Common Grid Services

Terms and Definitions Whitepaper

Public Review Draft – Do not cite or quote

**July 2022**

**Authors**

Jingjing Liu Steve Widergren

Jaime Kolln Rich Brown

Disclaimer:

This document was prepared as an account of work sponsored by the United States Government.

While this document is believed to contain correct information, neither the United States

Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

**Common Grid Services:**

**Terms and Definitions**

GMLC 2.5.2 project whitepaper

Jaime Kolln[[1]](#footnote-2) Jingjing Liu[[2]](#footnote-3)

Rich Brown2 Steve Widergren1

July 2022

**Public Review Draft – Do not cite or quote**

**Abstract**

This document is prepared as part of the Department of Energy’s Grid Modernization Laboratory Consortium (GMLC) 2.5.2 project, whose goal is to develop and socialize a common set of grid service definitions relevant to grid-related interactions with distributed energy resources (DER: responsive generation, storage, and loads), and to advance the concept and requirements of the Energy Services Interface (ESI) to the point of launching related interface standards and guides that can be implemented in communication protocols and business process definitions. The notion of “grid services” is integral to the definition of an ESI because a key principle of the ESI is that it permits coordination between grid operators and DER facilities in a way that is service-oriented, with an understanding of performance expectations.

The project investigated the current state of North American grid service definitions from various market operators and utilities, as well as FERC and NERC, actively used today (Brown 2022). This document builds on that work to propose terms and definitions for a set of grid service types that address operational objectives commonly found in power system operations. These grid service types derive from existing grid services used in bulk electric market operations recognizing that each operational authority uses somewhat different names with variations on service performance parameters. Finding commonality at the wholesale or bulk system operation level will hopefully engender progress in seeking agreement of grid services for DER engagement at the distribution level in the emerging retail marketplace.

This version of the document focuses on the energy schedule service and the reserve service with examples though proposals for the other types of services are included.

**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.

**Glossary**

TBD…

**Contents**

[1 The Need for Common Grid Service Definitions 2](#_Toc109742040)

[1.1 Smart Grid Considerations 2](#_Toc109742041)

[1.2 Jurisdictional Considerations 3](#_Toc109742042)

[2 Categorization of Grid Services 4](#_Toc109742043)

[2.1 Grid Service Identification 4](#_Toc109742044)

[2.2 Performance Attributes 5](#_Toc109742045)

[2.2.1 Electrical Attributes 5](#_Toc109742046)

[2.2.2 Timing Attributes 6](#_Toc109742047)

[2.2.3 Additional Information 6](#_Toc109742048)

[2.3 Grid Service Definitions 6](#_Toc109742049)

[3 Distribution Level Grid Services 12](#_Toc109742050)

[4 Appendix A: Existing Grid Services Mapping 14](#_Toc109742051)

[4.1 Energy Schedule Service Mapping 14](#_Toc109742052)

[4.1.1 CAISO Energy Services 14](#_Toc109742053)

[4.1.2 SPP – Energy Markets 16](#_Toc109742054)

[4.1.3 PJM Energy Service 18](#_Toc109742055)

[4.2 Reserve Service Mapping 21](#_Toc109742056)

[4.2.1 CAISO – Reserve Markets 21](#_Toc109742057)

[4.2.2 SPP – Reserve Markets 24](#_Toc109742058)

Need TOCs for Figures and Tables.

# The Need for Common Grid Service Definitions

The notions about grid services come from the operational paradigm for managing the electric power system. The terms and definitions for these services are formalized for transmission and wholesale electricity markets where market participants can compete for providing the service with different equipment. Each wholesale market has evolved unique grid service names and definitions even though there is significant alignment on the types of services being exchanged because of similar operational paradigms. Different names can cause confusion in discussions among various markets, but the terms and definitions within a market’s jurisdiction work well for the interactions of their participants.

Common terms and definitions of grid services become more critical to support interactions among much greater numbers of participants as coordination extend into electricity distribution systems. There, renewable generation, electric vehicle (EV) charging, and other customer-side flexibility that engages distributed energy resources (DERs) are becoming viable grid service providers.

Semantics will be critical to both business and cyber-physical transactions between the various systems, jurisdictions, and their participants. The intent of the common terms and definitions is to accommodate diverse grid and customer needs in a clear and broadly acceptable manner for improved communications between interested parties and to provide a common starting place for specialization to satisfy different regional jurisdictional requirements.

A review of the state of electricity transmission and distribution system grid services (Brown 2022) indicates that existing grid service names often derive from the operational objectives (i.e., why a service is used) rather than the performance desired from the service provider. While the objective is important to the requestor, the service provider only needs to understand what is expected of their resource(s). For example, the term “peak load management” contains little information of value to a generator or a DER like an EV charging system, but scheduling energy production or use to alter consumption during specific time periods (that might correspond with the service requestor’s peak periods) is understood. In other words, the grid service is the *means* to achieve the operational objective. By developing clear, concise, service-oriented, and performance-based grid service definitions, the service requested and the performance expectations are clear to both the provider and requestor.

## 1.1 Smart Grid Considerations

The future electric grid is becoming distributed in terms of generation mix and highly connected with communications and distributed intelligence. Though the electrical connections largely remain the same, the power flows will be bi-directional. Managing these flows will require communication across many interfaces and coordination among multiple stakeholders. This mix of widely distributed resources will require a high level of interoperability and a great deal of coordination between participants’ systems. Common definitions for performance-based grid services will facilitate interoperability through semantic understanding of grid services between these systems.

A distributed electrical system provides opportunities for more grid service providers. Participants will include distribution and transmission operators, aggregators, prosumers, regulators, integrators, and others. Agreements to define the roles and responsibilities associated with the service will proliferate. Third party energy market participants such as aggregators aiding in energy transactions between the grid operator and the grid service provider will be included in many of the agreements. Common definitions for performance-based grid services will improve contracts and negotiation through understanding of grid services, roles, and responsibilities between these actors.

The intelligence and connectivity of intelligent devices such as thermostats and water heaters has already made them popular resources in various direct load control programs. Common grid service definitions can provide a path to qualify assets for their capability to provide grid service. By understanding the physical operating characteristics required by the provider of the service, one could determine a test to determine if the DER qualifies for a service. For example, if a service requires that a resource is available within a couple of seconds of being requested this metric could be used to determine if this resource was a viable candidate to provide said service.

## 1.2 Jurisdictional Considerations

As more flexibility at the distribution level is introduced in the electric system, coordination across operating jurisdictions and amongst participants is increasingly important. While there are several operational jurisdictions at the bulk electricity system level, there are orders of magnitude more at the distribution level. As the number of participants increases, specialization of grid service terms and definitions becomes even more important for clear communications and expectations. Common definitions improve processes such as establishing agreements or contracts between interacting parties. They can also be beneficial for standardization of things like energy market interactions and exchanging information that characterizes a DER or DER facility’s capability to provide grid services.

In addition, technology solutions providers will be able to offer more affordable products as grid service terms and definitions become consistent across distribution system operations jurisdictions. While jurisdictional differences may be necessary, common terminology and definitions reduces the cost of DER integration and coordinated operation.

A common vocabulary and understanding of grid services, including requirements and characteristics associated with them, can provide a basis for grid-DER service agreements at the retail level that look more similar across jurisdictions.

