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Energy Services Interface: Requirements Document

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Energy Services Interface

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Abstract

This energy services interface (ESI) requirements document represents a process step in the path for creating an ESI specification, which will describe the technical characteristics of an ESI. This document outlines the concepts that need to be covered in the ESI specification, such as principal functions of the ESI, grid services communicated through the ESI, and the ESI lifecycle. It provides context for the Department of Energy's (DOE's) Grid Modernization Laboratory Consortium (GMLC) to engage industry participants in the development of the ESI specification. To do this, it describes the desired contents of the ESI specification and provides examples of the type of material that needs to be included in it.

The purpose of the ESI specification is to define the requirements that are to be addressed in information and communications technology (ICT) interface standards for enabling the integration of a facility containing responsive distributed energy resources (DER facility) to an electric system consistent with the fundamental ESI principles. In this context, a DER facility may consist of a single DER with a communicating controller or may be as complex as a microgrid campus with several buildings and many DERs. The ESI specification is not a technical interface standard, but 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, which is explained further in this document. In this way, the ESI specification can be used to guide standards advancement work in multiple standards development organizations.

To explain the scope of the ESI specification, this ESI requirements document provides examples of situations (or illustrative applications) for using an ESI to coordinate DER flexibility for grid operations. These examples originate from foundational work for describing common grid-DER service agreements that are anticipated to be supported using this interface.

Acknowledgments

This research was supported by the Grid Modernization Initiative of the U.S. Department of Energy (DOE) as part of its Grid Modernization Laboratory 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. The authors acknowledge the help and guidance received from the DOE manager, Christopher Irwin, in developing the plan for this document and encouraging outreach to relevant stakeholders. Thanks also go to members of the Smart Electric Power Alliance Task Force on ESI for their review and input.

Acronyms and Abbreviations

The following terms are described for their use in this requirements document.

coordination framework	Concepts, principles, and structure applied to the way components of an integrated system coordinate their operation to achieve individual and systemic goals.
DER	Distributed energy resources (DER) include responsive generation, storage, or load connected at the distribution system level. Responsive means that the operation of the assets can be managed to provide one or more grid-DER service.
DER facility	A site that includes one or more DER and has a single point of connection with the electric distribution system.
DER interconnection agreement	A legal contract between the electric utility and customer establishing all terms and conditions associated with operating DER in parallel with the utility's electric power system.[1]
ESI	An energy services interface (ESI) is 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.[2]
facility management function	Manages the operation of the electrical devices and systems at a customer site (a facility). In the ESI concept, this function interacts with outside parties through the ESI.
grid architecture	The application of system architecture, network theory, and control theory to the electric power grid. A grid architecture is the highest-level description of the complete grid. It is a key tool to help understand and define the many complex interactions that exist in present and future grids.
grid-DER service	A service provided between a DER Facility and an external interacting party (usually a grid entity) as coordinated by ESI interactions. The service definition describes what is expected to be provided but does not specify how it is accomplished or how it will be used. Managing the quantity of energy consumption over a period is an example of a grid-DER service.
grid-DER service agreement	Specifies what a service provider will accomplish for a service requester, how it will be measured, and any compensation (monetary or otherwise) from the service requester for performing that service.
grid-side entity	An external interacting party that interacts with a DER facility using the ESI.
layered decomposition	Hierarchical disaggregation of 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.

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[1] Augmented from "An Introduction to Interconnection Policy in the United States," NARUC, accessed June 2021 at https://pubs.naruc.org/pub.cfm?id=5375FAA8-2354-D714-51DB-01C5769A4007

[2] "Interoperability Strategic Vision, a GMLC White Paper," PNNL-27320, March 2018, accessed February 2022 at, https://gmlc.doe.gov/sites/default/files/resources/InteropStrategicVisionPaper2018-03-29.pdf

service-oriented	A style of a software interface where services are provided to other system components (service requesters) by service provider components, through a network communication protocol. Its principles are independent of vendors and other technologies.

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1.0 Purpose and Context

This document was prepared by the Department of Energy's (DOE's) Grid Modernization Laboratory Consortium (GMLC) as part of a project to advance the development of Information and Communication Technology (ICT) standards that support the Energy Services Interface (ESI) concept. A companion document describes the use cases (operational scenarios) for coordinating DER flexibility for power system operations. This ESI requirements document describes the nature and purpose of an ESI specification and the types of things that such a specification needs to address, such as principal functions of the ESI, grid services communicated through the ESI, and the ESI lifecycle. This requirements document is intended to inform work with industry participants in developing an ESI specification.

