

# Survey of U.S. Ancillary Services Markets

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**Energy Systems Division**

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# Survey of U.S. Ancillary Services Markets

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## Notation

|        |  |
|--------|--|
| ACE    | Area Control Error                           |
| AGC    | automatic generation control                 |
| ASMP   | ancillary service marginal price             |
| BAAL   | Balance Authority ACE Limit                  |
| CAISO  | California Independent System Operator       |
| CPS    | Control Performance Standard                 |
| DAM    | Day Ahead Market                             |
| EMS    | Energy Management System                     |
| ERCOT  | Electric Reliability Council of Texas        |
| FERC   | Federal Energy Regulatory Commission         |
| HAM    | Hour Ahead Market                            |
| ISO    | Independent System Operator                  |
| ISO-NE | ISO New England                              |
| LMP    | Locational Marginal Price                    |
| MAD    | Mid-Atlantic Dominion                        |
| MCP    | Market Clearing Price                        |
| MISO   | Midcontinent ISO                             |
| NERC   | North American Electric Reliability Council  |
| NRR    | Normal Response Rate                         |
| NYISO  | New York ISO                                 |
| ORDC   | Operating Reserve Demand Curve               |
| QSE    | Qualified Scheduling Entity                  |
| RIPS   | regulation interval performance score        |
| RMCP   | regulation market clearing price             |
| RMCCP  | regulation market capability clearing price  |
| RMPCP  | regulation market performance clearing price |

## Survey of U.S. Ancillary Services Markets

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|          |  |
|----------|--|
| RTC      | Real-time Commitment                     |
| RTM      | Real-time Market                         |
| RTO      | Regional Transmission Organization       |
| SCED     | Security-Constrained Economic Dispatch   |
| SERC     | SERC Reliability Corporation             |
| SPP      | Southwest Power Pool                     |
| Texas RE | Texas Reliability Entity, Inc.           |
| TMNSR    | Ten-minute Non-synchronized Reserves     |
| TMOR     | Thirty-minute Operating Reserves         |
| TMSR     | Ten-minute Synchronized Reserves         |
| WECC     | Western Electricity Coordinating Council |

### Summary

In addition to providing energy to end-consumers, power system operators are also responsible for ensuring system reliability. To this end, power markets maintain an array of ancillary services to ensure it is always possible to balance the supply and demand for energy in real-time. A subset of these ancillary services are commonly procured through market-based mechanisms: namely, Regulation, Spinning, and Non-spinning Reserves.

Regulation Reserves are maintained to respond to supply/demand imbalances over much shorter time frames, typically on the order of one to several seconds. Resources that provide Regulation Reserves adjust their generation or load levels in response to automatic generation control (AGC) signals provided by the system operator.

Operating reserves are maintained to provide additional generation capacity in the event that load increases or other supply side resources reduce their output or are taken offline. The reserves are typically segmented into two categories, 1) Spinning or Synchronized Reserves that are provided by generation units that are actively generating and have the ability to increase or decrease their output, 2) Non-spinning or Non-synchronized Reserves that are provided by generation resources that are not actively generating, but are able to start up and provide generation within a specified timeframe. Operating reserves typically have response times on the order of ten to 30 minutes and can similarly be provided by supply-side resources that are capable of reducing their load.

There are seven distinct power markets in the United States, each operated by a Regional Transmission Operator (RTO) or Independent System Operator (ISO) that manages transmission infrastructure in its territory, operates markets for energy and ancillary services, and maintains system reliability. Each power market offers its own set of ancillary services, and precise definitions, requirements, and market mechanisms differ between markets.

Despite the differences between markets, both in terms of services offered and system requirements, some broad trends generally apply. Regulation Reserves typically have the highest market prices, followed by Spinning Reserves and Non-spinning Reserves. Prices for Regulation Reserves have been the highest in the PJM market, since it opened in October 2012. This is partially because PJM experienced large price spikes during the period of extreme weather conditions in early 2014. ERCOT has traditionally had the highest prices for Spinning Reserves (called Responsive Reserves in ERCOT), including several periods of sustained high prices between 2010 and 2012. This can be explained in part by the relatively high penetration of variable wind resources and a similarly high requirement relative to peak load. ERCOT has also traditionally had the highest price for Non-spinning Reserves, followed by the NYISO East region. Both experienced several periods of prolonged high prices since their inception, an occurrence that has not been regularly seen in other markets.

Market size (in terms of capacity) typically follows the reverse order of prices, as systems maintain the most Non-spinning Reserves capacity followed by Spinning Reserves and Regulation Reserves. PJM has the largest market for Regulation Reserves both in terms of revenue and capacity. Total revenue in PJM has grown since the market opened in 2012 due to increased prices. The size of most Regulation

Reserves markets in terms of capacity stay relatively constant year-to-year, as this is dictated largely by system requirements. PJM also has the largest Spinning Reserves market in terms of capacity, but due to low prices in 2012 and 2013, total market revenue was relatively small prior to 2014. SPP, MISO, ISO-NE and SPP (beginning in 2014) all have Spinning Reserve markets with similar average capacity levels. When combined, the markets for Non-spinning and Operating reserves in ISO-NE have a comparable capacity to the market for Primary Reserves in PJM. SPP, MISO, and CAISO all have smaller markets for their respective Non-spinning Reserves products that are roughly the same size as each other in terms of capacity.

## 1 Overview

### 1.1 Ancillary Services Overview

In addition to generating energy to serve demand, generation units in a power system are also major providers of an array of ancillary services that support system reliability. Energy storage and demand response resources can also provide ancillary services, but currently do so to a lesser extent than supply-side resources in most power systems. The specific services offered and exact definitions of each service vary from market to market. In general, market operators procure ancillary services from market participants according to reliability standards established by the North American Electric Reliability Corporation (NERC) and/or regional Coordinating Councils, such as the Western Electricity Coordinating Council (WECC). Winning bids for energy and ancillary services are mutually exclusive, but a generator can be compensated for both generation and ancillary service provision in the same period as long as the capacities allocated to each do not overlap.

#### 1.1.1 Regulation and Frequency Response

Regulation service is used to constantly and automatically balance small fluctuations in supply and demand in real time. Generation units that are providing regulation service must be able to respond to automatic generation control (AGC) signals from the system operator and change their output accordingly on very short time scales, typically on the order of one to several seconds. Some markets offer only a single regulation product, while others offer separate products for Regulation-up (capacity that is available to increase output) and Regulation-down (capacity that is available to decrease output). Some markets have also created a separate market product for fast-frequency Regulation, which is typically provided by storage and demand response resources that can change output faster than traditional generators. Demand-side resources that are able to respond to AGC signals are also able to provide regulation services.

A product referred to as Regulation Mileage is also available in select markets. This is defined to be the “absolute change in automated generation control set points between four second intervals.” The market for Regulation Mileage compensates units for their performance in response to regulation signals, in addition to making their capacity available. This product is currently offered in the CAISO Expanded Region, NYISO (called Regulation Movement), and MISO. However, we do not include any analysis of these products here as they are relatively new, limited to only a handful of markets, and even then data are sparsely available.

#### 1.1.2 Operating Reserve – Spinning Reserve

Spinning reserves, sometimes also referred to as Synchronized Reserves, are intended to help the system respond quickly to forced outages or other contingency events. Spinning reserves are provided by generation units that are online but are not generating at full capacity and can therefore increase their output quickly to provide additional capacity to the system. Typically, generation units must be able to fully ramp up their generation within 10 to 15 minutes of receiving instructions to do so, depending on the details of the market. Demand-side resources can also provide spinning reserves if they are able to similarly reduce their load within 10 to 15 minutes of receiving an instruction.

### **1.1.3 Operating Reserve – Non-spinning Reserve**

Non-spinning reserves, sometimes referred to as Supplemental Reserves, are also intended to help the system recover from unplanned contingencies. However, non-spinning reserves can also be provided by generation units that are offline, as long as they are able to start up and increase their output to the target level within a predefined period of time, usually 10 to 30 minutes, depending on the market. Online units with available capacity can also provide non-spinning reserves. Therefore, the amount of non-spinning reserve capacity in a system is often calculated inclusive of any surplus spinning reserve capacity. The sum total of spinning and non-spinning reserves may also be collectively referred to as Primary Reserves, Supplemental Reserves, or Contingency Reserves.

### **1.1.4 Other Ancillary Services**

There are several other ancillary services that supply- and demand-side resources can provide to a power system, including black start capabilities, reactive supply and voltage control, and energy imbalance services. As many generation units require input energy in order to start up and begin operation, power systems must maintain a black start capability so that they are able to restore operations in the event of a system-wide power outage. Such black start generators typically rely on small diesel generators or energy storage resources to provide the initial energy needed for startup. Reactive power supply and voltage control are achieved by managing the amount of reactive power in an alternating-current power system. The provision of this service ensures that system voltages are maintained within a desired range and also seeks to minimize the congestion caused by reactive power in a transmission network, so as to maximize the transmission of real power. Energy imbalance service may be provided by either supply- or demand-side resources in the event that there is a difference between scheduled and delivered energy over the course of an operating period. Most U.S. power systems do not operate markets for these products but do maintain adequate resources through internal requirements and other procurement mechanisms. They are therefore not covered further in this report.

## **1.2 Overview of U.S. Power Markets**

There are seven distinct power markets in the United States (see Figure 1-1). In addition, there are three similar markets located within Canada. These markets are each operated by an Independent System Operator (ISO) or Regional Transmission Organization (RTO), hereafter jointly referred to as an ISO/RTO, which manages the transmission infrastructure in its service territory, administers markets for energy and ancillary services, and is responsible for ensuring that system reliability requirements that are established by NERC are met. With the exception of the Electric Reliability Council of Texas (ERCOT) system in Texas, each ISO/RTO is subject to the jurisdiction of the Federal Energy Regulatory Commission (FERC). As the ERCOT system is wholly contained within a single state, it does not participate in interstate commerce and is therefore not subject to FERC jurisdiction. Roughly two-thirds of all energy demand in the United States falls in territory served by an ISO/RTO; however, large portions of the Western and Southeastern United States are not served by an ISO/RTO. Generators and utilities in these regions do not participate in wholesale power markets, but rather fulfill service obligations through power purchase agreements, bilateral trades, and as vertically integrated utilities.

Each ISO/RTO operates markets for ancillary services. While these services typically fall into the three general categories outlined previously, Regulation, Spinning Reserves, and Non-spinning Reserves, the names and details of each service can differ from market to market. Table 1-1 summarizes the services offered in each ISO/RTO, and a more detailed discussion of each market is presented in the following sections.