# Categorization of Grid Services

An operational objective (Pratt 2020) refers to “the fundamental underlying physical needs, stated as objectives, of the grid for safe, reliable, robust, and economically efficient operation. These are often in the form of balancing supply and demand at various time scales and for various purposes.” Operational objectives may include things like peak load management, the need to move controllable generation up or down to follow load changes and manage area control error, and calling on extra generation capacity during an unplanned equipment outage.

A grid-DER service, on the other hand, describes a DER facility’s expected performance in response to a service request. The performance expectation should describe what needs to be done at the connection point to the grid and how it will be measured. The service provider clearly understands what is expected, not why or how the service is being used. In this way, the service requestor’s operational objective for reliably managing the operation of the power system is cleanly separated from the performance expectation of operating the DER facility.

Existing grid service terms used by system operators can derive from a limited operational objective instead of the more general service to be performed. While an operational objective descriptor might be something like “peak load management,” performance expectations are related to the physical and temporal characteristics of the service. Examples of performance characteristics include providing energy within a given response time for a specified duration. Performance characteristics can be used to quantify the capability of a DER to meet a performance expectation required by a service. For example, a service defined by a performance expectation might be defined as the ability of a service provider to respond in less than a minute to supply a certain amount of energy according to an agreed upon schedule.

The following sections present the proposed types of grid service terms and definitions. To clarify these definitions, performance expectations are described, along with potential ways to measure adequate performance to expectation. A subsequent section uses examples of operational objectives to demonstrate how these grid services can be applied by a service requester to reliably operate a power system.

## Grid Service Identification

To separate out the service being requested from the operational objective (how or why it is used) one must focus on the information the service provider needs to understand what physically needs to be delivered. After comparing performance expectations such as magnitude, capacity, response time, and service duration the following grid service categories are proposed:

* + Energy Schedule Service: The energy schedule service provides a planned import or export of energy from an electric service location over a specified scheduled period.
  + Reserve Service: The reserve service provides an import or export of energy or power operationally available during a predefined period. Reserved assets would be engaged as needed during this period.
  + Regulation Service: The regulation service provides an increase or decrease in real power import or export from an electrical service location over a specified scheduled period against a predefined real-power base point following a service requestor’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 schedule service performance period.
  + Frequency Response Service: The frequency response service is “the response of resources and load to arrest local changes in frequency” (NERC 2021)
  + Voltage Management Service: The voltage management service r provides voltage support (raise or lower) within a specified upper and lower voltage range at an electrical location over a specified scheduled period.
  + Emergency Service: The emergency service uses the capability of provider resources to energize without an outside electrical supply or quickly change energization levels during an electric grid emergency.

While the terms and concepts for each grid service should be consistent, the attributes or parameters used in the definitions must accommodate the need for specializing the performance expectations and characteristics to meet operational requirements. That is, aspects related to qualification, performance expectations, monitoring, reconciliation, and settlement will need to vary based on the operational policy of the region.

## Performance Attributes

Each grid service has performance expectations for the resources to fulfill the service. The performance expectation of each service can be described by a unique combination of several service attributes which dictate the behavior needed from the resource for the provided service to be meaningful. Performance metrics can then be created for each defined grid service based on the most appropriate service attribute(s) for that service. The metrics can be linked to performance-based reconciliation calculation and/or resource qualification.

Examples of grid service attributes are energy produced or consumed over a specified interval, real vs reactive power capacity, response time, service duration, and related measurement requirements. Note, to qualify for participating in a service agreement, resource owners may need to provide additional information or certification about things like real and reactive power capacity or speed of response.

The following material describes the types of attributes needed for defining grid services. Section 2.3 describes the grid service definitions with the appropriate attributes for each service. Table 1 provides a summary of the performance attributes of grid services discussed in the material that follows.

### Electrical Attributes

The electrical attributes are the electricity aspects of the service expectations.

**Energy, and real and reactive power, and service location**: Many grid services involve the resources producing or consuming power from the grid. From the grid service requester perspective, reducing load may be 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.

The electric service location is a physical property of where the service is delivered in the electric system. The impact of location in the system depends on the definition and performance expectation of each energy service type.

### 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 service is expected to take place. Its specification includes 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.

**Delivery schedule notification**: The timing associated with notification that the delivery schedule for a service is established. For example, the results of a market process are published by specified times and notify the participants of their scheduled delivery of the service.

**Response time**: Response time is the allowed 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 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 service agreement. Some grid services require such rapid response (nearly instantaneous) that autonomous behavior is required, such as those defined through volt/watt and frequency/watt curves.

### Additional Information

The following topics provide additional context for understanding the nature of the service and how it is used in practice.

**Performance Measurement**: To verify that a grid service provider meets the performance expectations for the service, an agreement describes how it will be measured. The measurement requirements, sometimes referred to as measurement and verification (M&V), vary depending on the grid service agreement as specialized by each authority. For example, energy metering requirements need to specify attributes like interval granularity for buffering data that matches the performance period.

**Example Service Requestor Operational Objectives**: Provides typical applications for system operations to call on the service. For example, scheduling energy is used to balance supply and demand. This includes addressing forecasted energy peaks by scheduling more supply and/or less demand during the peak period.

**Origin of Service Definition**: Describes any operational history for creating the service. For example, spinning reserve was created to address loss of generation or line outages that require quick response from generation to address the imbalance of energy in the system.

## Grid Service Definitions

The following are proposed common definitions for the types of grid services. The attributes (electrical and timing) are identified as the main places where operating authorities specialize the attributes for each service desired in their jurisdictions.

Table 1 provides a summary of the performance attributes of grid services discussed in the material that follows. Figure 1 shows the relative ranges for typical attribute values for various grid services’ response times and duration of delivery schedules.

Table 1: Common grid services with typical timing and measurement attributes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Grid Service** | **Electrical Attributes** | **Timing Attributes** | | |
| **Delivery Schedule** | **Del. Schedule Notification** | **Response Time** |
| Energy Schedule Service | Power (±kW)  Energy (±kWh)  Location (node, zone) | Start and end time or duration (date, time – minutes, hours) | Confirmation time (date, time) |  |
| Reserve Service | Power (±kW)  Energy (±kWh)  Location (node, zone) | Start and end time or duration (minutes, hours) | Confirmation time (date, time) | Seconds-Minutes to achieve % power |
| Regulation Service | Power (±kW)  Energy (±kWh)  Location (node, zone) | Start and end time or duration (hours) | Confirmation time (date, time) | Seconds |
| Frequency Response Service | Energy / freq. deviation (±kWh/Hz) | Start and end time or duration (hours) | Confirmation time (date, time) | Milliseconds |
| Voltage Management Service | Power factor, (±kW, ±kVAr)  Volt set pt (kV) | Start and end time or duration (hours) | Confirmation time (date, time) | Milliseconds - Hours |
| Emergency Service | Power (±kW, ±kVAr) | Start and end time or duration (hours) | Confirmation time (date, time) | Seconds-  Hours |