The ESI Concept

An electricity customer site that includes distributed energy resources (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.

An Energy Services 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] A graphic representation of this ESI concept is shown in Figure 1.

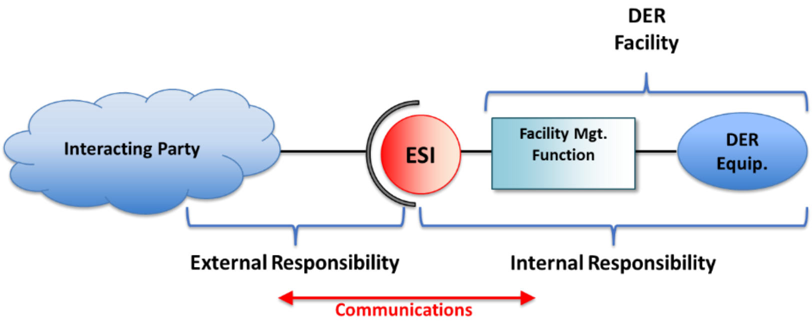

Figure 1. The ESI and adjacent entities[2]

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.

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

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[3] "Interoperability Strategy Vision – A GMLC Whitepaper," March 2018, PNNL-27320, accessed June 2021, https://gmlc.doe.gov/sites/default/files/resources/InteropStrategicVisionPaper2018-03-29.pdf

how the DER facility manages its DER equipment if the requested service satisfies the terms of the agreement.

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.

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 electrical 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.

This approach has advantages, in that the ESI:

- Makes for a simpler interface specification, with fewer rules and information needed to be agreed to or exchanged. Test procedures are simpler and integration effort is reduced.
- Supports adaptation to new DER technology or advances in existing technology.
- Avoids specialized interfaces based on DER technology type, by defining the service provided as a generalized type of electrical grid-DER service.
- 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.

ESI Specification Description

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 requirements 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. (Note, a facility may be as simple as a single DER with a communicating controller or as complex as a microgrid campus with several buildings and many DERs.) The ESI requirements specification is not a technical interface standard, but 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. Ultimately, it is possible that implements of the ESI that adhere to these principles could be certified as ESI-compliant.

The ESI requirements 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[4]. To address all the requirements, a set or profile of multiple technical standards are anticipated.

The ESI requirements specification references the common grid-DER service agreements that are anticipated to be supported using this interface.

Lastly, the ESI requirements 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 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 Requirements Document

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 team to engage industry partners by describing the nature and purpose of an ESI specification and proposing the types of concepts it should cover in order to be useful for reviewing ICT communication standards and implementation profiles for ESI compliance. In this context, the ESI requirements document outlines the contents expected in the ESI specification. Illustrations of real-world examples are included to help clarify the ideas.

2.0 ESI 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 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 below in Section 3.

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[4] Gridwise Architecture Council, Interoperability Context-Setting Framework, accessed June 2021, https://www.gridwiseac.org/pdfs/interopframework_v1_1.pdf

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 DERs without impacting the communication interactions of the ESI. That is, the ESI service agreement is agnostic to the types or assortment of DERs that perform the service.
4. The ESI 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 to the service agreement. The point of electrical connection is important for coordinating the physical delivery aspects by the external party.

3.0 Driving Business Requirements

The GMLC has also defined a set of Common Grid Services, which are distinct categories of services with clear performance expectations and characteristics.[5] 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. 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 are determined by the service requester's business requirements, which reflect the operational objectives.

3.1 Common Grid-DER Services

The list of common grid-DER services and their descriptions is as follows

- **Energy service:** A scheduled production or consumption of energy at an electrical location over a committed period.

- **Reserve service:** Reserves a specified capacity to produce or consume energy at an electrical location when called upon over a committed period.

- **Regulation service:** Continuously provides an increase or decrease in real power from an electrical location over a specified scheduled period against a predefined real-power basepoint following a service requestor's signal. The signal interval is typically one to several seconds, and the associated performance period is significantly shorter than the typical energy service performance period.

- **Frequency response service:** Responds to a change in system frequency nearly instantaneously by consuming or producing power over a committed period.

- **Voltage management service:** Provides voltage support (raising or lowering) within a specified upper and lower voltage range at an electrical location over a committed period.

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[5] Jaime Kolln, Steve Widergren, Jingjing Liu, and Rich Brown. "Common Grid Services: Terms and Definitions Report," July 2023, PNNL-34483. https://www.osti.gov/servlets/purl/1992370.

- **Blackstart service:** Energize or remain available without grid electrical supply to energize part of the electric system over a committed period.

