regulatory policies exist in different jurisdictions and has methods or configurable features to support them.
Implementation Assumptions:
Policies for integration of DER Facilities with the electric system are defined by local (jurisdictional) policies.
Review Process:
Evaluate standard for its ability to support relevant jurisdictional technical, economic, and regulatory policies.
Example questions:
Q18.1 -Does your interface comply with all technical, economic, and regulatory policies?
Notes:
For example, CA Rule 21 sets policy for inverter interconnection in CA and must be complied with and supported by the ESI.

3.3.7 Informational

Criteria 19, 20, and 21 emphasize the semantic aspects of interoperability. They focus on what information is being exchanged and its meaning and they focus on both human and device recognizable information. At this level, it is important to describe how entities are related to each other, including relations to similar entities across domains and any constraints that may exist.

Criterion 19:
Information models relevant for data exchanged across the interface are formally defined using standard information modeling languages.
Applied to the ESI:
Information model for the ESI compliant standard or profile is formally defined using standard modeling languages.
Implementation Assumptions:
Standard supports the necessary points within its information model using tools such as UML, XML, JSON...
Review Process:
Evaluate the information model used by the standard and the modeling language it uses.
Example questions:
Q19.1 -Do you have exchanged data elements that are represented in information model(s)? *Q19.2 -Are the data model(s) for these elements formally defined using standard information languages?*
Notes:
Unstructured or specialized information modeling approaches reduce interoperability by making it difficult to use commonly available software tool to understand, use the information, and manage the model.

Criterion 20:
Data exchange relevant to the business context is derived from the information model.
Applied to the ESI:
The information model of the ESI compliant standard or profile supports the business interactions required throughout the lifecycle phases. (related to Criterion 17)
Implementation Assumptions:
19 addresses transactional requirements like prices and metrics.
Review Process:
Evaluate the information model used by the standard and determine that messages and business procedures use of information concepts and relationships are consistent with the model.
Example questions:
Q20.1 -Is the information exchange relevant to the business context for which it is used? *Q20.2 -Is the business context derived from information models?*
Notes:
The information model in a standard may support many types of services and interactions. For the ESI, the necessary information to support the defined business interaction must be a subset of the overall information model. For example, if the CIM is the information model, only a portion of it may be needed to support the business context.

Criterion 21:
Where the data exchanged derives from multiple information models, the capability to link data from different information models is supported
Applied to the ESI:
If multiple information models exist, there is a mapping between the information models used by the ESI compliant standard or profile
Implementation Assumptions:
The ESI may use an information model derived from 2 or more sources. For example, it may use parts IEEE 61968 CIM that refer to DER and perhaps an SAE information model for EV charging. The mapping to these source models should be preserved so that changes in information model standards can be assessed and revised as necessary.
Review Process:
Evaluate the sources for the ESI information model used by the standard (if they exist), and see that the ESI information model concepts are mapped to their source.
Example questions:
Q21.1 -Are there multiple information models across the interface? *Q21.2 -Is there a capability to support linking different information models?*
Notes:
ESI is not a translator and contains no intelligence The ability to upgrade and maintain the ESI standard as information models from related standards are revised should be supported. Semantic information modeling tools, based on standards, exist to facilitate this mapping (e.g., OWL)

3.3.8 Technical

Criteria 22 and 23 address the syntax, format, delivery, confirmation/validation, and integrity of the information. They focus on how information is represented within a message exchange and on the communications medium. They focus on the digital exchange of data between systems, encoding, protocols, and ensuring that each interacting party is aligned.

Criterion 22:
The structure, format, and management of the communication protocol for all information exchanged shall be specified.
Applied to the ESI:
The ESI compliant standard or profile defines the structure, format, and management of all information exchanged.
Implementation Assumptions:
Layered communication protocols (which apply supporting standards) are referenced as part of the standards under review
Review Process:
Review the standard for structure, format, and management specifications of the communications protocols used or supported.
Example questions:
Q22.1 -Do you have a policy for managing the selection and use of protocols for all exchanged information that ensures consistency of implementation?
Notes:
Examples of message structures are in standards like TCP/IP or IEC 61850.