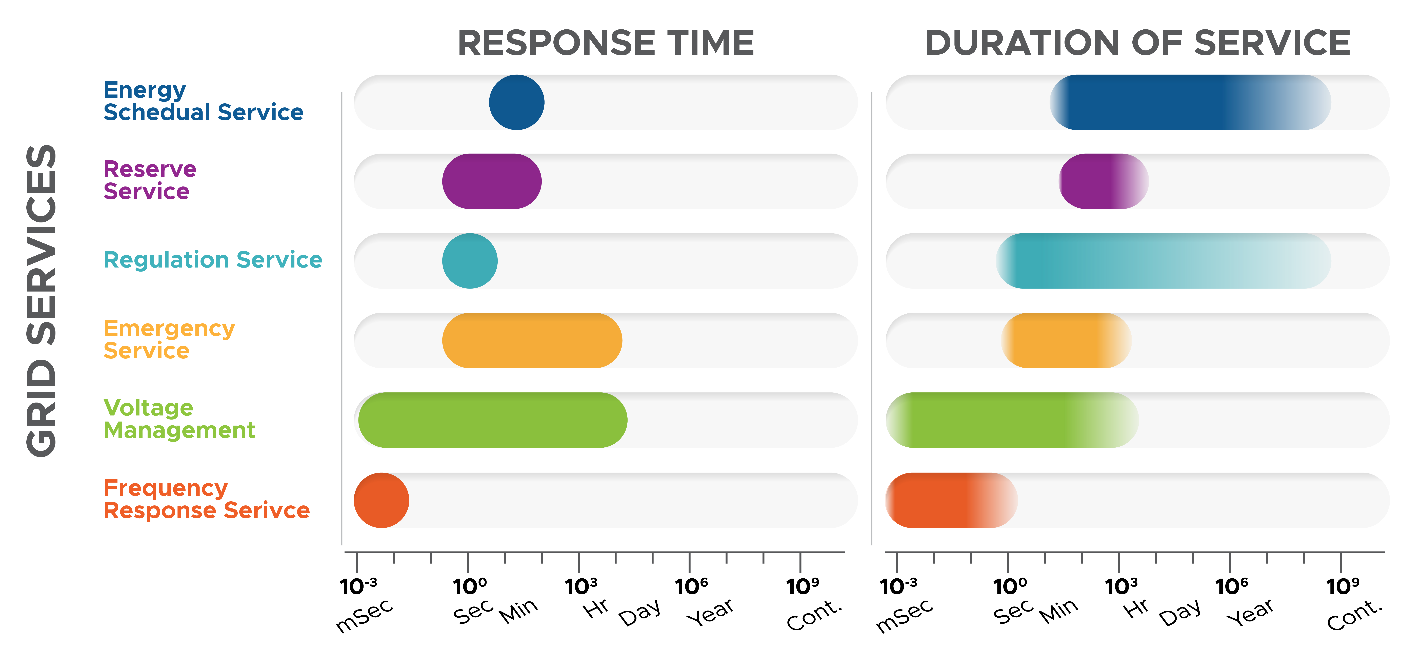


Figure 1: Common grid service types typical timing attributes variation

#### Energy Schedule Service

**Description**: The energy schedule service provides a planned import or export of energy from an electric service location over a specified scheduled period.

**Performance Expectation**

* **Electrical Attributes**:
  + **Power**: the power level of the resource for import or export over the performance period.
  + **Energy**: the quantity of electric energy for import or export over the performance period. The agreement can specify the price for a quantity of energy at different power levels (a curve).
  + **Electrical location**: the physical location where the service is delivered in the electric system.
* **Timing Attributes**:
  + **Delivery schedule**: the period of performance describes the start time and end time of the scheduled energy import or export. This can also be specified with a start time and a duration.
  + **Delivery schedule notification**: The timing associated with notification that the delivery schedule for the energy service is established. For example, the results of a market process are published by specified times and notify the participants of their scheduled delivery of the service.

**Performance Measurement**: The energy schedule service agreement specifies how performance is measured. This is usually done with revenue grade meters that measure energy in intervals synchronized to the delivery schedule for the service. Periodic power measurements are also used.

**Example Service Requestor Operational Objectives**: System peak load management, balance energy use with production, manage delivery limitations caused by power flow constraints.

**Origin of Service Definition**: Wholesale markets arrange for scheduled blocks of energy to match anticipated load. 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 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 also stipulate the penalties or fees for non-performance (over or under production and consumption).

Most ISO/RTOs have real-time (5-minute to one hour) and day-ahead (next operating day) markets at the wholesale level. They also have real-time and day-ahead demand response energy scheduling programs with programs for retail customers to be able to respond to wholesale electricity prices. Participants are compensated based on the amount of reduction made during the delivery schedule interval.

#### Reserve Service

**Description**: The reserve service provides an import or export of energy or power operationally available during a predefined period. Reserved assets would be engaged as needed during this period.

**Performance Expectation**

* **Electrical Attributes**:
  + **Power**: the power level of the resource for import or export over the performance period.
  + **Energy**: the quantity of available electric energy held in reserve which could be called upon for import or export. The agreement can specify the price for a quantity of energy at different power levels (a curve) that will be available to be called upon.
  + **Electrical location**: the physical location or region where the service is delivered in the electric system.
* **Timing Attributes**:
  + **Delivery schedule**: the period of performance describes the start time and end time of the reserve import or export. This can also be specified with a start time and a duration. The service agreement specifies the periodicity of the scheduling agreement (e.g., daily, hourly, 30-minute periods)
  + **Delivery schedule notification**: The timing associated with notification that the delivery schedule for the reserve service is established. For example, the results of a market process are published by specified times and notify the participants of their scheduled delivery of the service.
  + **Speed of response**: the quality of the resource to change its operating position over a time interval. This can be measured in amount of time to have the resource available (e.g., 30 minutes), the MW, a percent of reserved quantity per unit time, and/or agreed quantity over an interval.

**Performance Measurement**: The reserve service agreement specifies how performance is measured. Energy interval metering may be combined with time stamped power measurements.

**Example Service Requestor Operational Objectives**: System operations uses the concept of reserves to address unplanned situations that regularly occur. These include contingency response from line or generation equipment outages or derations that cause deviations from planned operations. Environmental events may also deviate from planned production from solar or wind generating resources. These deviations may require fast-acting reserves (such as from synchronized generators), slow response reserves (such as from non-synchronized generators that need several minutes to become available).

Depending upon the operational situation, reserves may need to be available at different rates. For example, a weather forecast event may have one or more hours for reserves to respond, while a line or generator outage may require a more rapid response time.

**Origin of Service Definition**: Power system operators use spinning and non-spinning reserves to maintain reliable balance of supply and demand in the system. Wholesale markets negotiate scheduled blocks of energy reserves to support this need. These are done in ISO/RTO markets, such as those run by independent market operators. In the wholesale situation the price and quantity of power or energy available over the 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.

While wholesale markets set prices for operating the resources, the owners relinquish control of their resources to the system operator during the operating period.

Demand side resources also participate in many wholesale markets and are used like contingency reserves. That is, aggregated demand response providers may be called upon for various operating situations. They usually have longer contract intervals and notification periods. They may have stipulations on the maximum number of times they are called in a year or season. Their process for determining performance and settlement is different than traditional generation reserve resources.

#### Regulation Service

**Description**: The regulation service provides an increase or decrease in real power import or export from an electrical service location over a specified scheduled period against a predefined real-power base point following a service requestor’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 schedule service performance period.