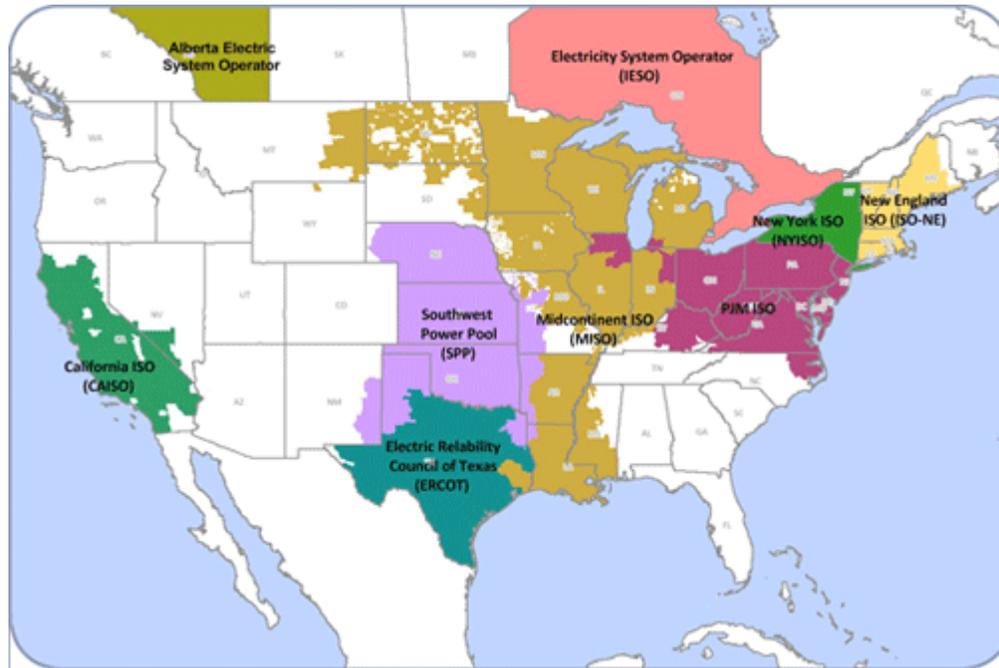


Figure 1-1 Map of the transmission operators that serve the United States

|               | Spinning Reserves                             | Non-spinning Reserves   | Regulation   |
|---------------|---|---|--|
| <b>CAISO</b>  | Spinning                                      | Non-spinning  | Regulation-up<br>Regulation-down<br>Regulation Mileage-up<br>Regulation Mileage-down |
| <b>ERCOT</b>  | Responsive                                    | Non-spinning  | Regulation-up<br>Regulation-down   |
| <b>ISO-NE</b> | Ten-minute Synchronized                       | Ten-minute Non-synchronized<br>Thirty-minute Operating        | Regulation   |
| <b>MISO</b>   | Spinning                                      | Supplemental  | Regulation   |
| <b>NYISO</b>  | Ten-minute Spinning<br>Thirty-minute Spinning | Ten-minute Non-synchronized<br>Thirty-minute Non-synchronized | Regulation   |
| <b>PJM</b>    | Synchronized                                  | Primary   | Regulation   |
| <b>SPP</b>    | Spinning                                      | Supplemental  | Regulation-up<br>Regulation-down   |

Table 1-1 Overview of the ancillary services offered by each ISO/RTO

## 2 CAISO

### 2.1 Overview

The California Independent System Operator (CAISO) was established in 1996 to operate the region's power grid and wholesale electric markets, which include an energy market, an ancillary service market, and a financial transmission rights market. CAISO procures Regulation-up, Regulation-down, Spinning Reserves, and Non-spinning Reserves in the Day Ahead Market (DAM) and Hour Ahead Market (HAM). Spinning and Non-spinning Reserves are jointly referred to as Contingency Reserves.

### 2.2 Regions

CAISO maintains two Ancillary Service Regions and eight Ancillary Service Sub-Regions. The two Ancillary Service Regions are the CAISO System Region and the CAISO Expanded System Region. The CAISO Expanded System Region is defined as the entire CAISO balancing authority area plus all system resources at scheduling points outside of the CAISO balancing authority area. The CAISO System Region is defined as the subset of certified resources defined in the CAISO Expanded System Region that are located internal to the CAISO balancing authority area.

There are eight sub-regions, each of which may have its own minimum ancillary service requirements based on system reliability conditions. Figure 2-1 illustrates the territory of the CAISO, and its sub-regions. Zone ZP26 in Figure 2-1 is divided into SP26 (South of Path 26) and NP26 (North of Path 26). There is an expanded region<sup>1</sup> for each of the four regions, with a total of eight sub-regions.

The minimum ancillary service constraints for the CAISO System Region are defined to be a percentage of the ancillary service requirements for the Expanded System Region, currently at 50%, to limit ancillary services procurement from System Resources for reliability purposes.



Figure 2-1 Map of the CAISO territory

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<sup>1</sup> The expanded ancillary service sub-region is defined to include all generators in the original sub-region, and specific inertie resources.

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## 2.3 Ancillary Services

CAISO currently has markets for Regulation-up, Regulation-down, Spinning Reserves, and Non-spinning Reserves. The requirements comply with both North American Electric Reliability Corporation (NERC) reliability criteria<sup>2</sup> and Western Electricity Coordinating Council (WECC) regional reliability standards. Table 2-1 summarizes the requirements and regions for each of the products.

| Product                    | Description  |
|----------------------------|--|
| Regulation-up              | <ul style="list-style-type: none"> <li>• Must immediately increase output in response to automated signals.</li> </ul>   |
| Regulation-down            | <ul style="list-style-type: none"> <li>• Must immediately decrease output in response to automated signals.</li> </ul>   |
| Regulation Mileage-up/down | <ul style="list-style-type: none"> <li>• The absolute change in output between four-second set points.</li> </ul>  |
| Spinning Reserves          | <ul style="list-style-type: none"> <li>• Synchronized to the grid.</li> <li>• Must respond within 10 minutes.</li> <li>• Must run for at least two hours.</li> </ul> |
| Non-Spinning Reserves      | <ul style="list-style-type: none"> <li>• Must respond within 10 minutes.</li> <li>• Must run for at least two hours.</li> </ul>                                      |

Table 2-1 Summary of ancillary services offered by CAISO

### 2.3.1 Regulation

Regulation Reserves must be able to respond to AGC signals in the CAISO balancing area. In CAISO, there are separate ancillary services for both Regulation-up and Regulation-down; the system requirement for Regulation is a target between 300 and 400 MW for each. This target is typically set as either a percentage of peak load or a fixed number so as to satisfy NERC reliability requirements. CAISO measures the accuracy of a resource’s response to CAISO Energy Management System (EMS) signals. It will sum a resource’s AGC set points for each four-second regulation interval every 15 minutes and then sum the total deviations from the AGC set point for each four-second regulation interval during that 15 minute period. CAISO then applies the resulting percentage to a resource’s instructed mileage to calculate the resource’s regulation performance payment.

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<sup>2</sup> For example, CAISO has applied the following NERC control performance standards, CPS 1, CPS 2, and Balance Authority ACE Limit (BAAL). CPS 1 is a statistical measure of area control error variability and its relationship to frequency error. CPS 2 is a statistical measure of ACE magnitude, designed to limit unacceptably large net unscheduled power flows by providing an oversight function that bounds area control error. Another control performance standard is BAAL, which maintains interconnection frequency within a predefined profile, under both normal and abnormal conditions, to prevent frequency-related instability, unplanned tripping of generation, or load, or uncontrolled separation, or cascading outages.

### **2.3.2 Spinning Reserves**

Spinning Reserves must be synchronized with the grid, able to respond within ten minutes, and able to run for at least two hours. Spinning Reserves must account for at least 50% of the total Contingency Reserves requirements.

### **2.3.3 Non-spinning Reserves**

Non-spinning Reserves must be able to respond within ten minutes and able to run for at least two hours. The combined requirement for Contingency Reserves (defined to be the sum of Spinning and Non-spinning Reserves) is equal to the largest single system contingency.

## **2.4 Market Process**

In the CAISO market, all ancillary service bids may be accompanied by an energy bid in the DAM, and must be accompanied by an energy bid in the Real-time Market (RTM). CAISO determines its ancillary service needs on the basis of an internal demand forecast, and obtains these ancillary services either through self-scheduling resources in its territory or through participation by resources in the CAISO Ancillary Services Market. Ancillary service bids are evaluated simultaneously with energy bids in the Integrated Forward Market to clear bid-in supply and demand. The Integrated Forward Market co-optimizes energy and ancillary services. The capacity of a resource with energy and ancillary service bids is optimally used to provide energy, and/or it is reserved for ancillary service provision in the form of ancillary service awards.

Contingency Reserves (Spinning Reserves and Non-Spinning Reserves) are procured in the DAM to meet 100% of the contingency reserve ancillary service requirement associated with the California Forecast of California Demand to satisfy current NERC Standards. If additional Contingency Reserves are necessary after the DAM, then they are purchased through the RTM.

Load serving entities in CAISO are required to procure ancillary services either through self-provision or through purchase on the CAISO market. They can also bid excess ancillary services into the market. Scheduling Coordinators simultaneously submit bids to supply any or all of the above products to the CAISO in conjunction with their preferred day-ahead and hour-ahead schedules. CAISO selects resources to provide ancillary service capacity based only on their capacity bid prices and deliverability.

Ancillary service marginal prices (ASMPs) are produced as a result of the co-optimization of energy and ancillary service for each ancillary region. They represent the marginal cost of providing an additional unit of that service. In supply shortage conditions, when co-optimization fails to clear the market and there is not a well-defined ASMP, CAISO will use scarcity reserve demand curves to set the administrative values for ASMPs. These are based upon a stepwise demand curve corresponding to the shortage of three upward reserve products (i.e. Spinning Reserves, Non-spinning Reserves, and Regulation-up) and a stepwise demand curve corresponding to shortage of Regulation-down service.

## 2.5 Resources

### 2.5.1 Data

<http://oasis.caiso.com/>

### 2.5.2 Ancillary Services Definition and Market Process

[http://www.caiso.com/Documents/Section8\\_AncillaryServices\\_Jul1\\_2013.pdf](http://www.caiso.com/Documents/Section8_AncillaryServices_Jul1_2013.pdf)

[http://bpmcm.caiso.com/BPM%20Document%20Library/Market%20Operations/BPM\\_for\\_Market%20Operations\\_V44\\_clean.doc](http://bpmcm.caiso.com/BPM%20Document%20Library/Market%20Operations/BPM_for_Market%20Operations_V44_clean.doc)

## 3 ERCOT

### 3.1 Overview

The Electricity Reliability Council of Texas (ERCOT) was established in its current form as a power market operator in 2001. ERCOT currently serves approximately 85% of the electrical load in Texas and, as its service territory is entirely within the state of Texas, is the only ISO/RTO in the United States that is not regulated by FERC. ERCOT operates a DAM for four ancillary services, Responsive Reserves, Regulation-up, Regulation-down, and Non-spinning Reserves. These services are co-optimized along with energy provisions in the DAM. In addition, ERCOT implemented a real-time Operating Reserve Demand Curve (ORDC) methodology in 2014. Through this process, price adders are generated to reflect the value of available reserves in the market in real time. These price adders are based on the administratively determined value of lost load in the system and the probability that load would have to be shed, given the realized reserve levels. Price adders are calculated for both online (synchronized) and offline (unsynchronized) reserves and are added to the real-time locational marginal price (LMP) to determine settlement price points. This process is intended to approximate the co-optimization of energy and reserves in real-time. ERCOT is subject to reliability standards that are developed by the Texas Reliability Entity, Inc. (Texas RE) through FERC approved processes. According to Texas RE, its standards “go beyond, add detail to, or implement NERC Reliability Standards.” ERCOT also updated their procedure for determining reserve requirements on June 1, 2015. The following discussion reflects these updated procedures.

### 3.2 Regions

There is only a single ERCOT region related to ancillary services, which spans the entire ERCOT service territory (see Figure 3-1). The real-time ORDC price adders for Spinning and Non-spinning Reserves are added to the real-time energy LMPs that are calculated for each energy settlement point. A single system-wide price adder is calculated for both Spinning and Non-spinning Reserves. These are then each added to energy prices at each node throughout the ERCOT system.



Figure 3-1 Map of the ERCOT service territory

### 3.3 Ancillary Services

As shown in Table 3-1, ERCOT operates markets for Regulation-up, Regulation-down, Responsive Reserves and Non-spinning Reserves.

| Product               | Description  |
|-----------------------|--|
| Regulation-up         | <ul style="list-style-type: none"> <li>Must immediately increase output in response to automated signals.</li> </ul>       |
| Regulation-down       | <ul style="list-style-type: none"> <li>Must immediately decrease output in response to automated signals.</li> </ul>       |
| Responsive Reserves   | Must respond within “the first few minutes of an event that causes a significant deviation from the standard frequency”    |
| Non-spinning Reserves | <ul style="list-style-type: none"> <li>Must respond within 30 minutes.</li> <li>Must run for at least one hour.</li> </ul> |

Table 3-1 Summary of ancillary services offered by ERCOT

#### 3.3.1 Regulation

Regulation Reserves are deployed by ERCOT in response to changes in the system frequency and are used to maintain system frequency within a predetermined range. The system requirements for Regulation-up and Regulation-down are determined as follows for Regulation-up/down respectively:

The largest of:

1. The 98.8th percentile of Regulation-up/down deployments over the last 30 days;
2. The 98.8th percentile of Regulation-up/down deployments in the same month of the previous year;
3. The 98.8th percentile of the positive/negative net load changes over the last 30 days; or
4. The 98.8th percentile of positive/negative net load deployments in the same month of the previous year.