Criterion 23:
The information exchanged and business process interactions at the interface are cleanly layered (described separately) from the technical (communication networking) layers in the interface specification.
Applied to the ESI:
The ESI compliant standard or profile separates the information model used in message exchange from the communications protocol that defines the format for packaging the messaging and handling the network connectivity.
Implementation Assumptions:
These are defined internally to the standards under review
Review Process:
Review that the standard clearly distinguishes the information model, associated with constructing messages, from the communications protocol (TCP/IP, etc.)
Example questions:
Q23.1 -Is the information transported on the communication network independent of the communication method? *Q23.2 -Is there agreement within the ecosystem about how semantic (governance) for interfaces is assigned?*
Notes:
Example: A problem with SEP1 was that it mixed the information model used by the messages with the communications protocol. That was a major fix in SEP2

3.3.9 Community

In addition, several criteria are focused more on the culture changes and collaboration activities that are required to help drive interoperability improvements and that reflect stakeholder maturity with respect to interoperability. These additional criteria reflect the participation of organizations in efforts to improve interoperability in general, not just specific interfaces. Note that in the initial stages of ESI development, a community will likely not exist, therefore other criteria are emphasized.

4 Results & Analysis

4.1 SME Engagement

The project team, in collaboration with external partners such as the SEPA ESI Task Force, has developed the set of work products, discussed previously, that will advance standardization of the ESI. These work products will be presented to standards SMEs in order to refine the requirements, estimate the level to which the existing standard or profile is ESI compliant, and preliminarily identify gaps within the standard or profile. Though the processes to evaluate the standard and develop the specification are similar, there will be refinement of the process at each step. The process discussed in this section is intended to prepare the team and socialize the concepts of the ESI to key SMEs who are active in working groups or SDOs for specific standards that address elements relevant to an ESI. This initial step of socialization will allow us to adapt our documents and methods for a more focused presentation and discussion to the potential SDO partners.

This document describes a series of interaction lifecycle phases that need consideration to achieve interoperability among grid entities and DER facilities. Initiatives that deploy ESI-related processes and technology to support this interaction need to specify and then design how they support the lifecycle of interactions. To the degree that aspects of the interactions can reference standards, the less custom design is needed, and more technology components can be made available by solution providers. This results in faster and more dependable deployments, as well as a more open marketplace for products that address components of the interface. Work products such as the lifecycle phases discussed in this paper will be presented first to SMEs for a cursory review of the standard, in this case expected to be IEEE Std 2030.5 and OpenADR.

The review of the standard or profile through the lens of the ESI specification includes a gap analysis by applying the IMM criteria interpretations, but they capture only the interoperability component. Once determining how the standard can meet the interoperability criteria to the level desired, the methods and information of the standard or profile that are used must not violate the ESI principles to be ESI compliant. This is essentially performed in the context of each lifecycle phase with the intention that if the criteria applies at any given point in the lifecycle, the method or information is needed for the ESI overall.

4.1.1 Portland State University Implementation Example

The PSU Power Engineering Team, as mentioned previously, has been engaged with the GMLC team to inform their own ESI based Distributed Energy Resource Management System (DERMS) platform. The team is applying the IEEE Std 2030.5 and demonstrating how the ESI principles can be applied. When reviewing the standard's commonly applied method and information model components, referred to as function sets, they found for example, that the methods applied in the CSIP identify the type of device providing the service [17]. Since the ESI principles include a device agnosticity requirement, they researched the standard further to find that the flow reservation function set will meet that requirement.

The PSU EGoT DERMS uses the IEEE Std 2030.5, Smart Energy Profile protocol as the primary information exchange mechanism between actors. This protocol has been identified as a viable candidate to support the ESI requirements for interoperability between aggregators and consumer-owned DER. The protocol includes capabilities for device discovery, resource identification, methods referred to as function sets, and subscription processes. IEEE Std 2030.5 also provides mechanisms for defining multiple security attributes in addition to its extensive library of resources and support services. IEEE Std 2030.5 is intended to enable information exchange between many types of energy-service devices including consumer appliances, energy management systems, metering devices, and storage systems.

IEEE 2030.5 uses a server/client model based on a REST architecture, which has a high maturity level for IMM Criterion 15 (time order dependency) and Criterion 16 (state management), wherein the server hosts resources and the client acts on those resources. In the EGoT implementation, the DER client initiates resource requests, including requests that allow the server to push resources to the client via pub/sub, which is particularly useful for fast-acting grid services.

IEEE Std 2030.5 is becoming a widely-adopted protocol for inverter-based systems and is the specified protocol in the CSIP. It is also specified as one of only three allowable inverter protocols for grid-interactive inverters by IEEE 1547-2018, with the others being SunSpec Modbus and DNP3 (IEEE 1815). Its adoption by these entities helps to ensure that IEEE Std 2030.5-compatible devices will become widespread in the EGoT ecosystem. This has implications toward the maturity of several IMM criteria including Criterion 19 (formally defined, standard information models).