**Performance Expectation**: TBD

**Performance Measurement**: TBD

**Example Service Requestor Operational Objectives**: TBD

**Origin of Service Definition**: TBD

#### Frequency Response Service

**Description**: The frequency response service is “the response of resources and load to arrest local changes in frequency” (NERC 2021).

**Performance Expectation**: TBD

**Performance Measurement**: TBD

**Example Service Requestor Operational Objectives**: TBD

**Origin of Service Definition**: TBD

#### Voltage Management Service

**Description**: The voltage management service provides voltage support (raise or lower) within a specified upper and lower voltage range at an electrical location over a specified scheduled period.

**Performance Expectation**: TBD

**Performance Measurement**: TBD

**Example Service Requestor Operational Objectives**: TBD.

**Origin of Service Definition**: TBD

#### Emergency Service

**Description**: The emergency service uses the capability of provider resources to energize without an outside electrical supply or quickly change energization levels during an electric grid emergency.

**Performance Expectation**: TBD

**Performance Measurement**: TBD

**Example Service Requestor Operational Objectives**: TBD

**Origin of Service Definition**: TBD

# Distribution Level Grid Services

The following material discusses aspects of the common grid services that pertain to their use at the distribution level of system operations.

#### Energy Schedule Service

**Electrical Attributes**: For distributed resources, the service may leave the amount of energy open, but specify the price of energy over the performance period.

**Performance Measurement**: For distribution customers, this is may be 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, submetering may be specified to isolate measuring performance.

#### Reserve Service

**Performance Measurement**: For distribution customers, 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, submetering may be specified to isolate measuring performance.

References

Brown, R et al, “The State of Grid Services, a GMLC 2.5.2 Report,” Lawrence Berkeley National Laboratory, July, 2022.

Federal Energy Regulatory Commission (FERC). (2012). Order on Compliance Filing (Issued September 20, 2012). California Independent System Operator Corporation. 140 FERC 61,206. <https://www.caiso.com/Documents/September202012FERCOrder-ComplianceFiling-DocketNoER12-1630-000.pdf> (accessed on 7/20/2021)

Nguyen, T. et al. (2017). Maximizing Revenue from Electrical Energy Storage in MISO Energy & Frequency Regulation Markets. 2017 IEEE Power & Energy Society General Meeting, 1-5.

North American Electric Reliability Corporation (NERC). (2011). Balancing and Frequency Control – A Technical Document Prepared by the NERC Resources Subcommittee (January 26, 2011).

NYISO. (2020). Manual 14 - Accounting and Billing Manual v5.3 (Issued: November 2020) <https://www.nyiso.com/documents/20142/2923231/acctbillmnl.pdf/b5c1ecb6-82cb-d1e0-9c84-4b2128f1f6bc> (accessed on 7/20/2021)

Pratt, R. et al. (2020). Grid Services from DER Device Fleets: Volume 2- Trial Analysis. Grid Modernization Laboratory Consortium Report: PNNL-31007 (June 2020).

Zhou, Z. Levin, T., and Conzelmann, G. (2016). Survey of U.S. Ancillary Services Markets. ANL/ESD-16/1 (January 2016).

[EQR] Federal Energy Regulatory Commission (2021): Electric Quarterly Reports (EQR), <https://www.ferc.gov/power-sales-and-markets/electric-quarterly-reports-eqr#eqr_data_filers>

# Appendix A: Existing Grid Services Mapping

This appendix reviews common grid services from several system operators. The material is provided in the format of the definitions of common grid services. The exercise shows how the electrical and timing parameters change between system operators while the basic definitions remain substantially consistent.

## Energy Schedule Service Mapping

### CAISO Energy Services

In addition to energy schedules established in bilateral agreements that are communicated for planning operations, the CAISO manages two wholesale energy market processes for energy scheduling: day-ahead and real-time.

#### CAISO Day-Ahead Scheduled Energy service

“The day-ahead market is made up of three market processes that run sequentially. First, the ISO runs a market power mitigation test. Bids that fail the test are revised to predetermined limits. Then the integrated forward market establishes the generation needed to meet forecast demand. And last, the residual unit commitment process designates additional power plants that will be needed for the next day and must be ready to generate electricity. Market prices set are based on bids.”

The objective of the market is “…to find the least cost energy to serve demand.”

(<http://www.caiso.com/market/Pages/MarketProcesses.aspx>)

**Description**: The day-ahead scheduled energy market receives bids for energy at an electric service location for each of the 24 hours in the trading day (the next operating day). The market operator resolves these bids with out-of-market energy schedules while ensuring that reliability constraints are honored. The results are binding agreements between the market participants.

**Electrical attributes**:

* **Power**: The MW level of the service. Bid curves consist of MW, $/MWhr quantities.
* **Energy**: The amount of energy produced or consumed in each of the hourly schedule intervals in MWh.
* **Electrical location**: The electrical locations involved are defined for each scheduled agreement as the “producing node” and “delivering nodes.” These nodes are related to PNodes (pricing nodes) in the CAISO market model. (Section 11 of <http://www.caiso.com/Pages/documentsbygroup.aspx?GroupID=E4ACC97A-173F-44CE-94CD-E33FA7EC5DF1>)

**Timing attributes**:

* **Delivery schedule**: The energy schedule covers each 24-hour period of the upcoming trading (i.e., operating) day.
* **Delivery schedule notification**: The day-ahead energy market results are published at 1pm prior to the start of the trading day.

**Performance measurement**: A Metered Entity enters into a Meter Service Agreement with CAISO. The meters are to be revenue quality (certified by CAISO) with readings at the point of system interconnection. The data collected is in kWh or MWh values. Meter data can be elected to be polled and validated from resources not providing ancillary services with 5 or 15-minute intervals to meet the hourly delivery schedule intervals. When there is a failure to get actual data, an estimation procedure is used for financial settlement. (Section 10 – Metering <http://www.caiso.com/Documents/Section10-Metering-asof-Jan1-2021.pdf>)

**Comments**: For the electrical attributes, the power level of the participant is assumed to be flat during the scheduled operating hour.

#### CAISO Hourly Real-Time Scheduled Energy service

“The real-time market is a spot market in which utilities can buy power to meet the last few increments of demand not covered in their day ahead schedules.” (<http://www.caiso.com/market/Pages/MarketProcesses.aspx>)

**Description**: The real-time scheduled energy market receives bids for energy at an electric service location using an hour-ahead scheduling process for delivery in the next trading (i.e., operating) hour. The market operator resolves these bids while ensuring that reliability constraints are honored. The results are binding agreements between the market participants. (<http://www.caiso.com/Documents/Section34-Real-TimeMarket-asof-Jun1-2022.pdf>)

**Electrical attributes**:

* **Power**: The MW level of the service. Bid curves consist of MW, $/MWhr quantities.
* **Energy**: The amount of energy produced or consumed in each of the hourly schedule intervals in MWh.
* **Electrical location**: The electrical locations involved are defined for each scheduled agreement as the “producing node” and “delivering nodes.” These nodes are related to PNodes (pricing nodes) in the CAISO market model.

**Timing attributes**:

* **Delivery schedule**: The energy schedule is for the upcoming trading (i.e., operating) hour.
* **Delivery schedule notification**: The real-time energy market results are published ~45 minutes prior to the start of the trading hour.