The “Energy Service” has been identified as a priority grid-DER service because examples of its possible application are common today. We use it as an example to illustrate the performance characteristics and related functional elements included in a grid-DER service. Under the Energy 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 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 in an Energy Service agreement.

- 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).
- other possible factors such as performance constraints that dictate the minimum or maximum power production or consumption limits during the period of operation, as well as how violations of the constraints would be determined and reconciled.

Under the Energy 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 Examples of Energy Service

In Table 1 below, we use two examples to illustrate how the operational objectives and service requirements can be supported by the above service characteristics proposed under Energy Service.

In Example 1, a distribution utility (service requester) organizes a bidding program for load and energy storage resources to respond to load curtailment events called for the next day. If a system peak load condition is predicted for the next day, then the utility would announce the curtailment event by noon on the day before the event. Upon receiving the day-ahead notice, the customers (service providers) will need to submit their net load reduction bids no later than 3 pm to participate in the next-day event. They will receive the utility’s acceptance of their bids by 4 pm, which ensures compensation for their load reduction on the next day.

This example involves 2-way communication between the utility and the customer. The customer will be compensated for each kWh of net load reduction during the event time window (e.g., 2-6 pm) that they actually delivered compared to a counterfactual baseline using the utility defined method. In addition, the actual load reduction during the event must be no less than a certain threshold value to qualify for compensation. The customer may choose to shed load or shift load away from the event period to a different time of the day or to a different day. However, such load shifting information is not captured by the utility in this program design scenario. The program requires a meter at the customer premises that can accumulate energy use in time periods that support the program's scheduling windows.

In Example 2, a distribution utility may offer customers a dynamic pricing program as an option in order to manage peak load periods in the bulk power system or locally. The installation of interval meters is a requirement for enrolling in a dynamic pricing tariff. There is no need for the customer to send any additional information back to the utility beyond the energy consumption profile measured by the interval meter. Therefore, it is a 1-way communication scenario.

The dynamic pricing retail tariff can be used for different grid operational objectives such as peak load management and load shifting and load shaping depending on the hourly price design details. In this example, the dynamic pricing program's prices are significantly higher during 2-6 pm to encourage load shedding or shifting away from this period.

These examples show how different coordination methods can be used to achieve similar operational objectives. The load management action (shedding or shifting) on the customer end is similar in these two examples.

Table 1. Energy Schedule Service in Two Retail Service Examples

	Example 1: Event-based peak load management	**Example 2: Dynamic Pricing**
Operational objective	peak load management	peak load management
Communication type	2-way	1-way
Nature of time periods of operation	scheduled for discrete periods	daily price schedule announcements
Scheduled time period of operation	next day during 2-6pm	next day 24 hours, each hour is its own period of operation
Amount of energy production or consumption during the scheduled period	reduce demand by 50 kWh each hour during 2-6pm next day	implied customer energy usage change from the service requester. Customers in aggregate are expected to reduce load from normal in high-price periods and increase load from normal in low-price periods.
Measurement & Verification method	electricity meter at the point of connection to the utility able to	electricity meter able to accumulate interval energy use to support periods of

	accumulate interval energy use to support periods of performance, and counterfactual baseline (e.g., using a “10-in-10 with adjustment” method[1] for tariff or incentive calculation)	performance for bill calculation
Calculation of compensation	$0.50/kWh x (baseline kWh - actual kWh) during 2-6 pm	accumulation of dynamic price times energy consumed in each respective hour. Compensated for using less energy during peak pricing periods.
When the scheduling needs to be established	utility notifies customer of next-day event by noon customer submits bid by 3 pm utility notify acceptance of customer’s bid by 4 pm	utility publishes hourly prices for the next day by noon

Note 1: create a baseline using the average usage from the previous ten qualifying days, with the customer having the option to include a day-of adjustment based on their usage during pre-event hours.

4.0 Lifecycle of Interaction Use Cases for Grid-DER Service Agreements

The ESI specification will provide examples of the types of interactions and information exchange 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. These interactions may be realized by designing multiple 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:

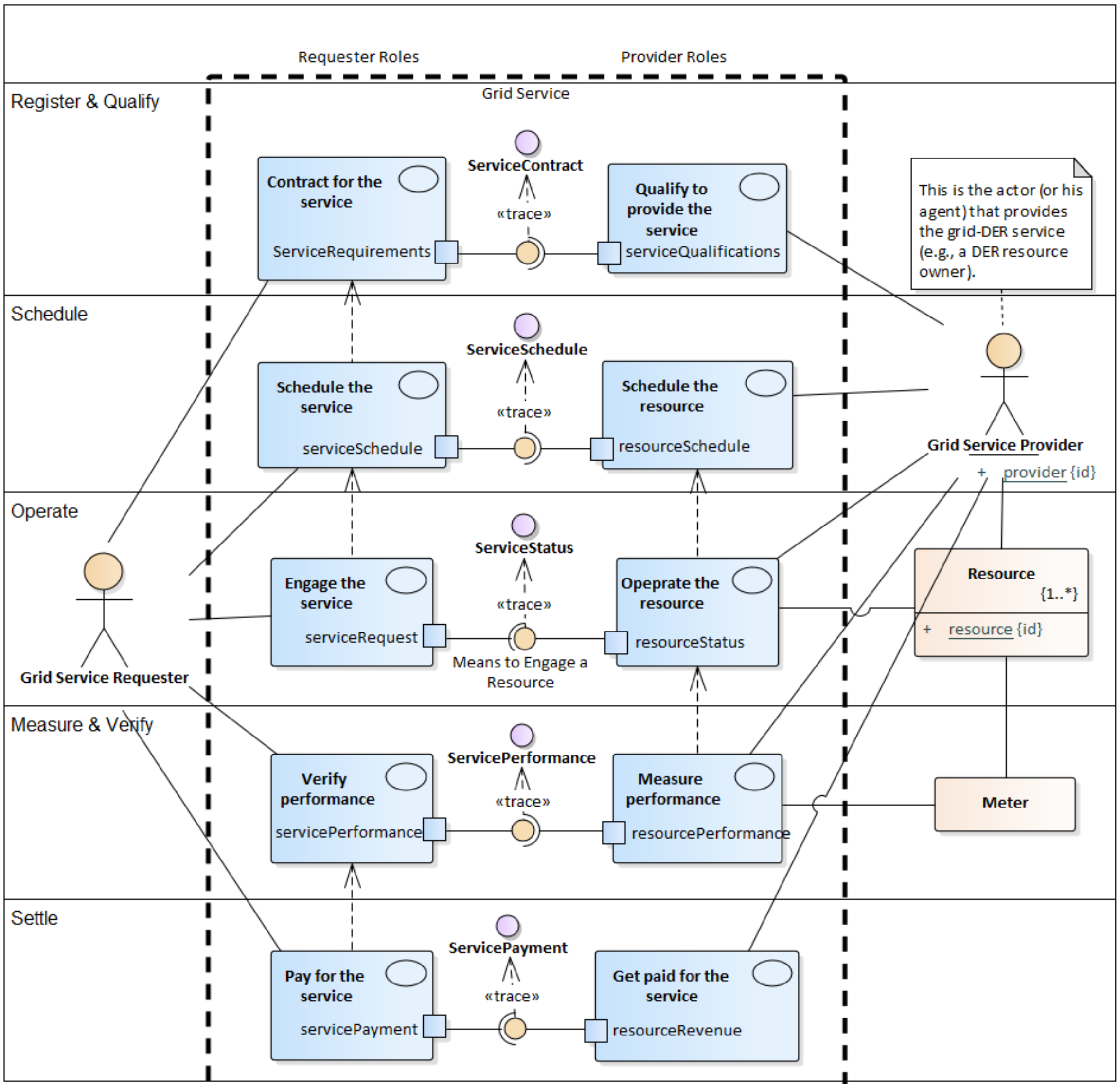

Figure 2. General ESI Lifecycle Use Case Diagram

Lifecycle Phases

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. **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.

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, as well as feedback of telemetry data from a previous Measure and Verify cycle, in order to guide the operation of the service. The agreement may or may not require ongoing communication between interacting parties during this phase.

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.

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.

The lifecycle phases aim to cover the full interaction experience of the DER Facility with one or more external parties. To address this broad scope, an ESI agreement will likely need to reference multiple technical standards, appropriate profiles of those standards, as well as specific business and regulatory policy requirements. To the extent that the aspects of these agreements can be codified in broadly accepted terms and conditions, interoperability will be easier to achieve, and adoption speed enhanced.

Interface standards today tend to focus on the Schedule and Operate Phases. Register & Qualify, Measure & Verify, and Settle Phases are seen as more specialized to each deployment. Restricting the scope of a standards effort to such phases is wise for the ability to achieve practical results in a timely manner. Nevertheless, the types of information covered by an ESI specification should apply to all the phases to achieve interoperability, recognizing that agreements in one phase may become assumed requirements in another.

Segmentation of scope for assessing existing standards and planning new standards efforts is an important area not covered in this document but will be valuable to pursue with the standards and industry groups that make up the ESI integration ecosystem.