This base value may be further adjusted as necessary because of increased wind penetration and other circumstances. Resources with the technical ability to provide Regulation Reserves may bid their supply into the market. Resources with winning bids after the market clears are paid the market clearing price (MCP) for each unit of capacity that they are selected to provide.

### 3.3.2 Responsive Reserve Service

Responsive Reserves must be able to respond quickly to changes in system frequency. Requirements for Responsive Reserves are calculated in four-hour blocks on the basis of forecasted load and wind patterns. Interruptible load resources can provide Responsive Reserves, but their contribution is limited to 50% of the total requirement in each hour.

### 3.3.3 Non-spinning Reserves

Non-spinning Reserves must be able to become synchronized with the grid, ramp to a specified output level within 30 minutes, and generate at that level for at least one hour. Reserve capacity that is already synchronized with the grid can also provide this service, as can demand-side resources that can reduce their load.

The system requirement for Non-spinning Reserves is determined by first calculating the 95th percentile of net load uncertainty from both the previous 30 days and the same month of the previous year. Net load is defined as total load minus wind generation, and net load uncertainty is defined as the difference between the realized net load and forecast net load. ERCOT then subtracts the Regulation-up requirement from this 95<sup>th</sup> percentile to obtain the Non-spinning Reserves requirement. During on-peak hours (hours 0700 through 2200 Central time, ERCOT also maintains a minimum Non-spinning requirement that is equal to the largest single unit in the system. The Non-spinning requirement is also never permitted to exceed 2000 MW during all hours of operation.

## 3.4 Market Process

In the DAM, ERCOT establishes an Ancillary Services Plan and publishes relevant system information each day by 0600 hours Central time. This Ancillary Services Plan identifies the ancillary service obligations of all Qualified Scheduling Entities<sup>3</sup> (QSEs) during each hour of the following day. QSEs can meet their obligations either through self-supply, bilateral trades with other QSEs, or purchases from ERCOT through the DAM. QSEs must submit their bids and offers for ancillary services by 1000 hours Central time. The day-ahead market is executed between 1000 and 1330 hours Central time, at which point results are posted. QSEs then have the opportunity to make bilateral trades with other QSEs based upon the results of the day-ahead market; any such trades must be reported to ERCOT by 1430 hours Central time.

In real-time operations security constrained economic dispatch (SCED) is conducted every five minutes and two price-adders are calculated on the basis of the reserve levels that are realized during each settlement period—currently every 15-minute interval. One adder is calculated on the basis of the realized level of online reserves and the other is calculated on the basis of the sum of the realized levels of online and offline reserves. These adders are then added to the LMP-based energy price that is paid

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<sup>3</sup> QSEs submit bids and offers on behalf of generating resource entities or load-serving entities..

to generating entities and charged to load-serving entities in each settlement period. If the Responsive Reserve level falls below a 2000 MW minimum contingency in any period, ERCOT will set the price adder to the administratively determined value of lost load (VOLL) in the system, which is currently \$9000/MWh.

### 3.5 Resources

#### 3.5.1 Methodologies for Determining Ancillary Service Requirements

<http://www.ercot.com/content/mktinfo/dam/kd/ERCOT%20Methodologies%20for%20Determining%20Ancillary%20Service.zip>

#### 3.5.2 Methodology for Implementing ORDC to Calculate Real-Time Reserve Price Adder

<http://www.ercot.com/content/mktinfo/rtm/kd/Methodology%20for%20Implementing%20ORDC%20to%20Calculate%20Real-Time%20Res.zip>

#### 3.5.3 ERCOT Training Documentation

[http://www.ercot.com/content/wcm/training\\_courses/107/ordc\\_workshop.pdf](http://www.ercot.com/content/wcm/training_courses/107/ordc_workshop.pdf)

[http://www.ercot.com/content/wcm/training\\_courses/58/GEN101\\_M2\\_Jan2010.pdf](http://www.ercot.com/content/wcm/training_courses/58/GEN101_M2_Jan2010.pdf)

## 4 ISO New England

### 4.1 Overview

ISO New England (ISO-NE) was established in 1997 and began operating a wholesale power market in 1999. It currently operates a forward reserve market and a real-time reserve pricing market, as well as a regulation market.

The forward reserve market secures commitments for Ten-minute Non-synchronized Reserves (TMNSR) and Thirty-minute Operating Reserves (TMOR) in the system during peak hours. A real-time reserve pricing market is also conducted throughout the operating day for both TMNSR and TMOR, as well as for an additional product, Ten-minute Synchronized Reserves (TMSR). This market is designed to offset the opportunity cost a resource faces when it is selected to provide reserves instead of energy in real-time. It also provides additional revenues that are consistent with the increased value of reserves and energy when the system is short.

### 4.2 Regions

ISO-NE consists of four zones for reserve products:

1. Southwest Connecticut
2. Connecticut
3. Northeast Massachusetts and Boston
4. Rest of System (all territory not included in the other zones)

There are system-wide requirements for TMSR, TMNSR and TMOR. In addition, there are individual requirements for TMOR in each of the first three zones (Table 4-1).

| Product                                      | Description  |
|--|--|
| Regulation                                   | <ul style="list-style-type: none"> <li>• Must immediately increase or decrease output in response to automated signals.</li> </ul> |
| Ten-minute Synchronized Reserves (TMSR)      | <ul style="list-style-type: none"> <li>• Synchronized to the grid.</li> <li>• Must respond within 10 minutes.</li> </ul>           |
| Ten-minute Non-synchronized Reserves (TMNSR) | <ul style="list-style-type: none"> <li>• Must respond within 10 minutes.</li> </ul>  |
| Thirty-minute Operating Reserves (TMOR)      | <ul style="list-style-type: none"> <li>• Must respond within 30 minutes.</li> </ul>  |

Table 4-1 Summary of ancillary services offered by ISO-NE

## 4.3 Ancillary Services

### 4.3.1 Regulation

Regulation Reserves must be able to increase or decrease generation output in response to automated signals from the system operator. These generation resources receive signals to adjust output every four seconds. The system requirements for Regulation Reserves are calculated in accordance with NERC Control Performance Criteria and vary hourly, daily and seasonally. Historical requirements are available on the ISO-NE website<sup>4</sup>. For every four-second interval, if observed performance closely matches AGC set points, the regulation interval performance score (RIPS) will be 100%. The compensation for each Regulation Reserves supplier is then adjusted in proportion to the RIPS performance score in each interval.

### 4.3.2 Ten-Minute Spinning Reserves

Ten-minute Spinning Reserves must be synchronized with the grid and able to convert their capacity into generation within ten minutes of receiving a signal from the system operator.

### 4.3.3 Ten-Minute Non-spinning Reserves

Ten-minute Non-spinning Reserves must be able to convert their capacity into generation within ten minutes of receiving a signal from the system operator, but do not necessarily have to be synchronized with the grid.

During normal conditions, the combined quantity of TMSR and TMNSR must be at least as great as the capacity of the largest single system contingency multiplied by a Contingency Reserve Adjustment Factor for the most recent operating quarter. Regulation Reserves that are available within 10 minutes can also contribute to this requirement. As a baseline, 100% of the total ten-minute reserve capacity

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<sup>4</sup> <http://www.iso-ne.com/isoexpress/web/reports/operations/-/tree/daily-regulation-requirement>

must be spinning (TMSR); however, this requirement may decrease to as low as 25% at the discretion of the ISO. The process for adjusting the required TMSR percentage is outlined in detail in NE-ISO Operating Procedure No. 8<sup>5</sup>.

### 4.3.4 Thirty-Minute Operating Reserves

Thirty-minute Operating Reserves must be able to convert their capacity into generation within thirty minutes of receiving a signal from the system operator, but do not necessarily have to be synchronized with the grid. The TMOR requirement is equal to 50% of the second-largest system contingency. Excess TMSR and TMNSR may also contribute to meeting this requirement.

## 4.4 Market Process

A forward market auction for reserve (non-energy) capacity occurs twice per year, prior to the beginning of each seasonal capability period. These periods run from June through September (summer) and October through May (winter). Forward reserve resources are assigned hourly schedules one day in advance of the operating day. The market is designed to set threshold prices at approximately the marginal cost of a peaking plant with a 2–3% capacity factor.

In real-time operations, ISO-NE co-optimizes energy and reserves, finding the least-cost means of serving energy demand and meeting reserve requirements for TMSR (whole-system), TMNSR (whole-system) and TMOR (whole-system and the three specified zones). If necessary, the system will re-dispatch resources to increase the amount of reserves that are available. This typically involves reducing the output of fast-response resources, which may increase the real-time energy LMP. There are administratively defined limits on these potential LMP increases, known as Reserve Constraint Penalty Factors. In addition to these real-time reserve prices, a regulation clearing price is also calculated on the basis of the offer of the highest marginal cost resource providing regulation capacity in each 5-minute settlement period.

## 4.5 Resources

### 4.5.1 Overview of ISO New England's Wholesale Electricity Markets and Market Oversight

[http://www.iso-ne.com/pubs/spcl\\_rpts/2013/markets\\_overview\\_051513\\_final.pdf](http://www.iso-ne.com/pubs/spcl_rpts/2013/markets_overview_051513_final.pdf)

### 4.5.2 ISO New England Operating Procedure No. 8: Operating Reserve and Regulation

[http://www.iso-ne.com/static-assets/documents/rules\\_proceeds/operating/isone/op8/op8\\_rto\\_final.pdf](http://www.iso-ne.com/static-assets/documents/rules_proceeds/operating/isone/op8/op8_rto_final.pdf)

## 5 MISO

### 5.1 Overview

The Midcontinent Independent System Operator (MISO) operates an Ancillary Services Market for Regulation and Contingency Reserves, which began operation in 2009. Currently, MISO operates both a DAM and RTM for ancillary services, which are simultaneously co-optimized with its Day-ahead and

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<sup>5</sup> [http://www.iso-ne.com/static-assets/documents/rules\\_proceeds/operating/isone/op8/op8\\_rto\\_final.pdf](http://www.iso-ne.com/static-assets/documents/rules_proceeds/operating/isone/op8/op8_rto_final.pdf)

Real-time energy market. MISO’s contingency reserve consists of two separate products for Spinning Reserves and Supplemental (Non-spinning) Reserves.

### 5.2 Regions

MISO manages the transmission network and energy markets throughout a geographic area from Montana to Michigan, and Manitoba, Canada. In late 2013, MISO expanded to include the new MISO South sub-region, which spans portions of Texas, Louisiana, Mississippi, and Arkansas.

MISO determines the ancillary service requirements on both a system-wide level and a zonal level. Figure 5-1 illustrates the MISO reserve zones, also known as MCP zones. Separate MCPs are calculated for Regulating, Spinning and Supplemental Reserves in each zone. There are seven such zones in MISO related to ancillary services provision.