In order to comply with the GMLC ESI principles, the PSU EGoT ESI requires, among other things, that the EGoT DERMS reduce complexity by limiting information exchange between the Grid Service Provider (GSP) (ie. aggregator) and Service Provisioning Customer (SPC)'s (ie. Facility Manager's) DER and obscure the SPC's management of its DER from external parties.

As previously mentioned, the PSU team identified that the function sets typically applied, such as Demand Response Load Control (DRLC), identify the type of resource being managed, such as an inverter. In order to meet the ESI principle for device agnosticity, the PSU EGoT DERMS uses flow reservation requests from DER to determine the available energy for participation.This flow reservation function set does not identify the resource and appears to be ESI compliant. The flow reservation function set uses DER client resource requests to temporarily allow the GSP server to schedule the DER client, which is particularly useful for dispatching DER and can be used to meet the Energy Schedule Service electrical and timing requirements.

By using flow reservation, the EGoT DERMS limits information exchange and obscures customer-side DER management better than using another resource such as DRLC. For example, DRLC has 34 potential elements, and the use of each increases customer exposure, complicates control, and imposes direct load control, all of which reduce the ability to meet the ESI principles and reduce the maturity according to the IMM. The performance-based services only require the requester to know that they can anticipate a certain reduction in load, and not that they are requesting a load reduction from a water heater. Additionally, a GSP does not need to know or have control of thermal cycle setpoints, which DRLC allows.

Flow reservation requires minimal information exchange, consisting only of power, energy, interval, and duration. The use of the resource can be obscured through the Facility Management Function, which chooses how it will meet the service requirement. The flow reservation interval also improves DER participation, in contrast to DRLC, which does not guarantee a reduction in load within the service period.

The PSU DERMS also includes the DER resources DERProgram, DERControl, DER-Curve, and DERCapability, which are the primary resources to achieve frequency response and voltage services. The DER client uses the DERCapability resource to inform the EGoT server of the DER Facility nameplate ratings to allow the server to capture the combined capabilities when bidding within a frequency response or voltage management service. While these DER resources expose significantly more information about the DER and DER Facility location, these are necessary to provide these frequency and voltage management services within the balancing area.

As discussed, this PSU implementation work has already provided several insights into the inner workings of the candidate ESI standard, and has introduced the GMLC Team to several topics for discussion when engaging SMEs. It is expected that the PSU work will continue to inform the specification, and likely a future IEEE Std 2030.5 Project

Authorization Request (PAR) or even an implementation profile, which that team has already been drafting for their EGoT project.

4.1.2 The Road Ahead

These are the types of preliminary discussions that this author and his team expect to have with the SMEs to provide the GMLC team with an understanding of the gaps that may exist and help to prioritize areas for work in existing standards. This insight will be presented in a more formal setting to the SDO that oversee those standards or profiles. In some cases these efforts fall into the roles of alliances or industry consortiums. The next objective to engage with SDO ecosystem stakeholders can then begin with one or more of these organizations and a tailored description of the gaps appropriate to pursue can be developed with that group.

5 Conclusion

5.1 Contribution to Future Work

Though the goal of the project is to develop an ESI Specification, this will likely be only the first of several iterations as the ESI evolves over time based on various stakeholder engagements. Once SMEs have provided their input, the next task is to bring the draft specification to a group with the capability to bring an ecosystem of stakeholders together to work through the criteria review process similarly to how the SMEs are being engaged.

ICT standards evolve in at least two dimensions. First, layered standards separate the communications networking aspects that support message exchange, from the information content in the messages, and the business process and regulatory guidelines that provide context and rules of engagement. Second, the scope of a standard describes the extent of the business use cases that a standard is designed to address. In the case of the ESI, multiple standards may cover portions of the layered dimension, while some standards target business scope areas such as seen in the lifecycle phases. Parts of a deployment that supports the ESI concept are likely covered by several standards for the various dimensions of the greater interface. With this in mind, the tasks discussed in this paper will lead to further SDO engagements.