4.1 An Illustrative Example

As an illustration of lifecycle phase interactions, one possible series of interactions relating to Example #1 is described in the following section. 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. This registration phase would also associate any unique IDs and other information necessary for communications in later phases. In Example #1 discussed in Section 3, 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 the 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.

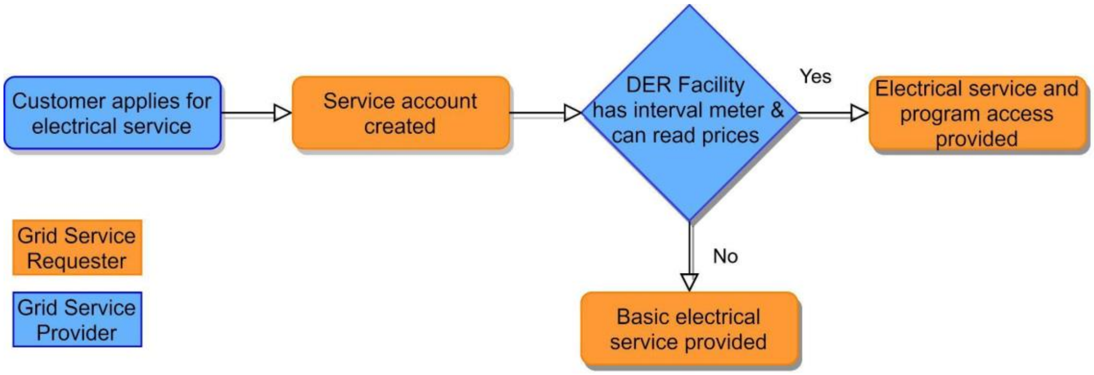

Figure 3. Example of the Registration Phase

In Example #1, the scheduling phase 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 2PM until 6PM 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 50kWh 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 3PM. 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.

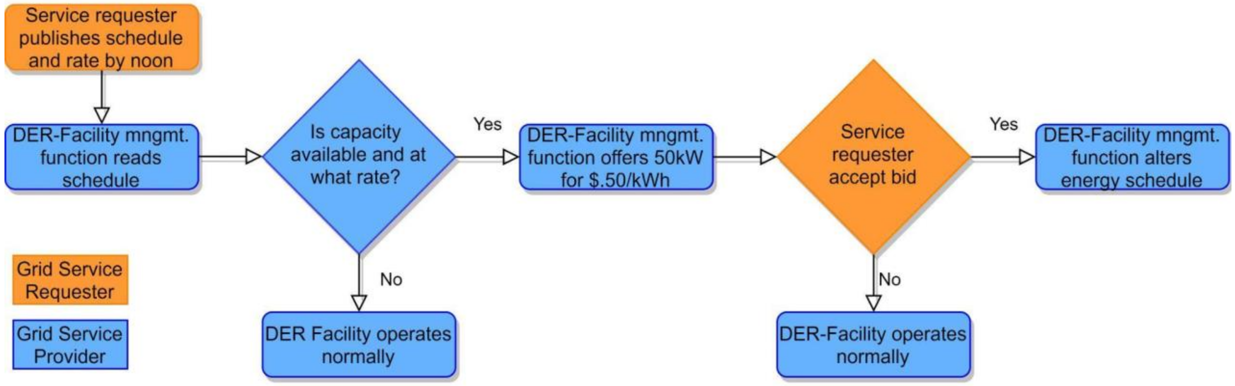

Figure 4. Example of the Schedule Phase

At 2PM 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 5. Example of the Operate Phase

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. 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.

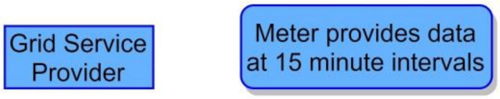

Figure 6. Example of the Measure and Verify Phase

In the fifth phase, 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.

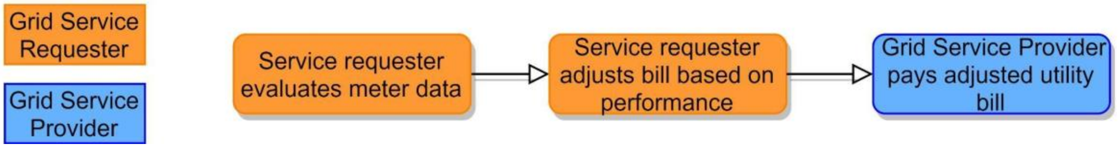

Figure 7. Example of the Settle Phase

5.0 Interoperability Criteria Requirements

The interoperability maturity model (IMM)[6] is a tool that was developed to measure the effectiveness of methods for integrating the information and communications technology aspects of intelligent devices and systems to coordinate their operation with the rest of the electric power system. Under this task, the project team used the IMM to develop interoperability requirements criteria for an ESI specification. Application of the IMM tool identifies gaps between current and desired levels of interoperability. The full IMM contains 33 interoperability criteria, which are grouped into 6 categories:

Configuration & Evolution: These criteria 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.