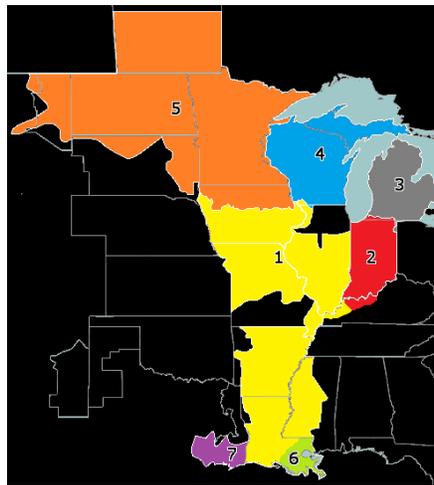


Figure 5-1 Map of MISO ancillary market

### 5.3 Ancillary Services

MISO currently has markets for Regulation, Spinning Reserves, and Supplemental Reserves in both the Day-ahead and Real-time Energy and Operating Reserve Market. Table 5-1 summarizes the ancillary services offered by MISO.

| Product              | Description  |
|----------------------|--|
| Regulation           | <ul style="list-style-type: none"> <li>• Must respond fully within five minutes.</li> <li>• Online and synchronized with the grid.</li> <li>• Able to respond to automated signals.</li> </ul> |
| Spinning Reserve     | <ul style="list-style-type: none"> <li>• Synchronized to the grid.</li> <li>• Must respond within 10 minutes.</li> </ul>   |
| Supplemental Reserve | <ul style="list-style-type: none"> <li>• Not necessarily synchronized to the grid.</li> <li>• Must respond within 10 minutes.</li> </ul>   |

Table 5-1 Summary of ancillary services offered by MISO.

### 5.3.1 Regulation Reserves

Regulation Reserves are comprised of two components: generation-based resources and stored energy resources. These resources must be able to adjust their output in response to automatic signals within five minutes of receiving a signal to do so. MISO has only a single product for Regulation Reserves. The system requirement for total Regulation Reserves across all zones varies between 300 MW and 500 MW, depending on system conditions. This requirement is not based explicitly on NERC standards, but rather on operational experience.

### 5.3.2 Spinning Reserves

Spinning Reserves can be provided by either generation resources or demand-side resources at MISO. This capacity must be synchronized to the grid and able to adjust output within ten minutes of receiving an instruction to do so. There is a fixed requirement of 1000 MW for Spinning Reserves.

### 5.3.3 Supplemental Reserves

Supplemental Reserves can be provided by either generation resources or demand-side resources at MISO. This capacity does not necessarily need to be synchronized to the grid, but must be able to start up and adjust output within ten minutes of receiving an instruction to do so. There is a fixed requirement of 1000 MW for Supplemental Reserves.

## 5.4 Market Process

In the MISO market, resource owners who wish to participate in the DAM must submit offers no later than 1100 hours EST on the day prior to the operating day for use in clearing the market. At 1500 hours EST, the results for the DAM are posted. From 1500 to 1600 hours EST, participants can revise offers for RAC Post Day-Ahead (with knowledge of DAM results).

MISO calculates ex-ante and ex-post MCPs for Regulation Reserves, Spinning Reserves and Supplemental Reserves at all Resource nodes in the system. These ancillary service prices are determined through co-optimization with the energy market using a SCED-pricing algorithm, in both Day-ahead and Real-time operations. In the Day-ahead Operating Reserve Market, ex-ante MCPs and ex-post MCPs are calculated on an hourly basis. In the Real-time Operating Reserve Markets, MCPs are calculated for each five-minute dispatch interval on both an ex-ante and ex-post basis.

When the market is short of one or more of its ancillary service products, MISO uses an administratively defined demand curve to set prices. This price of each ancillary service is also included in the price of all higher-valued reserves and the energy price as a consequence of co-optimized market clearing. The demand curves are designed such that i) under abundant conditions, the supply curve sets the price and the demand curve determines the amount supplied, and ii) under scarcity conditions, the demand curve sets the price and the supply curve determines the amount supplied. Separate demand curves are applied both to the entire market (Market-Wide Operating Reserve, etc.) and to each Reserve Zone (Zonal Operating Reserve, etc.).

## 5.5 Resources

### 5.5.1 Ancillary Services Definition and Market Process

<https://www.misoenergy.org/Library/Repository/Report/IMM/2014%20State%20of%20the%20Market%20Report.pdf>

<https://www.misoenergy.org/MarketsOperations/RealTimeMarketData/Pages/AncillaryMarketMCP.aspx>

<https://www.misoenergy.org/Library/BusinessPracticesManuals/Pages/BusinessPracticesManuals.aspx>

<https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/Training%20Materials/200%20Level%20Training/Level%20200%20-%20Energy%20and%20Operating%20Reserves%20Markets.pdf>

## 6 NYSIO

### 6.1 Overview

In December 1999, New York ISO (NYISO) took over responsibility for the electric grid in New York. NYISO operates DAMs for both ancillary services and energy, which are co-optimized. In February 2005, a number of enhancements to the RTM systems were implemented, and a two-settlement system was designed for the Reserve and Regulation Markets. NYISO operates markets for Regulation Reserves and four Operating Reserve products: Ten-minute Spinning Reserves, Ten-minute Non-synchronized Reserves, Thirty-minute Spinning Reserves, and Thirty-minute Non-synchronized Reserves.

### 6.2 Regions

NYSIO consists of three zones for reserve products:

1. West of Central-East (West or Western)
2. East of Central-East, Excluding Long Island (East or Eastern)
3. Long Island

NYISO determines separate DAM and RTM prices for Regulation and each of the three Operating Reserve products in the East and West regions. NYISO also calculates separate reserve prices in the Long Island Region, but does not post them or use them for settlement purposes. The regions are illustrated in Figure 6-1.



Figure 6-1 Map of NYISO East, West, and Long Island regions

### 6.3 Ancillary Services

Operating Reserves provide backup generation and/or demand response in the event that the NYISO experiences a real-time power system contingency requiring emergency corrective action (Table 6-1).

| Product                                  | Description  |
|--|--|
| Regulation                               | <ul style="list-style-type: none"> <li>Must immediately increase or decrease output in response to automated signals.</li> </ul> |
| Ten-minute Spinning Reserves             | <ul style="list-style-type: none"> <li>Synchronized to the grid.</li> <li>Must respond within 10 minutes.</li> </ul>             |
| Ten-minute Non- synchronized Reserves    | <ul style="list-style-type: none"> <li>Must respond within 10 minutes.</li> </ul>  |
| Thirty-minute Spinning Reserves          | <ul style="list-style-type: none"> <li>Synchronized to the grid.</li> <li>Must respond within 30 minutes.</li> </ul>             |
| Thirty-minute Non- synchronized Reserves | <ul style="list-style-type: none"> <li>Must respond within 30 minutes.</li> </ul>  |

Table 6-1 Summary of operating reserve services offered by NYISO

#### 6.3.1 Regulation

Regulation Reserves are necessary for the continuous balancing of resources (generation and NY Control Area interchange) with load, and to assist in maintaining scheduled interconnection frequency at 60 Hz. The system requirements for Regulation Reserves are determined by the NYISO, consistent with industry standards set by NERC, and may vary by hour or season. These requirements may also consider transmission constraints and include additional locational requirements. Resources may submit bids for Regulation Reserves until the RTM closes, 75 minutes prior to the operating hour. Each potential supplier includes several different response rates (in MW per minute) that can be achieved by its resource under various system conditions as part of each bid. Generators and demand-side resources are not permitted to provide regulation capacity in excess of their normal response rate (NRR) times five minutes.

#### 6.3.2 Ten-minute Spinning Reserves

Ten-minute Spinning Reserves must be synchronized with the grid and able to convert their capacity into generation within ten minutes of receiving a signal from the system operator. The system-wide requirement for Ten-minute Spinning Reserves is equal to 50% of the largest single system contingency (655 MW). There is also an additional specific requirement for the East region (330 MW).

### 6.3.3 Ten-minute Non-synchronized Reserves

Ten-minute Non-synchronized Reserves must be able to convert their capacity into generation within ten minutes of receiving a signal from the system operator, but do not necessarily have to be synchronized with the grid. The combined quantity of Ten-minute Reserves (Spinning and Non-synchronized) must be greater than or equal to the single largest system contingency (1310 MW). There are also additional specific requirements for the East region (1200 MW) and for Long Island (120 MW).

### 6.3.4 Thirty-minute Spinning Reserve

Thirty-minute Spinning Reserves must be synchronized with the grid and able to convert their capacity into generation within thirty minutes of receiving a signal from the system operator. There is no specific system requirement for Thirty-minute Spinning Reserves alone.

### 6.3.5 Thirty-minute Non-synchronized Reserves

Thirty-minute Non-synchronized Reserves must be able to convert their capacity into generation within thirty minutes of receiving a signal from the system operator, but do not necessarily have to be synchronized with the grid. The combined quantity of Thirty-minute Reserves (Spinning and Non-synchronized) must be greater than or equal to 150% of the single largest system contingency (1965 MW). There are also additional specific requirements for the East region (1200 MW) and for Long Island (270–540 MW).

## 6.4 Market Process

Ancillary services are procured through a DAM, HAM, and RTM. The DAM ancillary service prices are posted at approximately 1100 hours Eastern time for the East and West regions. In the DAM, resources may submit availability bids for each hour of the upcoming day. NYISO selects operating reserve suppliers for each hour of the upcoming day through a co-optimized day-ahead commitment process that minimizes the total cost of energy, operating reserves, and regulation service, according to the bids submitted by market participants. The HAM ancillary service prices are posted approximately 75 minutes before each Real-time Commitment (RTC) interval for the East and West regions.

The RTM ancillary service prices for the selected date are posted every five minutes for the East and West regions. NYISO will automatically select operating reserve suppliers in the RTM from eligible resources. All suppliers will automatically be assigned a real-time operating reserves availability bid of \$0/MW. Suppliers will thus be selected on the basis of their response rates, their applicable upper operating limit, and their energy bid (which will reflect their opportunity costs). This selection takes place through a co-optimized RTC and dispatch process that minimizes the total cost of energy, regulation, and operating reserves.

In order to balance operating reserve settlements, when the real-time schedule is less than the day-ahead schedule, the supplier pays a charge for the imbalance equal to the product of (i) the RTM Clearing Price for the relevant operating reserves product in the relevant location and (ii) the difference between the supplier's day-ahead and real-time operating reserves schedules. When the supplier's real-time operating reserves schedule is greater than its day-ahead operating reserves schedule, the NYISO pays the supplier for the imbalance equal to the product of (i) the RTM clearing price for the relevant

operating reserve product in the relevant location and (ii) the difference between the supplier's day-ahead and real-time operating reserves schedules.

## 6.5 Resources

### 6.5.1 Data

[http://www.nyiso.com/public/markets\\_operations/market\\_data/pricing\\_data/index.jsp](http://www.nyiso.com/public/markets_operations/market_data/pricing_data/index.jsp)

### 6.5.2 Ancillary Services Definition and Market Process

[http://www.nyiso.com/public/webdocs/markets\\_operations/documents/Manuals\\_and\\_Guides/Manuals/Operations/ancserv.pdf](http://www.nyiso.com/public/webdocs/markets_operations/documents/Manuals_and_Guides/Manuals/Operations/ancserv.pdf)

[http://www.nyiso.com/public/webdocs/markets\\_operations/documents/Manuals\\_and\\_Guides/Guides/User\\_Guides/mpug.pdf](http://www.nyiso.com/public/webdocs/markets_operations/documents/Manuals_and_Guides/Guides/User_Guides/mpug.pdf)

[http://www.nyiso.com/public/webdocs/markets\\_operations/committees/bic\\_miwg/meeting\\_materials/2014-11-04/Comprehensive%20Shortage%20Pricing%20November%20MIWG%20FINAL.pdfPJM](http://www.nyiso.com/public/webdocs/markets_operations/committees/bic_miwg/meeting_materials/2014-11-04/Comprehensive%20Shortage%20Pricing%20November%20MIWG%20FINAL.pdfPJM)

## 7 PJM

### 7.1 Overview

PJM implemented several coordinated ancillary service markets in 2001 to co-optimize the provision of energy, regulation and operating reserves. These include a Day-Ahead Energy Market, Real-Time Energy Market, Forward Regulation Market, Forward Synchronized Reserve Market, and Forward Day-Ahead Scheduling Reserve Market. Both generation and demand resources are allowed to participate in each ancillary service market with eligibility validation. Load-serving entities are obliged to acquire a share of the PJM ancillary services requirement in any of three ways: self-scheduling the entity's own resources; bilateral contracts to purchase services from other participants; and purchasing services from the ancillary service markets. The share of obligation is determined on the basis of the entity's total load in the PJM RTO.