To move the ESI concept to practical implementation, the standards efforts will need to include engagement with organizations such as NAESB to formalize common grid-DER service definitions. This will provide both credibility and formality to the GMLC projects efforts to that end. This effort is already in progress with a subcontract issued for support from an industry expert familiar with the processes of that organization

The SME engagement activities are to inform the next process of engagement with SDOs. This is anticipated to be through an alliance such as the IEEE Std 2030.5 Ecosystem Steering Committee (ESC) which in an Industry Connections Activity Initiation Document (ICAID) effort started for the IMM roadmap effort mentioned previously. This group has a diverse membership from utility stakeholders, ICT implementers, integrators, and many members of the standards body working group. The team is also engaging with OpenADR, and recently fellow members of SEPA working on the Common Transactive Services (CTS) profile being developed. This CTS work has been informed by the ESI work and the working group members are very eager to evaluate their work through the tools discussed in this paper.

Other future efforts could include the multiple standards that are required to support the lifecycle phases. These could include measurement standards or orders often found in regulatory documents such as those by FERC or North American Electric Reliability Corporation (NERC). In that same fashion, work could easily be extended to cover standards for different mechanisms deployed for the various phases. Perhaps registration occurs via a web portal or measurement via Advanced Metering Infrastructure (AMI). In order to meet ESI requirements, any component involved in the overall ESI interaction cycle should be demonstrated to be ESI compliant.

PSU has been a leading implementer of the ESI concept and as such has been applying the concept to their innovative approaches to privacy and security [25, 26]. Figure 5.1 shows how the various paths of their platform communication has to meet the requirements of the ESI. The DTM, which is not actively involved in communication objectives or capabilities, still must have the “rules” applied to the interaction process [27]. This is also true for metering or third party interactions, such as those with aggregators, which may vary from the power system operator or interconnection communications.

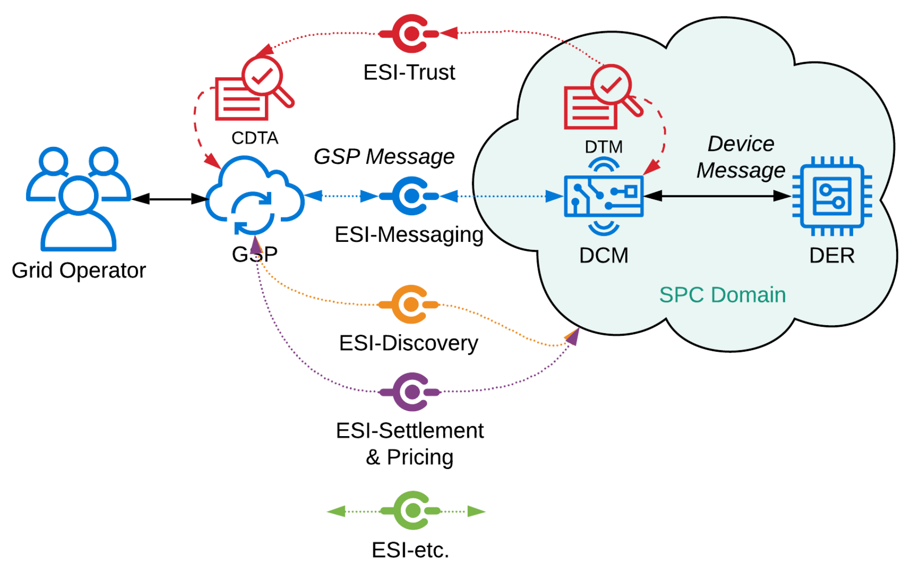

Figure 5.1: Portland State University Platform Communication Diagram

5.2 Transferring the Work

Ultimately, adoption of the ESI is dependant on a vibrant stakeholder ecosystem. The specification document will be distributed as an initial version and socialized with anticipation of stakeholder groups such as the IEEE Std 2030.5 ESC or an alliance such as the OpenADR

Alliance. The ESI profile would then be further developed in a formal working group and perhaps demonstrated. The next step will be for those champion entities to initiate a PAR, which is the means by which IEEE standards projects are started.

Standards working groups are one outlet to promote adoption of the ESI. Another is through regulatory bodies, as with the CSIP through interconnection requirements in California Rule 21 [28]. The CSIP activities were supported by stakeholders in California, under direction of the California Public Utility Commission. This profile is now the mandatory means by which interconnection of inverters to the electric grid is implemented. The CSIP is now managed by the SunSpec Alliance, who also lead the IEEE 2030.5 ESC. This experience should be invaluable as the ESI specification development moves into profile development.

The overall process to develop an implementation profile is quite lengthy and may take many years. The ESI specification itself has already been under development for two years and based on a concept that dates back at least ten years. Standards typically have a three to five year development process and if a new standard is needed, could take longer. That said, this document provides an overview of the specification development process, just one step in a process to develop a scalable, device-agnostic, service-oriented interface; the ESI.

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