Security & Safety: These criteria are concerned with aligning security policies and maintaining a balance of the tension 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.

Operation & Performance: These criteria 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.

Organizational: These criteria represent the pragmatic aspects of interoperability. They represent 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.

Informational: These criteria 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.

Technical: These criteria 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.

In addition, several criteria identified 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. Instead of creating an additional category

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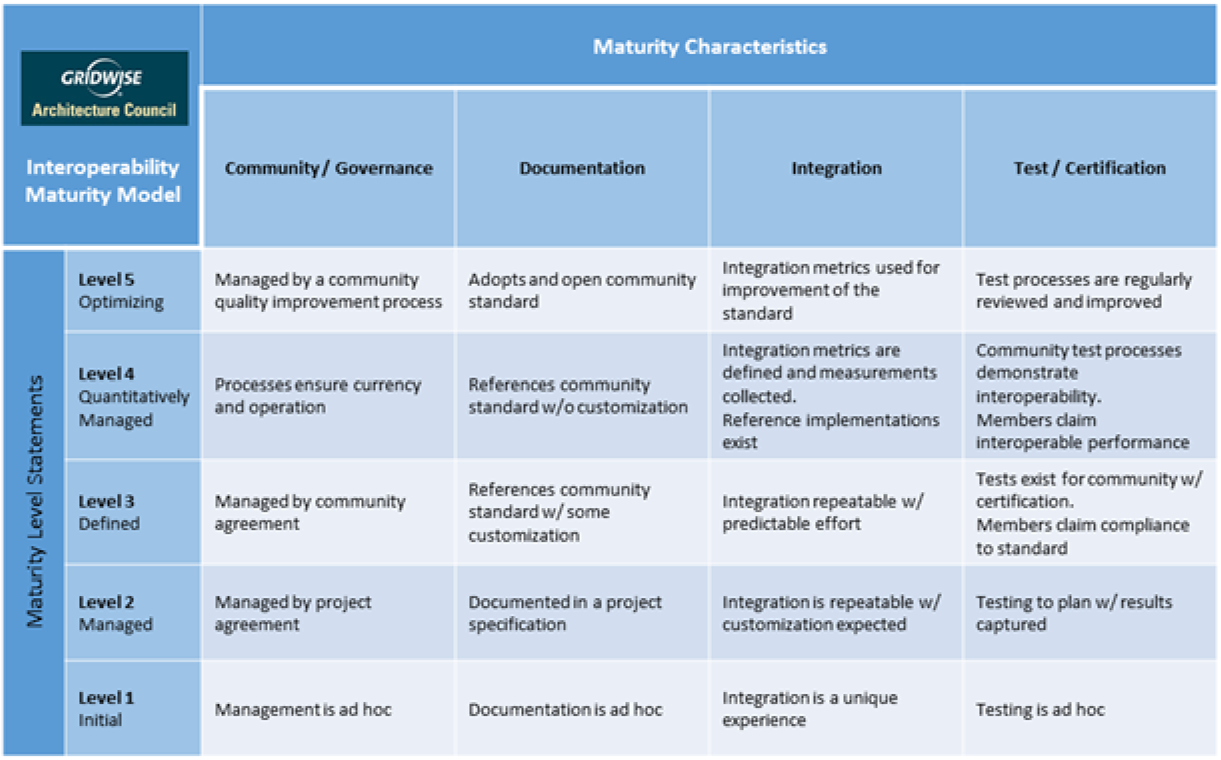
[6] "Interoperability Maturity Model – A Qualitative and Quantitative Approach for Measuring Interoperability," January 2020, PNNL-29683, accessed June 2021, https://gmlc.doe.gov/sites/default/files/resources/InteropIMMToolv1Final.pdf

for these "community criteria" each community criterion was categorized as belonging to one or more of the other six categories. Thus, when using the IMM a number of the criteria used for measuring interoperability maturity would come from those community requirements in so far as they were relevant to the selected categories. Note that in the initial stages of ESI development, a community will likely not exist, therefore other criteria are emphasized.

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.