### 7.2 Regions

PJM consists of two zones for reserve products:

1. PJM RTO
2. PJM Mid-Atlantic Dominion (PJM MAD)

The PJM RTO zone spans the entire PJM territory (including PJM MAD), while PJM MAD is a sub-zone covering the eastern portion of the PJM territory. PJM applies a unified regulation requirement for the whole PJM RTO region. Owing to potential deliverability issues, PJM also established the MAD sub-zone for synchronized reserve and primary reserve services, as illustrated in Figure 7-1.

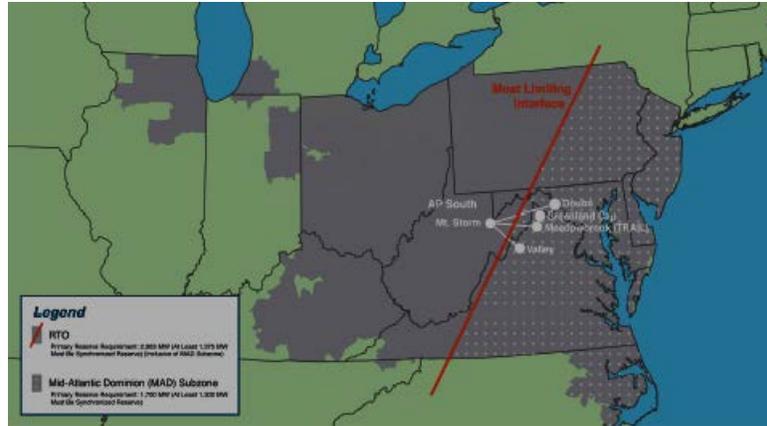


Figure 7-1 Map of PJM RTO territory and MAD Sub-Zone

### 7.3 Ancillary Services

PJM currently has markets for Regulation, Synchronized Reserves, and Primary Reserves. PJM determines the hourly zonal demands for Regulation and Synchronized Reserves in accordance with NERC reliability requirements. PJM monitors and adjusts reserves to ensure compliance with NERC, SERC Reliability Corporation (SERC), and ReliabilityFirst Corporation (RFC) Balance standards for the PJM Balancing Area. Table 7-1 summarizes the requirements and regions for each of the products.

| Product               | Description  |
|-----------------------|--|
| Regulation            | <ul style="list-style-type: none"> <li>Must immediately increase or decrease output in response to automated signals.</li> </ul> |
| Synchronized Reserves | <ul style="list-style-type: none"> <li>Synchronized to the grid.</li> <li>Must respond within 10 minutes.</li> </ul>             |
| Primary Reserves      | <ul style="list-style-type: none"> <li>Must respond within 10 minutes.</li> <li>Includes Synchronized Reserves.</li> </ul>       |

Table 7-1 Summary of ancillary services offered by PJM

#### 7.3.1 Regulation

Regulation Reserves must be able to increase or decrease their output in response to automated control signals within five minutes in order to maintain target system frequency. There are two important regulation signals: regulation signal A and D. Regulation signal A is a function of total ACE. Signal D was specifically developed for energy storage devices with limited storage capabilities. It is designed so that storage can provide more signal-correcting output in the short-term with less storage needs. The resource is monitored for accuracy at a ten-second scan rate; payments are reduced for poor accuracy. Resources must be able to sustain full output for 40 minutes. There is no separate Regulation product for the PJM MAD sub-zone, only a single product for the entire PJM RTO. The Regulation requirement is equal to 700 MW during peak periods (0500–2359 hours) and 525 MW during off-peak periods (0000–0459 hours).

### 7.3.2 Synchronized Reserves

Synchronized Reserves must be synchronized with the grid and able to convert their capacity into generation within ten minutes of receiving a signal from the system operator. There are two separate Synchronized Reserve products for the whole PJM RTO and for the PJM MAD sub-zone. The requirement for the whole PJM system is equal to the greater of (i) the RFC-imposed minimum requirement and (ii) the largest contingency on the system. The requirement for the PJM MAD sub-zone is equal to the largest contingency in PJM MAD.

### 7.3.3 Primary Reserves

The Primary Reserves product in PJM represents the combined quantity of available Synchronized Reserves and Non-synchronized Reserves (also available within ten minutes). There are two separate Primary Reserve products for the whole PJM RTO and for the PJM MAD sub-zone. The requirement for the whole PJM system is equal to 150% of the largest contingency on the system. The requirement for the PJM MAD sub-zone is set to a predefined value, usually 1700 MW.

## 7.4 Market Process

Ancillary service prices and cost-related data must be supplied by 1800 hours Eastern time one day ahead of operation and are applicable for the entire 24-hour period. All data can be revised until 60 minutes before the operating hour. Sixty minutes prior to the operating hour, PJM executes the Ancillary Services Optimizer to jointly optimize energy, Synchronized Reserves, Primary Reserves, and Regulation on the basis of forecasted system conditions to determine an economical set of inflexible reserve resources to commit for the operating hour.

In the PJM regulation market, resource owners also submit specific offers for regulation capability and regulation performance. PJM optimizes the RTO dispatch profile and forecasts LMPs to calculate an hourly regulation market clearing price (RMCP), regulation market performance clearing price (RMPCP), and regulation market capability clearing price (RMCCP). For each hour, RMCP is the total of RMPCP and RMCCP.

PJM calculates real-time prices for Synchronized Reserves and Primary Reserves simultaneously with the LMP every five minutes in real time. When there is no Synchronized Reserve shortage, the prices will be determined by the cost of the marginal Synchronized Reserve resource, which is defined as the Synchronized Reserve offer plus any opportunity cost for this resource relative to forgone energy or other ancillary service payments. When there is no Primary Reserve shortage, the prices will be determined by the cost of the marginal Primary Reserve resource, which is defined as the opportunity cost for this resource relative to forgone energy or other ancillary service payments. When there is a shortage in Synchronized Reserves, then the price will be the sum of the Primary Reserve and Synchronized Reserve penalty factors. When there is a shortage in Primary Reserves, the Primary Reserves price will be equal to the penalty factor of the location where the shortage occurred.

## 7.5 Resources

### 7.5.1 Data

<http://www.pjm.com/markets-and-operations/ancillary-services.aspx>

### 7.5.2 Ancillary Services Definition and Market Process

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

[http://www.monitoringanalytics.com/reports/PJM\\_State\\_of\\_the\\_Market/2015.shtml](http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2015.shtml)

## 8 SPP

### 8.1 Overview

In March 2014, the Southwest Power Pool (SPP) began operating an Integrated Marketplace that conducts a market-based procurement of three types of ancillary services: Regulation (Regulation-up and Regulation-down), Spinning Contingency Reserves, and Non-spinning Contingency Reserves. These services are supplied by generators and are purchased by SPP on the basis of a pre-determined requirement. The market-based mechanisms for ancillary service procurement are part of the SPP Integrated Marketplace, whereby ancillary services are introduced in conjunction with the SPP's day-ahead energy and the real-time balancing markets. Furthermore, SPP co-optimizes procurement of ancillary services with day-ahead and real-time energy. Regulation is a power supply product that is used to continuously supply the SPP balancing authority area in order to maintain Area Control Error in accordance with NERC control performance criteria. Regulation-up and Regulation-down services are provided by generators that are specially equipped with AGC, which allows near-continuous adjustment to meet the regulation set points. Contingency Reserves are supplied by resources that are able to supply energy to the system within ten-minutes of a contingency event (unexpected generator or transmission equipment outages). Contingency Reserves are comprised of Synchronized (Spinning) Reserves, from online resources that are synchronized with the system, and Non-spinning (Supplemental) Reserves, from offline resources. SPP operates both a DAM and RTM for ancillary services.

### 8.2 Regions

The SPP region covers Kansas, Oklahoma, and parts of New Mexico, Texas, Louisiana, Missouri, Mississippi, and Arkansas. As illustrated in Figure 8-1, the SPP regional footprint is composed of 16 balancing authorities:

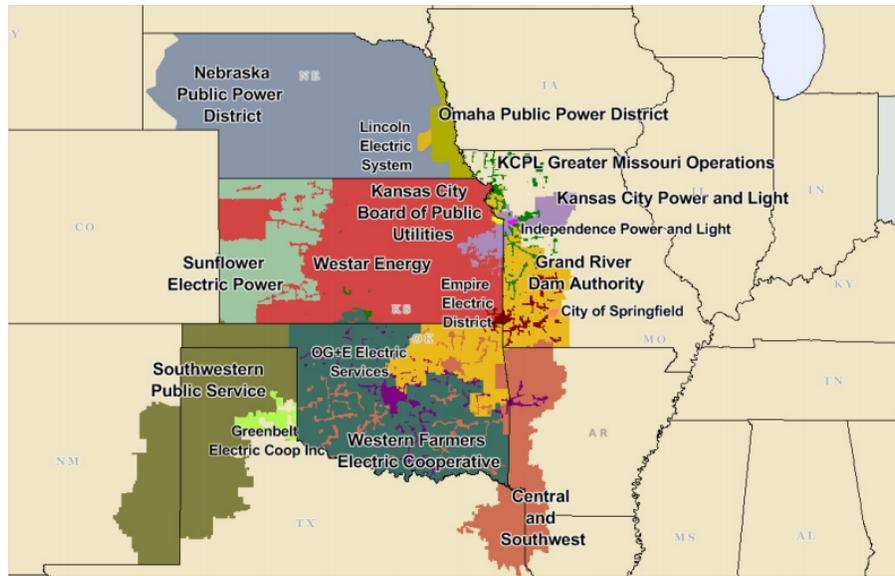


Figure 8-1 Map of the SPP territory

### 8.3 Ancillary Services

SPP currently has markets for Regulation Reserves, Spinning Reserves, and Non-spinning Reserves. Table 8-1 summarizes the requirements and regions for each of the products. Regulation Reserves must be able to respond to AGC on a four-second basis, including telemetering that can be scanned and updated on a two-second basis. They must also be capable of deploying 100 percent of their cleared Regulation-up or Regulation-down capacity within the Regulation Response Time for a continuous duration of 60 minutes.

SPP establishes a minimum Regulation Reserve requirement for each of its balancing authorities, each of which is sufficient to maintain compliance with control performance standards.

The Spinning Reserve allocated to any generating unit shall not exceed the amount of capacity increase that will be realized by prime-mover governor action because of a drop in frequency to 59.5 Hertz (less than or equal to 16.7% of unit capability at a 5% droop setting). At least half of the total Contingency Reserves must be Spinning Reserves.

| Product               | Description  |
|-----------------------|--|
| Regulation            | <ul style="list-style-type: none"> <li>Must immediately increase or decrease output in response to automated signals.</li> </ul>     |
| Spinning Reserves     | <ul style="list-style-type: none"> <li>Synchronized to the grid.</li> <li>Must respond within 10 minutes.</li> </ul>                 |
| Non-spinning Reserves | <ul style="list-style-type: none"> <li>Not necessarily synchronized to the grid.</li> <li>Must respond within 10 minutes.</li> </ul> |

Table 8-1 Summary of ancillary services offered by SPP

## **8.4 Market Process**

The DAM provides market participants with the ability to submit bids and offers for energy and ancillary services. Market participants submit offers and bids from 0000 to 1100 hours Central time, and SPP posts operating reserve requirements at 0700 hours Central time. SPP performs the DAM process from 1100 to 1600 hours Central time, and posts the DAM results at 1600 hours Central time.