**Performance measurement**: The metering requirements (Meter Service Agreement) are the same as the day-ahead scheduled energy service (kWh or MWh), except that the hourly settlement process is based on 15-minute market schedule intervals so that CAISO can integrate the settlement of the real-time ancillary service markets. 60-minute metering is only allowed for Scheduling Coordinators.

**Comments**: The CAISO description of the real-time energy market is complicated by other real-time market products. Reference is made to market system dispatches to participants at 15, 5, and 1-minute intervals, but these appear to be for other energy balancing operations involving operator dispatch not real-time scheduled energy.

### SPP – Energy Markets

In addition to energy schedules established in bilateral agreements that are communicated for planning operations, SPP manages two wholesale energy market processes for energy scheduling: day-ahead (DA Market) and real-time balancing (RTBM).

Reference: “Market Protocols SPP Integrated Marketplace,” Revision 89.1 (<https://www.spp.org/spp-documents-filings/?id=18162>)

#### SPP Day-Ahead Market for energy service

“The DA Market provides Market Participants with the ability to submit offers to sell Energy…” This information goes into an integrated process involving an analysis of unit commitment and security constraints to minimize total projected production costs.

**Description**: The day-ahead market for energy receives bids for energy at an electric service location for each of the 24 hours in the next operating day. The market operator resolves these bids with out-of-market energy schedules while ensuring that reliability constraints are honored. The results are binding agreements between the market participants.

**Electrical attributes**:

* **Power**: The MW level of the service. Bid curves consist of MW, $/MWhr quantities.
* **Energy**: The amount of energy produced or consumed in each of the hourly schedule intervals in MWh. Used in settlement.
* **Electrical location**: The electrical locations involved are defined for each scheduled agreement. “Electrical nodes (ENodes) represent the physical connection points in the transmission system model.” PNodes (pricing nodes) in the SPP commercial model link to ENodes and define the places where market prices are established.

**Timing attributes**:

* **Delivery schedule**: The energy schedule covers each 24-hour period of the upcoming operating day.
* **Delivery schedule notification**: The day-ahead energy market cleared results are published at 1pm prior to the start of the operating day.

**Performance measurement**: Revenue quality metering equipment and meter data are supplied by a meter agent at the PNodes (meter settlement location – the nearest transmission system bus associated with an asset) for each participant. Meter data of energy (kWh) are supplied at least hourly, or every 5 minutes and synchronized with the delivery intervals. Real-time metering of power (kW or MW) can be used as a backup for interval energy meter failure to produce estimated energy (MWh). SPP receives meter data converted to MWh. (See Appendix D of the above reference.)

**Comments**: For the electrical attributes, the power level of the participant is assumed to be flat during the scheduled operating hour.

#### SPP Real-Time Balancing Market for energy service

“The RTBM provides Market Participants with the ability to submit offers to sell Energy…” This information goes into an integrated process involving the results of the day-ahead market “by determining the security-constrained dispatch that is the least costly means of balancing generation and load (supply/demand) while meeting operating reserve requirements.”

**Description**: The real-time balancing market for energy operates on a 5-minute basis and calculates dispatch instructions for energy. It receives bids for 5-minute intervals of energy in the next operating hour from participants at an electric service location for delivery. The market operator resolves these bids while ensuring that reliability constraints are honored. The results are binding agreements between the market participants.

**Electrical attributes**:

* **Power**: The MW level of the service. Bid curves consist of MW, $/MWhr quantities.
* **Energy**: The amount of energy produced or consumed in each of the real-time dispatch (i.e., schedule) intervals in MWh. Used in settlement.
* **Electrical location**: The electrical locations involved are defined for each scheduled agreement. “Electrical nodes (ENodes) represent the physical connection points in the transmission system model.” PNodes (pricing nodes) in the SPP commercial model link to ENodes and define the places where market prices are established.

**Timing attributes**:

* **Delivery schedule**: Offers may be submitted up to 30 minutes prior to each operating hour. The market operator determines the energy dispatch schedule for every 5-minute operating interval in the operating hour.
* **Delivery schedule notification**: The real-time energy market results are not published prior to the start of the operating hour. The settlement is done based on the 5-minute dispatch decisions.

**Performance measurement**: Revenue quality metering equipment and meter data are supplied by a meter agent at the PNodes (meter settlement location – the nearest transmission system bus associated with an asset) for each participant. Meter data of energy (kWh) are supplied on a 5-minute basis and synchronized with the delivery intervals. These are combined for an hourly settlement. Where 5-minute energy data is not measured, SPP uses state estimator real-time data profiles for the corresponding PNode. Power (in MW, not MWh) is sampled every 5 minutes and the profile is used to calculate the hourly energy settlement.

**Comments**: The real-time balancing energy market is linked to other real-time market services. The asset owners bid their resources for dispatch in the upcoming operating hour. If their bids are the most economical (determined by the market operator), then the system operator controls (dispatches) their unit in 5-minute intervals over the operating hour. The result direct control result though the resource was selected for control by a service-oriented market.

### PJM Energy Service

PJM has markets to address their operational objectives of balancing supply and demand. They manage wholesale market processes for energy scheduling: day-ahead and real-time, and additionally have integrated demand response programs which provide an opportunity for aggregators representing end-use resources to participate in energy markets and “…receive payments for demand reductions they make”.

#### PJM Day-Ahead Energy Market

“The Day-ahead Energy Market enables participants to purchase and sell energy at binding Day-ahead LMPs”. “...The Day-ahead scheduling process incorporates PJM reliability requirements and reserve obligations into the analysis. The resulting Day-ahead hourly schedules, generated by the dispatch run, and Day-ahead LMPs, generated by the pricing run, represent binding financial commitments to the market participants.”

<https://www.pjm.com/~/media/documents/manuals/m11.ashx>

**Description**: Day-ahead bids of energy are submitted for each of the 24 hours in the upcoming operating day. The bids are processed at 11am and results are posted by 1:30pm the day prior to the operating day of the resource. There is a re-bid period between the posted results and 2:15pm. The market operational day begins at midnight.

**Electrical attributes**:

* **Power**: The MW level of the service. Bid curves consist of MW, $/MWhr quantities.
* **Energy**: The amount of energy produced or consumed in each of the hourly schedule intervals in MWh. Used in settlement.
* **Electrical location**: The electrical location is defined as a pnode and is “a single pricing node or subset of pricing nodes where a physical injection or withdrawal is modeled and for which a locational marginal price is calculated and used for financial settlements.”

**Timing attributes**:

* **Delivery Schedule**: The energy schedule covers each hour of the 24-hour period of the upcoming (i.e., operating) day.
* **Delivery schedule notification**: The day-ahead energy market results are published at 1:30pm. A rebidding period takes place and results are posted at 2:15pm prior to the start of the operating day.

**Performance measurement**: “For each hour of the Operating Day, PJM calculates an hourly-integrated telemetry MWh value using the time-weighted telemetry MW values for each of the five-minute intervals in the hour”. (<https://pjm.com/-/media/documents/manuals/m28.ashx>)

**Comments**: Non-binding energy offers can be submitted for days beyond the next operating day. Subsequent offers supersede these non-binding offers.