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)[7]. 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 Table 2.[8]

Table 2. Interoperability Maturity Levels



GridWise Architecture Council Interoperability Maturity Model		Maturity Characteristics			
		Community / Governance	Documentation	Integration	Test / Certification
Maturity Level Statements	**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

By looking at each level of maturity for each category the evaluation team can make an informed decision about which categories are of most interest for interoperability improvement. Within the categories there are the individual criteria, each of which also has five levels of descriptions that can be used to assess interoperability maturity on a more specific basis.

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[7] The CMMI Institute. 2010. Capability Maturity Model Integration. Accessed June 2021 at, http://cmmiinstitute.com/

[8] GWAC (GridWise® Architecture Council). 2011. Smart Grid Interoperability Maturity Model, Beta Version. Accessed June 2021 at, http://www.gridwiseac.org/about/imm.aspx

The IMM thus cannot only help identify important aspects of interoperability but can also be used to identify gaps between current and desired maturity.

The Interoperability Maturity Criteria are reproduced in Appendix A. These statements are to be reviewed for contributing to the requirements that ESI standards should include to address interoperability concerns. The following is an example of the proposed process for developing requirements that would be included in a specification.

As noted above, the ESI interaction lifecycle has several phases. These are summarized in Figure 8.

Figure 8.ESI transaction lifecycle phases

The dimensions of interoperability to be covered by the ESI requirement specification are informed by the IMM.

IMM criteria can be applied at every phase of the ESI interactions shown in Figure 8. For example, during the registration and qualification phase, IMM Criterion 8 applies:

> ***IMM Criterion 8:*** *Resource discovery methods for assisting with identification and integration between actors are supported (such as access to information like owner, DER type, location, etc.). In addition, service requesters may provide resource discovery methods for service providers to find available grid-DER service programs and the terms of their agreements.*

During the schedule phase, IMM Criterion 7 applies:

> ***IMM Criterion 7:*** *Unambiguous resource identification and its management are described.*

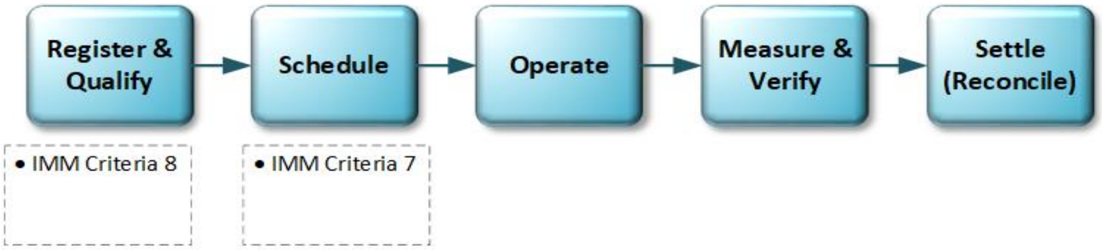

Figure 9. Example of IMM criteria applied to ESI transaction phases

After determining the relevant IMM criteria, requirements must be developed. This is illustrated in the following example.

Consider the illustration in Figure 10 which shows a transaction between actors. Although the grid-DER service transaction is between the service provider and the service requester, since DERs are by definition connected to the distribution system, the local EPS operator is a required actor, especially in the initial setup of the DER.

In our example, a request will be made for energy scheduling. Note that an ESI could already have been utilized for transactions prior to the grid service request. For example, during the DER registration and qualification step. Note also that the grid service request function could originate from any actor, including an electric utility, aggregator, and so forth.

Figure 10. Example ESI transaction between the relevant functions

Note that both nodes are abstracted as functions inherent to a specific actor in the transaction. This allows each actor to manage local facility tasks as desired. For example, the DER facility management function is a feature of the DER facility that engages in an ESI transaction. The DER facility management function exposes only the information needed for the transaction at the ESI. Other functions such as housekeeping and managing individual DERs at the facility are managed separately.

The result of applying IMM criteria to the lifecycle phases is intended to answer the question: What are the requirements for each criterion? An example of applying Criterion 8 is illustrated in Table 3.[9]

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[9] Note: this feeds IMM Criterion 7 as well.

Table 3. Example application of IMM Criteria during registration phase

ESI Interaction Phase	**Register & Qualify**
IMM Criterion 8	Resource discovery methods for assisting with identification and integration between actors are supported (such as access to information like owner, DER type, location, etc.).
Interpretation	This is interpreted as an accessible list of DER facility performance requirements that is supported by the service requester. The list can be accessed by a potential service provider with knowledge of the discovery service.
Assumptions	● DER Facility Management Function Exists that manages individual DERs at the facility. ● DER Interconnection agreement in place if required (e.g., between DER owner and local utility, including associations such as physical location) ● 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)
Out of Scope	1. DER Facility internal DER management Functions 2. Grid-DER Service Entity back-office functions
Requirements	1. Listing of information needed to provide grid service a. Tariff or program b. Performance characteristics i. Energy requirements ii. Energy qualifications iii. Energy service terms c. DER Facility ID d. Service provider ID e. Contract ID f. Contract start g. Contract end
	2. TBD (if applicable)

During the next step of the transaction, scheduling, IMM Criterion 7 applies (see Table 4).