## 9 Comparative Analysis

This section presents ancillary service market data for the various RTO markets over the entire period for which such data are available. It also provides direct annual comparisons of the prices and market sizes for each product in each market in terms of both revenue and capacity. Price data are shown as a 7-day moving average to reduce noise, isolate trends, and make the results easier to interpret. Sections 9.1, 9.2, and 9.3 present time-series price and market size data for the Regulation, Spinning, and Non-spinning Reserves products in each market. More detailed annual summary data are presented in tabular form in Section 9.4. Additional figures and other market data are also available in the Appendix.

### 9.1 Regulation Reserves Market Data

The Regulation Reserves market data that are analyzed in this section are summarized in Table 9-1.

| Market | Date Available | DAM/RTM | Availability of Market Size Data | Additional Information  |
|--------|----------------|---------|----------------------------------|---|
| CAISO  | 4/1/2009       | DAM     | Y                                | Price and market size data are reported for the CAISO Expanded Region.  |
| ERCOT  | 7/31/2001      | DAM     | N                                |   |
| ISO-NE | -              | -       | N                                | Regulation data currently unavailable.  |
| MISO   | 1/1/2010       | DAM     | Y                                | Regulation prices are the same across all zones.  |
| NYISO  | 2/1/2005       | RTM     | N                                | Regulation prices are the same across all zones.  |
| PJM    | 10/1/2012      | RTM     | Y                                | Price and market size data are reported for the whole PJM Region. PJM does not operate a separate Regulation market for its MAD sub-region. |
| SPP    | 3/1/2014       | DAM     | Y                                | Regulation prices are the same across all zones.  |

Table 9-1 Summary of the Regulation Reserves market data that are analyzed in this section

Figures 9-1 and 9-2 show the seven-day moving average price for all Regulation Reserves in each market over the entire period for which data are available. The prices for Regulation Reserves in the NYISO East and West regions are always the same, although the prices for Spinning and Non-spinning Reserves do differ between regions. NYISO consistently experienced higher prices for Regulation Reserves than ERCOT between 2006 and 2011; however, ERCOT experienced large price spikes in 2001 immediately after the market opened, as well as in 2003 and 2011. Note that because Figure 9-1 presents a seven-day moving average, these price spikes represent relatively sustained price increases, as opposed to events lasting for just a single hour. PJM has only operated its current market for Regulation Reserves since October 2012. In that time, prices at PJM have been consistently higher and more volatile than those found in other markets. PJM experienced particularly large price spikes for Regulation Reserves as a consequence of extreme weather conditions during the “Polar Vortex” of early 2014. PJM also has less Regulation Reserves provided by relatively inexpensive hydroelectric resources than most other markets do. Additional factors that might also play a role in the price differentiation across markets are payment structure, generation mix, network topology, etc. CAISO, ERCOT, and SPP have separate Regulation-up and Regulation-down prices, while ISO-NE, NYISO, MISO, and PJM have the same prices for Regulation-up and Regulation-down (a single ancillary service called Regulation). Price data for Regulation Reserves

are not available for ISO-NE. In general, Regulation-up prices are higher and more volatile than Regulation-down prices because it is more costly to deploy Regulation-up.

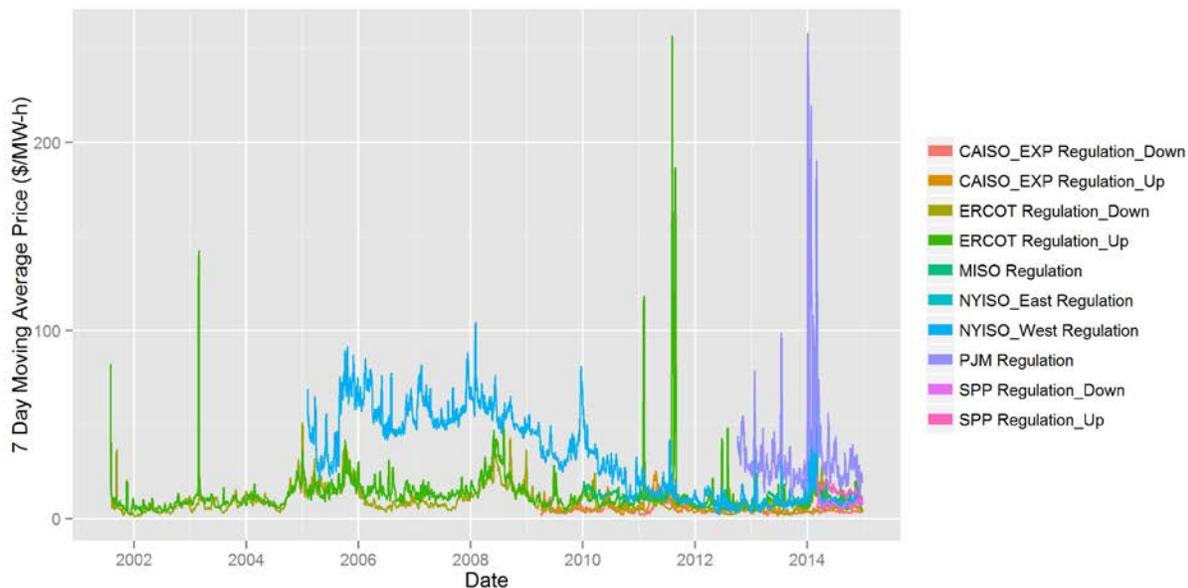


Figure 9-1 Seven-day moving average prices in each Regulation Reserves market

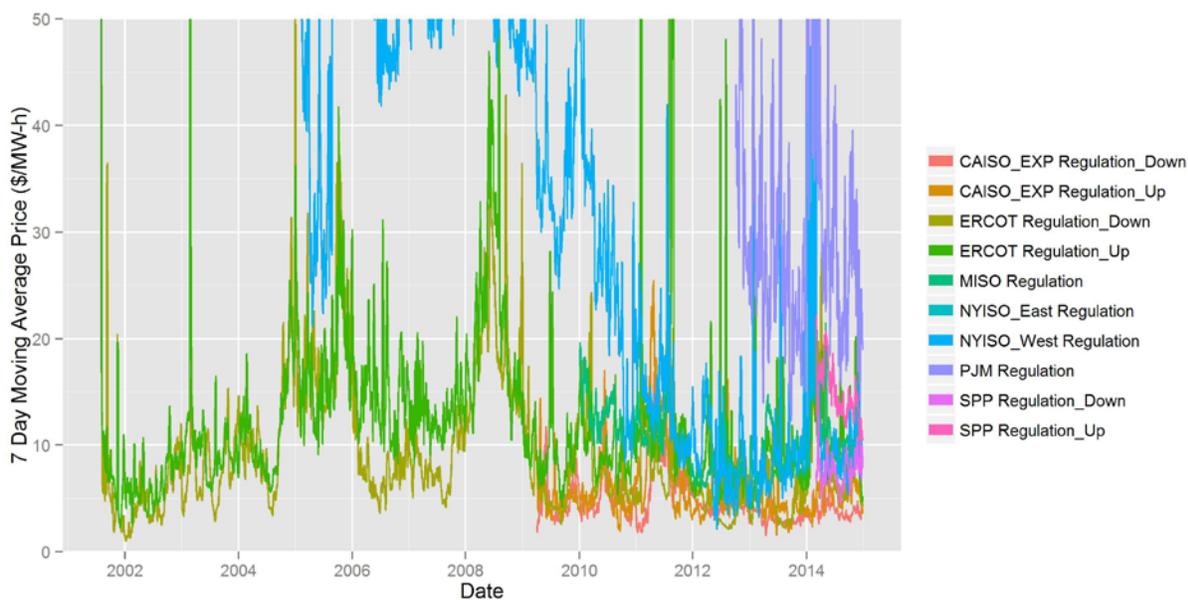


Figure 9-2 Seven-day moving average prices in each Regulation Reserves market with the y-axis capped at \$50/MW-h

Figures 9-3 and 9-4 show the growth in market size for Regulation Reserves across all ISO/RTOs for which data are available, expressed in terms of total market revenue and average market capacity respectively. The three markets for which market size data are not available, ERCOT, ISO-NE, and NYISO, are not depicted in this figure. Therefore, even though ERCOT and NYISO have operated markets for Regulation Reserves since 2001 and 2005, respectively, data are not presented for the period before CAISO began operating its market in 2009. The total revenue of the CAISO Regulation market has decreased since 2009, while the MISO market has maintained a roughly constant revenue level since it began operation in 2010. The PJM market is by far the largest of those for which data are available, at over \$250 million in 2014, and it has grown in revenue consistently since being established in 2012. MISO had the next-largest Regulation market in 2014, with \$43 million in revenue. Most market sizes in terms of capacity remain relatively constant year-to-year as these are largely dictated by system requirements.

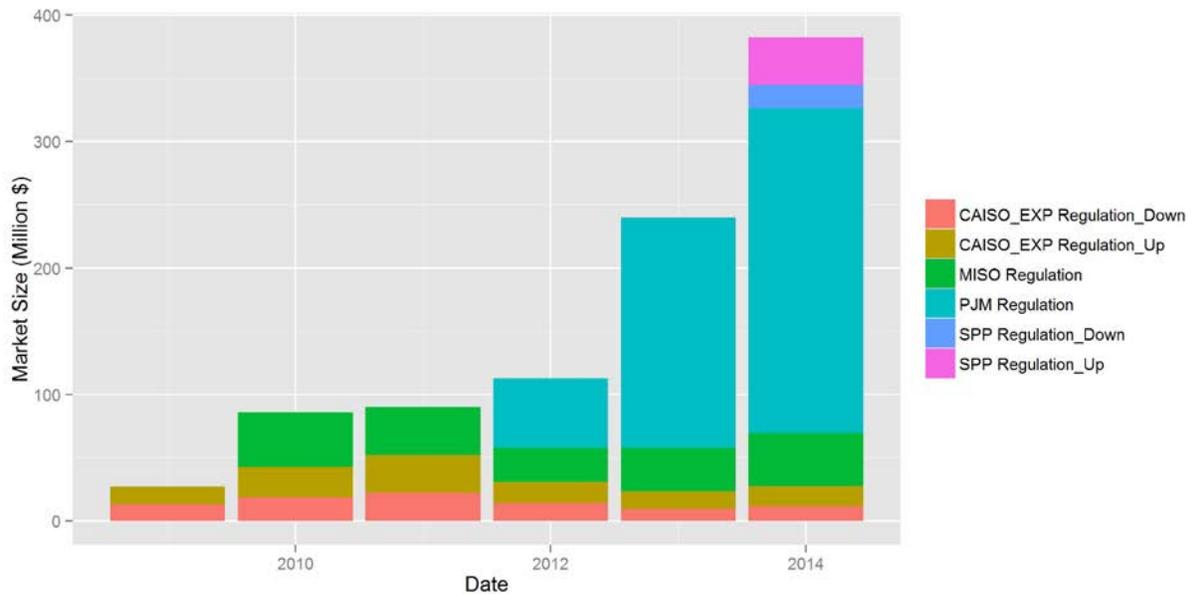


Figure 9-3 Total market size (in terms of revenue) in each Regulation Reserves market