#### PJM Real-Time Energy Market

The PJM intraday balancing market clearing prices are calculated every 5 minutes and based on deviations between day-ahead market positions and real-time operations.

**Description**: PJM operates “a spot market – meaning that the product is procured for immediate delivery - in which current prices (called locational marginal prices) are calculated at five-minute intervals based on actual grid operating conditions. Real-time energy prices are posted on the PJM Operational Data webpage.” (<https://learn.pjm.com/three-priorities/buying-and-selling-energy/energy-markets>)

**Electrical attributes**:

* **Power**: The MW level of the service. Bid curves consist of MW, $/MWhr quantities.
* **Energy**: The amount of energy produced or consumed in each of the real-time dispatch (i.e., schedule) intervals in MWh. Used in settlement.
* **Electrical location**: The electrical location is defined as a pnode and is “a single pricing node or subset of pricing nodes where a physical injection or withdrawal is modeled and for which a Locational Marginal Price is calculated and used for financial settlements.”

**Timing attributes**:

* **Delivery Schedule**: Offers for every 5 minutes of an operating hour may be submitted up to 65 minutes prior to each operating hour. The market operator determines the energy dispatch schedule for every 5-minute operating interval in the operating hour.
* **Delivery schedule notification**: The real-time energy market results are not published prior to the start of the operating hour. The settlement is done based on the 5-minute dispatch decisions.

**Performance measurement**: Generator data is reported as 5-minute revenue meter data is expected to be flat and bid in MW, thus compensated in MWh. “The balancing settlement is calculated for each Real-time Settlement Interval (five (5) minute interval) based on actual five (5) minute Revenue Data for Settlement MW quantity deviations from Day-ahead scheduled quantities resulting from the dispatch run and on the applicable Real-time prices resulting from the pricing run.” (<https://pjm.com/-/media/documents/manuals/m11.ashx>, pg. 23)

**Comments**: The calculations for real-time market compensation account for commitments agreed upon in the day-ahead market.

#### PJM Day-Ahead Demand Response Market

Through a curtailment service provider (CSP), this program allows retail customer to respond to wholesale day-ahead market prices, participating with either generation or demand resources. In the Demand Response Market program, the CSP will bid aggregated energy (MWh) according to the service requirements in a similar manner to the regular Day- Ahead Markets; bids of energy are submitted for each of the 24 hours that is expected to be flat and bid in MW, thus compensated in MWh.

**Description**: “In the day-ahead option, a CSP’s customers can offer – in advance of real-time operations – to reduce the amount of electricity they will draw from the PJM system. If the offers are accepted, they will receive payments based on the day-ahead prices for the reductions.” (<https://learn.pjm.com/-/media/about-pjm/newsroom/fact-sheets/demand-response-fact-sheet.ashx>)

**Electrical attributes**:

* **Power**: The MW level of the service. Bid curves consist of MW, $/MWhr quantities.
* **Energy**: The amount of energy reduction in each of the real-time dispatch (i.e., schedule) intervals in MWh. Used in settlement.
* **Electrical location**: The electrical location is defined as a pnode and is “a single pricing node or subset of pricing nodes where a physical injection or withdrawal is modeled and for which a Locational Marginal Price is calculated and used for financial settlements.”

**Timing attributes**:

* **Delivery Schedule**: The energy schedule covers each hour of the 24-hour period of the upcoming (i.e., operating) day.
* **Delivery schedule notification**: The day-ahead energy market results are published at 1:30pm. A rebidding period takes place and final results are posted at 2:15pm prior to the start of the operating day.

**Performance measurement**: “Demand Resources must be equipped with interval meters recording electrical usage at the EDC account level. The interval of data collection must be sufficient to provide PJM with hourly, one minute or real time load data as applicable for the wholesale market.” The meters capture energy usage for each interval. (<https://www.pjm.com/directory/manuals/m11/index.html#Sections/10.4%20Demand%20Resource%20Metering%20and%20Settlement%20Data%20Requirements.html>)

**Comments**: CSP’s aggregate the participating customers demand response and submit the verification to PJM. This needs to be resolved on a pnode basis for compensation. The distribution of payments to the demand reduction participants is between the CSP and their customers. Customers’ responses are based upon the change of energy consumption from a baseline load shape.

#### PJM Real-Time Demand Response Market

Through a CSP, this program allows retail customer to respond to wholesale real-time market prices, participating with either generation or demand resources. In the demand response market program, the CSP will bid aggregated energy in a similar manner to the other energy schedule real-time market. Intraday offers may make changes beginning at 4:30PM the previous day up to 65 minutes before the operating hour according to 5-minute increment schedule that is expected to be flat and bid in MW, thus compensated in MWh. Bids are made in terms of $/MWh.

**Description**: “The Real-time Option provides a mechanism by which any qualified Market Participant may offer Demand Resources the opportunity to commit to a reduction and receive payments based on Real-time LMP for the reductions.” (<https://www.pjm.com/directory/manuals/m11/index.html#Sections/101%20Overview%20of%20Demand%20Resource%20Participation.html>)

**Electrical attributes**:

* **Power**: The MW level of the service. Bid curves consist of MW, $/MWhr quantities.
* **Energy**: The amount of energy reduction in each of the real-time dispatch (i.e., schedule) intervals in MWh. Used in settlement.
* **Electrical location**: The electrical location is defined as a pnode and is “a single pricing node or subset of pricing nodes where a physical injection or withdrawal is modeled and for which a Locational Marginal Price is calculated and used for financial settlements.”

**Timing attributes**:

* **Delivery Schedule**: Offers for every 5 minutes of an operating hour may be submitted up to 65 minutes prior to each operating hour. The market operator determines the demand response dispatch schedule for every 5-minute operating interval in the operating hour.
* **Delivery schedule notification**: The real-time energy market results are not published prior to the start of the operating hour. The settlement is done based on the 5-minute dispatch decisions.

**Performance measurement**: “Demand Resources must be equipped with interval meters recording electrical usage at the EDC account level. The interval of data collection must be sufficient to provide PJM with hourly, one minute or real time load data as applicable for the wholesale market.” The meters capture energy usage for each 5-minute interval. (<https://www.pjm.com/directory/manuals/m11/index.html#Sections/10.4%20Demand%20Resource%20Metering%20and%20Settlement%20Data%20Requirements.html>)

**Comments**: Like the other real-time energy schedule markets, the service providers do not know how to correct the operation of the demand response resources until they are given the 5-minute signal from the system operator. However, they understand their planned operation for the hour based on the results of the day-ahead market. Customers’ responses are based upon the change of energy consumption from a baseline load shape. The compensation incorporates their day-ahead commitment and deviation based on the real-time market price.

## Reserve Service Mapping

### CAISO – Reserve Markets

“Spinning reserve is standby capacity from generation units already connected or synchronized to the grid and that can deliver their energy in 10 minutes when dispatched. Non-spinning reserve is capacity that can be synchronized to the grid and ramped to a specified load within 10 minutes.” <http://www.caiso.com/market/Pages/MarketProcesses.aspx>

Certified loads are also able to supply spinning and non-spinning reserve based on their qualifying characteristics.

CAISO runs day-ahead and real-time markets for arranging these reserves. The business practices for interacting with the market for these services in terms of timing attributes are the same as the energy schedule service.