Table 4. Example application of IMM Criteria during scheduling phase

ESI Interaction Phase	**Schedule**
IMM Criterion 7	Unambiguous resource identification and its management are described.
Interpretation	Requirements must address unambiguous resource identification.
Assumptions	1. Service Provider has a DER Facility Management Function that manages individual DERs at the facility. 2. The grid-DER service requester has a "back office" method to create and relate the various unique IDs to the service provider's DER facility. This can include items such as locational identification and customer identification. 3. A shared list of DER facility performance requirements exists and can be accessed by the potential service provider and managed by the grid service requester. 4. Method to relate the service provider Unique ID to contract/Agreement ID
Out of Scope	1. DER Facility internal DER management Functions 2. DER-Grid Service Entity back-office functions
Requirements	1. Unique IDs for the DER Facility and service provider (customer) 2. Location of the DER Facility on the distribution feeder. 3. Communicate a list of DER facility performance characteristics. 4. An agreement or contract ID

Using this methodology, IMM criteria can be used to assess and develop requirements for the ESI associated with the various lifecycle phases. Results will be used to identify gaps in specific communications standards that are commonly used in energy exchange transactions and provide recommendations to standards development organizations (SDOs) for increasing maturity and support for ESI.

6.0 Requirements for Standards Development Organization Engagement

This document describes a series of interaction lifecycle phases that need consideration to achieve interoperability among grid-side 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.

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, standards 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 supported by several standards that cover various dimensions of the greater interface.

By reviewing the ESI specification, gaps not addressed by existing standards are expected to be revealed. Articulating the gaps and prioritizing areas for work in existing standards should identify the standards development organizations that oversee those standards. Engagement can then begin with one or more of these organizations and a tailored description of the gaps appropriate to pursue with that group.

Appendix A

List of IMM Criteria
From the Interoperability Maturity Model[10]

(Community Criteria omitted)

Ref	Statement	Category
01	The ability of the interface to accommodate the integration with legacy components and systems is described along with an upgrade migration path.	Configuration & Evolution
02	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).	Configuration & Evolution
03	The way regional and jurisdictional differences are supported is described.	Configuration & Evolution
04	Configuration methods to negotiate options or modes of operation including the support for user overrides are described.	Configuration & Evolution
05	The capability to scale the integration of many components or systems over time without disrupting overall system operation is supported.	Configuration & Evolution
06	The ability of overall system operation and the quality of service to continue without disruption as interfacing actors (distributed energy resources [DERs], utilities, aggregators) enter or leave the system is supported.	Configuration & Evolution
07	Unambiguous resource identification and its management are described.	Configuration & Evolution
08	Resource discovery methods for assisting with identification and integration between actors (such as access to information like owner, DER type, location, etc.) are supported.	Configuration & Evolution
09	The requirements and mechanisms for auditing and logging the exchange of information is described.	Safety & Security
10	Privacy policies are defined, maintained, and aligned among the parties of interoperating systems.	Safety & Security
11	Security policies are defined, maintained, and aligned among the parties of the interoperating systems.	Safety & Security
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.	Safety & Security
13	Performance and reliability requirements are defined.	Operation & Performance

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[10] "Interoperability Maturity Model – A Qualitative and Quantitative Approach for Measuring Interoperability," January 2020, PNNL-29683, accessed June 2021, https://gmlc.doe.gov/sites/default/files/resources/InteropIMMToolv1Final.pdf

14	The interface definition specifies the handling of errors in exchanged data.	Operation & Performance
15	Time order dependency and sequencing (synchronization) for interactions are specified.	Operation & Performance
16	The interface definition specifies the mechanism for message transaction and state management.	Operation & Performance
17	Compatible business processes and procedures exist across interface boundaries.	Organizational
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.	Organizational
19	Information models relevant for data exchanged across the interface are formally defined using standard information modeling languages.	Informational
20	Data exchange relevant to the business context is derived from the information model.	Informational
21	Where the data exchanged derive from multiple information models, the capability to link data from the different information models is supported.	Informational
22	The structure, format, and management of the communication protocol for all information exchanged are specified.	Technical
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.	Technical

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