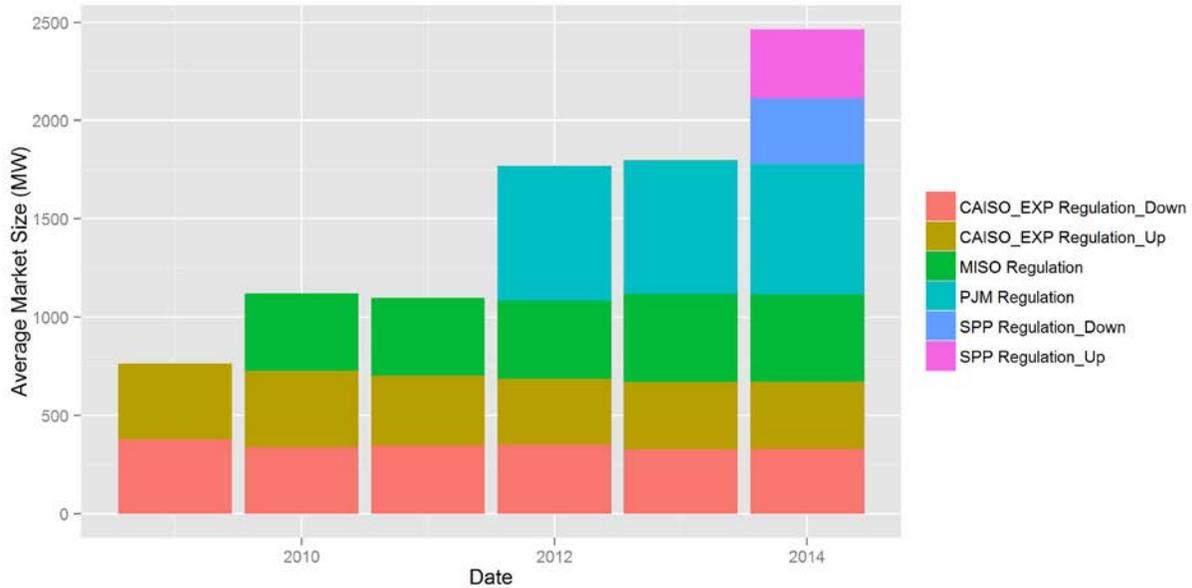


Figure 9-4 Total market size (in terms of average capacity) in each Regulation Reserves market

## 9.2 Spinning Reserves Market Data

The Spinning Reserves market data that are analyzed in this section are summarized in Table 9-2.

| Market | Date Available | DAM/RTM | Availability of Market Size Data | Additional Information  |
|--------|----------------|---------|----------------------------------|---|
| CAISO  | 4/1/2009       | DAM     | Y                                | Price and market size data are reported for the CAISO Expanded Region.                      |
| ERCOT  | 7/31/2001      | DAM     | N                                |   |
| ISO-NE | 1/1/2007       | RTM     | Y                                | Reported prices are weighted average across all zones; data from the DAM are not available. |
| MISO   | 1/1/2010       | DAM     | Y                                | Reported prices are weighted average across all zones.                                      |
| NYISO  | 2/1/2005       | RTM     | N                                | Data reported separately for East and West zones.   |
| PJM    | 10/1/2012      | RTM     | Y                                | Price and market size data are reported for the whole PJM Region.                           |
| SPP    | 3/1/2014       | DAM     | Y                                | Reported prices are weighted average across all zones.                                      |

Table 9-2 Summary of the Spinning Reserves market data that are analyzed in this section

Figures 9-5 and 9-6 compare the Spinning Reserves (Synchronized Reserve in PJM) price data for each of the seven ISO/RTOs, including separate data for the East and West regions of NYISO. The average Spinning Reserves prices are highest for ERCOT, and lowest in the CAISO Expanded region. The NYISO East region has the most volatile prices, while the CAISO Expanded region has the least volatile prices. Prices for NYISO East are also consistently greater than those for NYISO West. ERCOT has higher and

more volatile Spinning Reserves prices for two reasons: (1) ERCOT has a relatively higher Spinning Reserves requirement compared to its peak load, and (2) ERCOT has a higher fraction of its energy provided by renewable resources, which requires more reserves to be deployed.

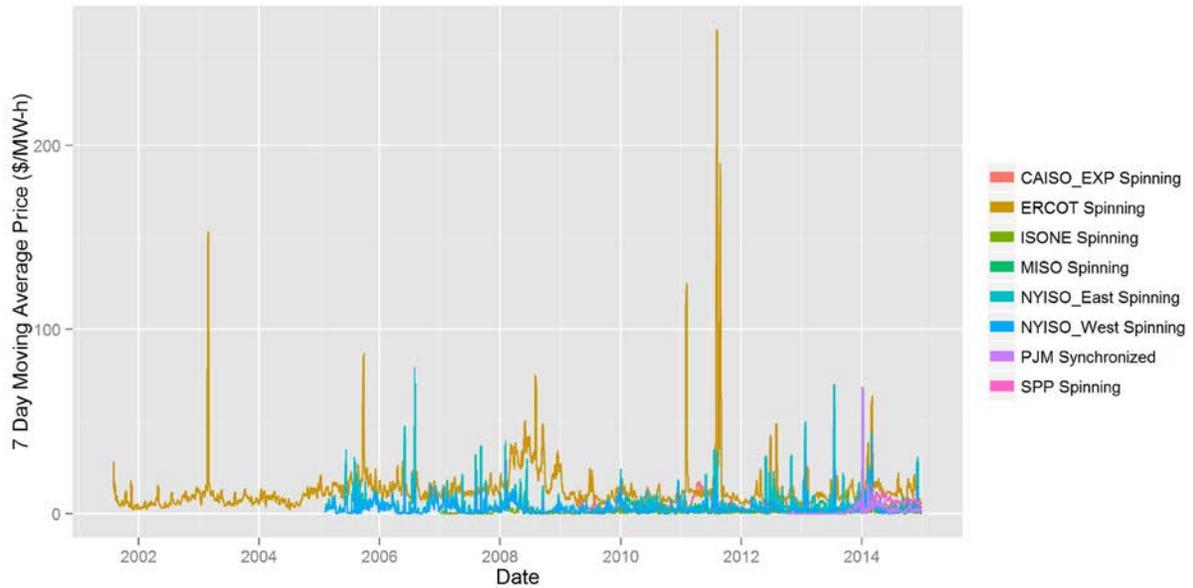


Figure 9-5 Seven-day moving average prices in each Spinning Reserves market

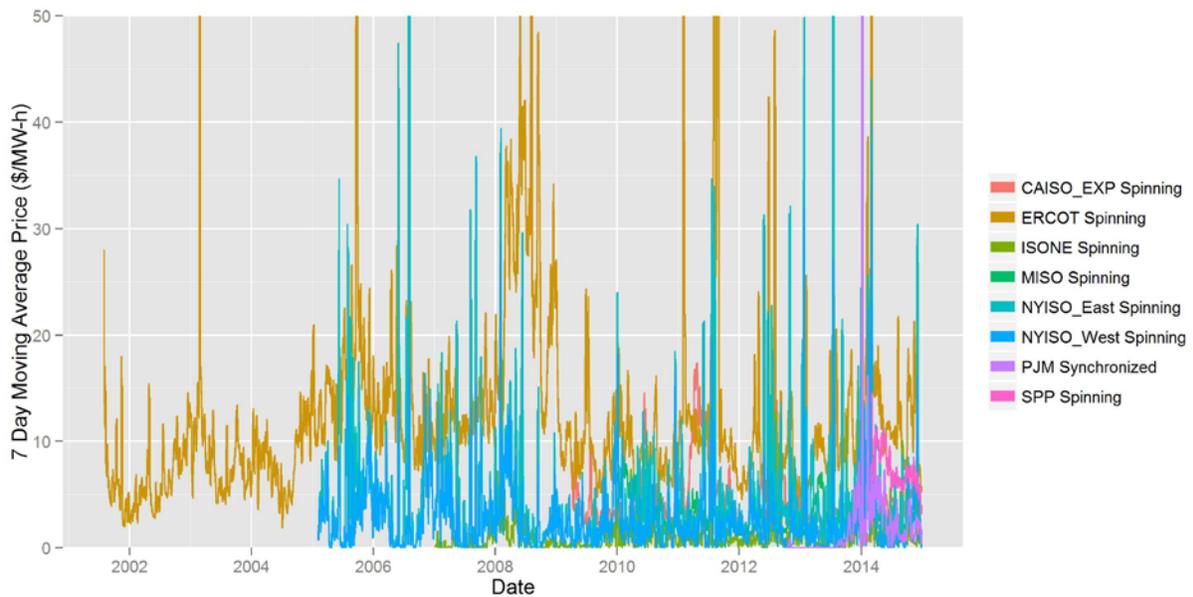


Figure 9-6 Seven-day moving average prices in each Spinning Reserves market with the y-axis capped at \$50/MWh-h

Figures 9-7 and 9-8 show the growth in market size for Spinning Reserves across all ISO/RTOs for which data are available, expressed in terms of total market revenue and average market capacity respectively. Of the markets with available data, PJM currently has the largest market for Spinning Reserves, with \$54 million in revenue in 2014. This is a significant increase compared to \$12 million in 2013 and less than \$1 million in 2012. However, the average capacity of the PJM Synchronized Reserve market has actually decreased since 2012. SPP initiated its current market for Spinning Reserves in March 2014, and was the next-largest at nearly \$34 million despite operating for less than an entire year.

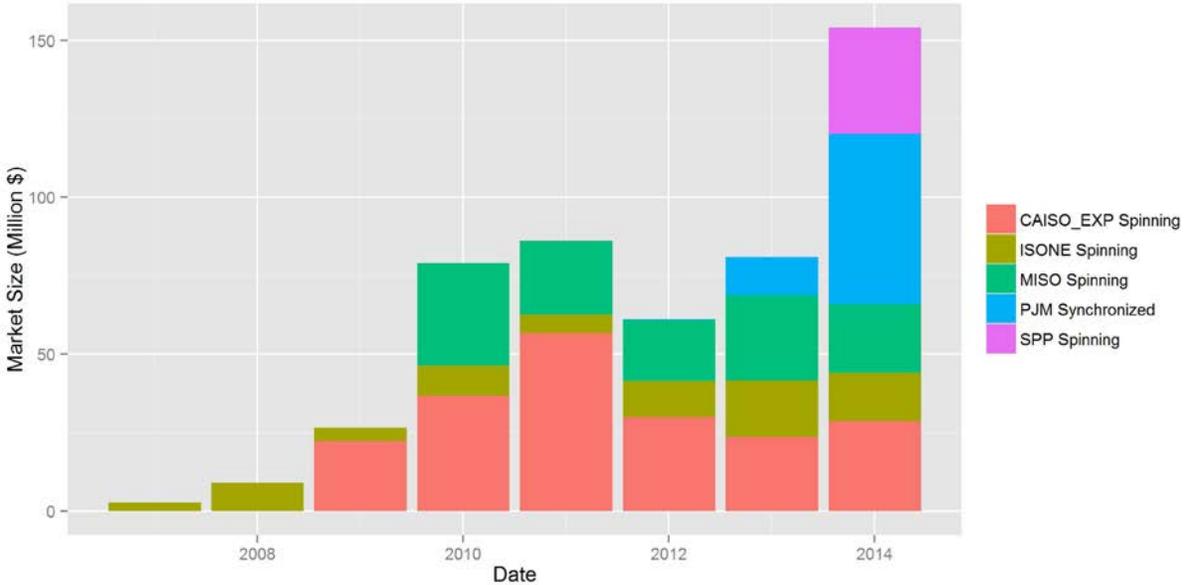


Figure 9-7 Total market size (in terms of revenue) in each Spinning Reserves market