#### CAISO Day-Ahead Spinning and Non-Spinning Reserves

Spinning Reserve (must be synchronized, be available in 10 minutes, and be maintainable for 30 minutes). Non-Spinning Reserve (must be able to deliver the AS (ancillary service) Award within 10 minutes and be maintainable for 30 minutes). (“Business Practice Manual for Market Instruments, v71,” 29 June 2022, <https://bpmcm.caiso.com/Pages/BPMDetails.aspx?BPM=Market%20Instruments>)

**Description**: The day-ahead markets for spinning and non-spinning reserves receives bids for a power capacity at an electric service location for each of the 24 hours in the next operating day. The market operator resolves these bids ensuring that reliability constraints are honored. The results are binding agreements between the market participants.

**Electrical attributes**:

* **Power**: The MW level of the service (called spinning or non-spinning reserve capacity). Bid curves consist of MW, $/MW quantities.
* **Electrical location**: “The CAISO will procure Ancillary Services using Ancillary Service Regions and Ancillary Service Sub-Regions. There are two Ancillary Service Regions and eight Ancillary Service Sub-Regions.” (Section 8.3.3, California Independent System Operator Corporation, Fifth Replacement FERC Electric Tariff, Effective as of June 17, 2022, <http://www.caiso.com/Documents/Conformed-Tariff-as-of-Jun17-2022.pdf> )

**Timing attributes**:

* **Delivery schedule**: The reserve schedule covers each 24-hour period of the upcoming trading (i.e., operating) day.
* **Delivery schedule notification**: The day-ahead spinning and non-spinning reserve market results are published at 1pm prior to the start of the trading day.
* **Speed of response**: “Each provider of Spinning Reserve or Non-Spinning Reserve must be capable of receiving a Dispatch Instruction within one (1) minute from the time the CAISO Control Center elects to Dispatch the Spinning Reserve resource or Non-Spinning Reserve resource and must ensure that its resource can be at the Dispatched operating level within ten (10) minutes after issuance of the Dispatch Instruction.” (Section 8.4.2, California Independent System Operator Corporation, Fifth Replacement FERC Electric Tariff, Effective as of June 17, 2022, <http://www.caiso.com/Documents/Conformed-Tariff-as-of-Jun17-2022.pdf>) and be maintainable for a continuous duration of 30 minutes.

**Performance measurement**: Scheduling Coordinators must ensure that Settlement Quality Meter Data submitted to the CAISO is in intervals of five (5) minutes for Loads and Generators providing Ancillary Services (includes reserves). (Source: California Independent System Operator Corporation Fifth Replacement FERC Electric Tariff January 1, 2021, Section 10 Services, <http://www.caiso.com/Documents/Section10-Metering-asof-Jan1-2021.pdf> .

**Comments**: Spinning reserves are allocated based on reliability criteria that include capability of frequency response that non-spinning reserves may not have.

#### CAISO Hourly Real-time Spinning and Non-Spinning Reserves

The CAISO operates an hour-ahead scheduling process (HASP) for operating reserves (spinning and non-spinning). The process framework is the same as the energy schedule service hour-ahead scheduling process. The HASP produces advisory schedules in the upcoming hour, providing guidance as to the expected resource output.

**Description**: The hour-ahead markets for spinning and non-spinning reserves receives bids for a power capacity at an electric service location for the next operating hour. The results of these markets are used to create binding commitments of resources for use by the system operator to operate the least cost resources to meet reliability criteria in real-time.

**Electrical attributes**:

* **Power**: The MW level of the service (called spinning or non-spinning reserve capacity). Bid curves consist of MW, $/MW quantities.
* **Electrical location**: “The CAISO will procure Ancillary Services using Ancillary Service Regions and Ancillary Service Sub-Regions. There are two Ancillary Service Regions and eight Ancillary Service Sub-Regions.” (Section 8.3.3, California Independent System Operator Corporation, Fifth Replacement FERC Electric Tariff, Effective as of June 17, 2022, <http://www.caiso.com/Documents/Conformed-Tariff-as-of-Jun17-2022.pdf> )

**Timing attributes**:

* **Delivery schedule**: The reserve schedule covers the next trading (i.e., operating) hour.
* **Delivery schedule notification**: The real-time energy market results are published ~45 minutes prior to the start of the operating hour.
* **Speed of response**: “Each provider of Spinning Reserve or Non-Spinning Reserve must be capable of receiving a Dispatch Instruction within one (1) minute from the time the CAISO Control Center elects to Dispatch the Spinning Reserve resource or Non-Spinning Reserve resource and must ensure that its resource can be at the Dispatched operating level within ten (10) minutes after issuance of the Dispatch Instruction.” (Section 8.4.2, California Independent System Operator Corporation, Fifth Replacement FERC Electric Tariff, Effective as of June 17, 2022, <http://www.caiso.com/Documents/Conformed-Tariff-as-of-Jun17-2022.pdf>) and be maintainable for a continuous duration of 30 minutes.

**Performance measurement**: Scheduling Coordinators must ensure that Settlement Quality Meter Data submitted to the CAISO is in intervals of five (5) minutes for Loads and Generators providing Ancillary Services (includes reserves). (Source: California Independent System Operator Corporation Fifth Replacement FERC Electric Tariff January 1, 2021, Section 10 Services, <http://www.caiso.com/Documents/Section10-Metering-asof-Jan1-2021.pdf> .

**Comments**: The hour-ahead attributes are the same as the day-ahead attributes for spinning and non-spinning reserves.

### SPP – Reserve Markets

SPP procures spinning and supplemental reserves in day-ahead and real-time “operating reserve” markets. SPP operating reserves also include ramp capability up/down and regulation up/down services; however, these are classified and discussed in the regulation service category. A contingency reserve requirement also needs to be met for SPP reliable operations; however, this is a required reserve operating level to which other procured services contribute. It is not procured separately.

Reference: “Market Protocols SPP Integrated Marketplace,” Revision 89.1 (<https://www.spp.org/spp-documents-filings/?id=18162>)

#### SPP Day-Ahead Spinning Reserve

Spinning reserve is the unloaded generation that is synchronized to the system and ready to serve additional demand. (SPP Glossary)

**Description**: The day-ahead market for spinning reserves receives bids from generating resources as allocated to SPP defined reserve zones for each of the 24 hours in the next operating day. The market operator resolves these bids ensuring that reliability constraints are honored. The results imply that the selected generating resources will be scheduled to be on-line the operating day and are binding agreements. A resource offer for spinning reserve means that a supplemental reserve offer cannot be made. Only spin qualified resources can make offers.

**Electrical attributes**:

* **Power**: The power capacity reserved and available in the resource in MW for dispatch. Bid curves consist of MW, $/MWh quantities.
* **Energy**: The amount of energy produced or consumed (MWh). Used in settlement.
* **Electrical location**: Operating reserves (includes spinning reserves) are procured on a reserve zone basis. A reserve zone is, “A zone containing a specific group of Price Nodes for which a minimum and maximum Operating Reserve requirement is established.”

**Timing attributes**:

* **Delivery schedule**: The reserve schedule covers each 24-hour period of the upcoming operating day.
* **Delivery schedule notification**: The results for spinning reserve generators are posted at 6am prior to the operating day.
* **Speed of response**: the resource is to be capable of deploying 100% of the cleared spinning reserve quantity within a continuous duration of 60 minutes from when a contingency reserve deployment period is called. That is, “The time period following the issuance of a Contingency Reserve Deployment Instruction within which a Resource has to deploy Contingency Reserve which is set at ten (10) minutes.”

**Performance measurement**: Revenue quality metering equipment and meter data are supplied by a meter agent at the PNodes (meter settlement location – the nearest transmission system bus associated with an asset) for each participant. Meter data of energy (kWh) are supplied on a 5-minute basis and synchronized with the delivery intervals. These are combined for an hourly settlement. Where 5-minute energy data is not measured, SPP uses state estimator real-time data profiles for the corresponding PNode. Power (in MW, not MWh) is sampled every 5 minutes and the profile is used to calculate the hourly energy settlement. Spin qualified resources must provide telemetered output data that can be scanned every 10 seconds.

**Comments**: The day-ahead spinning reserve market is linked to the other real-time market services. The asset owners bid their resources for dispatch in the upcoming day. If their resource is chosen, the system operator can issue a contingency reserve deployment instruction and directly dispatch the resource.

#### SPP Real-time Spinning Reserve

The real-time spinning reserve market applies only to those resources available from the day-ahead spinning reserve market results.

**Description**: The real-time market for spinning reserves receives bids from generating resources who have already been cleared in the day-ahead spinning reserve market. They may update their offers up to 30 minutes before the operating hour and are binding agreements.

**Electrical attributes**:

* **Power**: The power capacity reserved and available in the resource in MW for dispatch.
* **Energy**: The amount of energy produced or consumed (MWh). Used in settlement.
* **Electrical location**: Operating reserves (includes spinning reserves) are procured on a reserve zone basis. A reserve zone is, “A zone containing a specific group of Price Nodes for which a minimum and maximum Operating Reserve requirement is established.”

**Timing attributes**:

* **Delivery schedule**: Offers may be submitted up to 30 minutes prior to each operating hour. The market operator determines the energy dispatch schedule for every 5-minute operating interval in the operating hour.
* **Delivery schedule notification**: The real-time energy market results are not published prior to the start of the operating hour. The settlement is done based on the 5-minute dispatch decisions.
* **Speed of response**: the resource is to be capable of deploying 100% of the cleared spinning reserve quantity within a continuous duration of 60 minutes from when a contingency reserve deployment period is called. That is, “The time period following the issuance of a Contingency Reserve Deployment Instruction within which a Resource has to deploy Contingency Reserve which is set at ten (10) minutes.”

**Performance measurement**: The same performance measurement requirements for the day-ahead spinning reserve market apply to the real-time balancing market.

**Comments**: The real-time spinning reserve market is linked to the other real-time market services. The system operator can issue a contingency reserve deployment instruction based upon the updated real-time bid and directly dispatch the resource.

#### SPP Day-Ahead Supplemental Reserve

Supplemental reserve is generation not connected to the system but capable of serving demand within a specified time or interruptible load that can be removed from the system in a specified time. (SPP Glossary)

**Description**: The day-ahead market for supplemental reserves receives bids from generating resources as allocated to SPP defined reserve zones for each of the 24 hours in the next operating day. The market operator resolves these bids ensuring that reliability constraints are honored. The results imply that the selected generating resources will be scheduled to be available the operating day but not necessarily online (spinning) and are binding agreements.

**Electrical attributes**:

* **Power**: The power capacity reserved and available in the resource in MW for dispatch. Bid curves consist of MW, $/MWh quantities.
* **Energy**: The amount of energy produced or consumed (MWh). Used in settlement.
* **Electrical location**: Operating reserves (includes supplemental reserves) are procured on a reserve zone basis. A reserve zone is, “A zone containing a specific group of Price Nodes for which a minimum and maximum Operating Reserve requirement is established.”

**Timing attributes**:

* **Delivery schedule**: The reserve schedule covers each 24-hour period of the upcoming operating day.
* **Delivery schedule notification**: The day-ahead supplemental reserve market cleared results are published at 1pm prior to the start of the operating day.
* **Speed of response**: The supplemental qualified resource is to be capable of deploying 100% of the cleared spinning reserve quantity from an off-line state within a continuous duration of 60 minutes from when a contingency reserve deployment period is called. That is, “The time period following the issuance of a Contingency Reserve Deployment Instruction within which a Resource has to deploy Contingency Reserve which is set at ten (10) minutes.”

**Performance measurement**: Revenue quality metering equipment and meter data are supplied by a meter agent at the PNodes (meter settlement location – the nearest transmission system bus associated with an asset) for each participant. Meter data of energy (kWh) are supplied on a 5-minute basis and synchronized with the delivery intervals. These are combined for an hourly settlement. Where 5-minute energy data is not measured, SPP uses state estimator real-time data profiles for the corresponding PNode. Power (in MW, not MWh) is sampled every 5 minutes and the profile is used to calculate the hourly energy settlement. Spin qualified resources must provide telemetered output data that can be scanned every 10 seconds.

**Comments**: The day-ahead supplemental reserve market is linked to the other real-time market services. The asset owners bid their resources for dispatch in the upcoming day. If their resource is chosen, the system operator can issue a contingency reserve deployment instruction and directly dispatch the resource.

#### SPP Real-time Supplemental Reserve

The real-time supplemental reserve market applies only to those resources available from the day-ahead supplemental reserve market results.

**Description**: The real-time market for supplemental reserves receives bids from generating resources who have already been cleared in the day-ahead supplemental reserve market. They may update their offers up to 30 minutes before the operating hour and are binding agreements.

**Electrical attributes**:

* **Power**: The power capacity reserved and available in the resource in MW for dispatch.
* **Energy**: The amount of energy produced or consumed (MWh). Used in settlement.
* **Electrical location**: Operating reserves (includes supplemental reserves) are procured on a reserve zone basis. A reserve zone is, “A zone containing a specific group of Price Nodes for which a minimum and maximum Operating Reserve requirement is established.”

**Timing attributes**:

* **Delivery schedule**: Offers may be submitted up to 30 minutes prior to each operating hour. The market operator determines the energy dispatch schedule for every 5-minute operating interval in the operating hour.
* **Delivery schedule notification**: The real-time energy market results are not published prior to the start of the operating hour. The settlement is done based on the 5-minute dispatch decisions.
* **Speed of response**: The supplemental qualified resource is to be capable of deploying 100% of the cleared spinning reserve quantity from an off-line state within a continuous duration of 60 minutes from when a contingency reserve deployment period is called. That is, “The time period following the issuance of a Contingency Reserve Deployment Instruction within which a Resource has to deploy Contingency Reserve which is set at ten (10) minutes.”

**Performance measurement**: The same performance measurement requirements for the day-ahead spinning reserve market apply to the real-time balancing market.

**Comments**: The real-time supplemental reserve market is linked to the other real-time market services. The system operator can issue a contingency reserve deployment instruction based upon the updated real-time bid and directly dispatch the resource.

###### 

Address Line 1

Address Line 2

City, ST Zip

Phone Number

*https://gmlc.doe.gov*

1. Pacific Northwest National Laboratory [↑](#footnote-ref-2)
2. Lawrence Berkeley National Laboratory [↑](#footnote-ref-3)