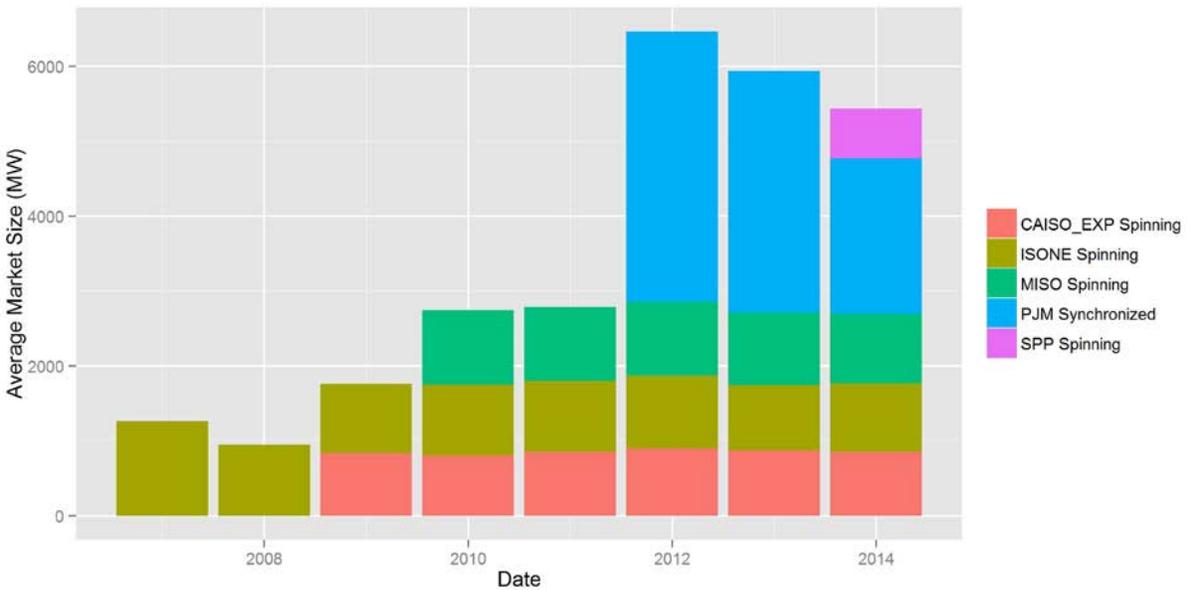


Figure 9-8 Total market size (in terms of average capacity) in each Spinning Reserves market

### 9.3 Non-Spinning Reserves Market Data

The Non-spinning Reserves market data that are analyzed in this section are summarized in Table 9-3.

| Market | Date Available | DAM/RTM | Availability of Market Size Data | Additional Information  |
|--------|----------------|---------|----------------------------------|---|
| CAISO  | 4/1/2009       | DAM     | Y                                | Price and market size data are reported for the CAISO Expanded Region.                      |
| ERCOT  | 7/31/2001      | DAM     | N                                |   |
| ISO-NE | 1/1/2007       | RTM     | Y                                | Reported prices are weighted average across all zones; data from the DAM are not available. |
| MISO   | 1/1/2010       | DAM     | Y                                | Reported prices are weighted average across all zones.                                      |
| NYISO  | 2/1/2005       | RTM     | N                                | Data reported separately for East and West zones.   |
| PJM    | 10/1/2012      | RTM     | Y                                | Price and market size data are reported for the whole PJM Region.                           |
| SPP    | 3/1/2014       | DAM     | Y                                | Reported prices are weighted average across all zones.                                      |

Table 9-3 Summary of the Non-spinning Reserves market data that are analyzed in this section

Figures 9-9 and 9-10 compare the price data from the various Non-spinning Reserve products in each of the seven ISO/RTOs, including separate data for the East and West regions of NYSIO. In general, the Non-spinning Reserve prices are lower than Spinning Reserve prices. The average Non-spinning Reserve prices are highest for ERCOT, and lowest in the CAISO Expanded region and both NYISO regions. The prolonged price spikes are not as large as they are for Spinning Reserves; however, a number of periods of prolonged moderate prices have occurred across many markets, particularly ERCOT, NYISO, and PJM.

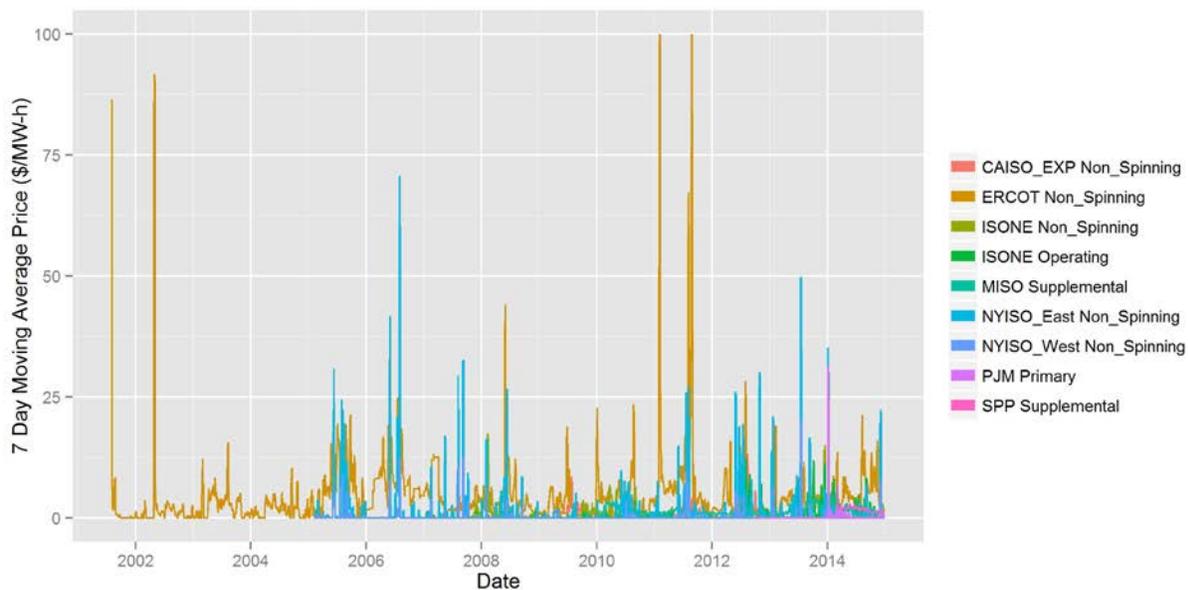


Figure 9-9 Seven-day moving average prices in each Non-spinning Reserves market

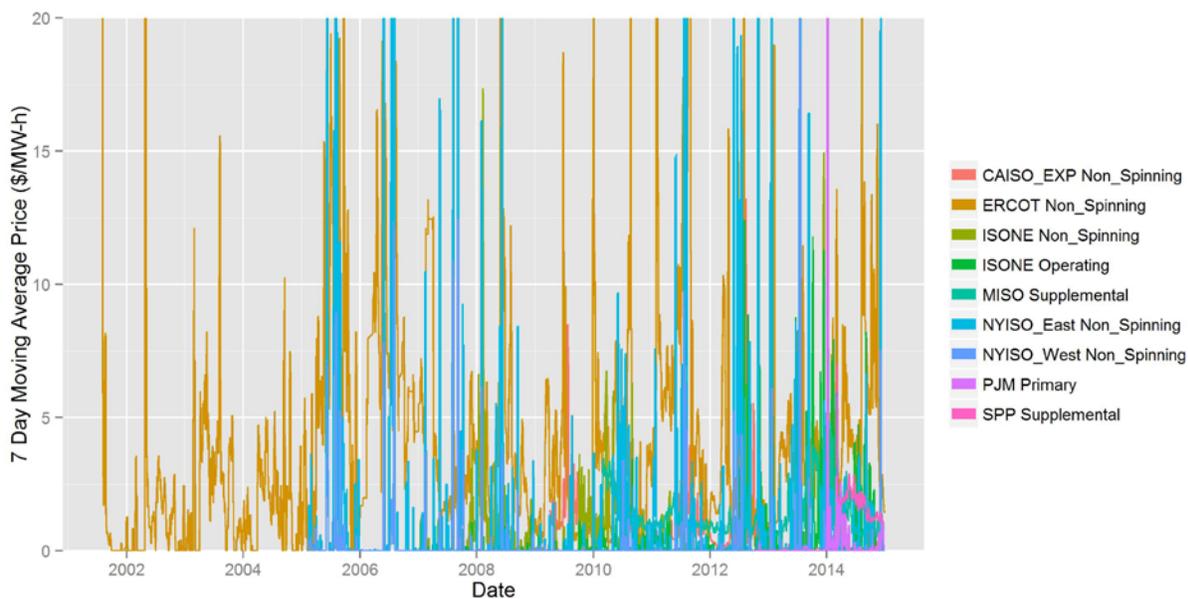


Figure 9-10 Seven-day moving average prices in each Non-spinning Reserves market with the y-axis capped at \$20/MW-h

Figures 9-11 and 9-12 show the change in market size for Non-Spinning Reserves across all ISO/RTOs for which data are available, expressed in terms of total market revenue and average market capacity respectively. Total revenues in Non-spinning Reserves markets are generally smaller than those in Spinning Reserves markets. This difference is due to lower average prices, as volumes in Non-spinning

Reserves markets are generally at least as large as those for Spinning Reserves. ISO-NE had the largest Non-spinning Reserves market in both 2013 and 2014, with \$26 million and \$17 million in revenue, respectively. PJM also had a large Non-spinning Reserves market in 2014, with \$15 million in revenue. PJM had a sizable Non-spinning Reserves market in 2012 and 2013 in terms of capacity, but prices were very low (roughly \$0.02 on average) so the total market size in terms of revenue was also quite small. The market size of the CAISO Expanded Region has diminished significantly in terms of revenue, from \$5–10 million between 2009 and 2012 to less than around \$1 million in 2013 and 2014. This again is due to a reduction in average prices, as the market volumes have remained relatively constant.

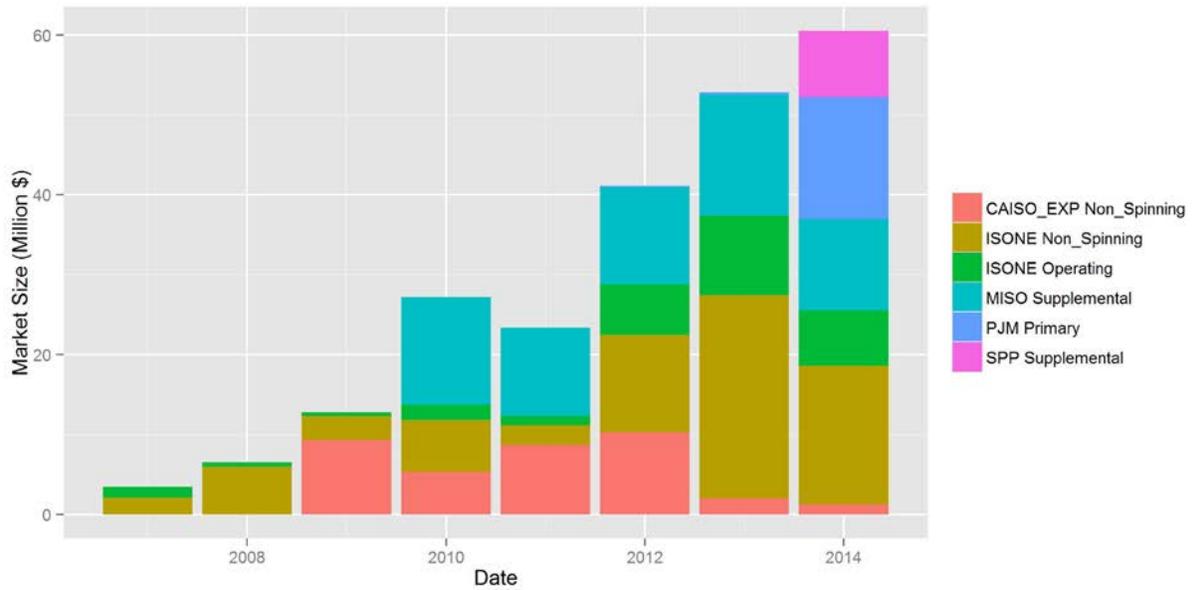


Figure 9-11 Total market size (in terms of revenue) in each Non-spinning Reserves market

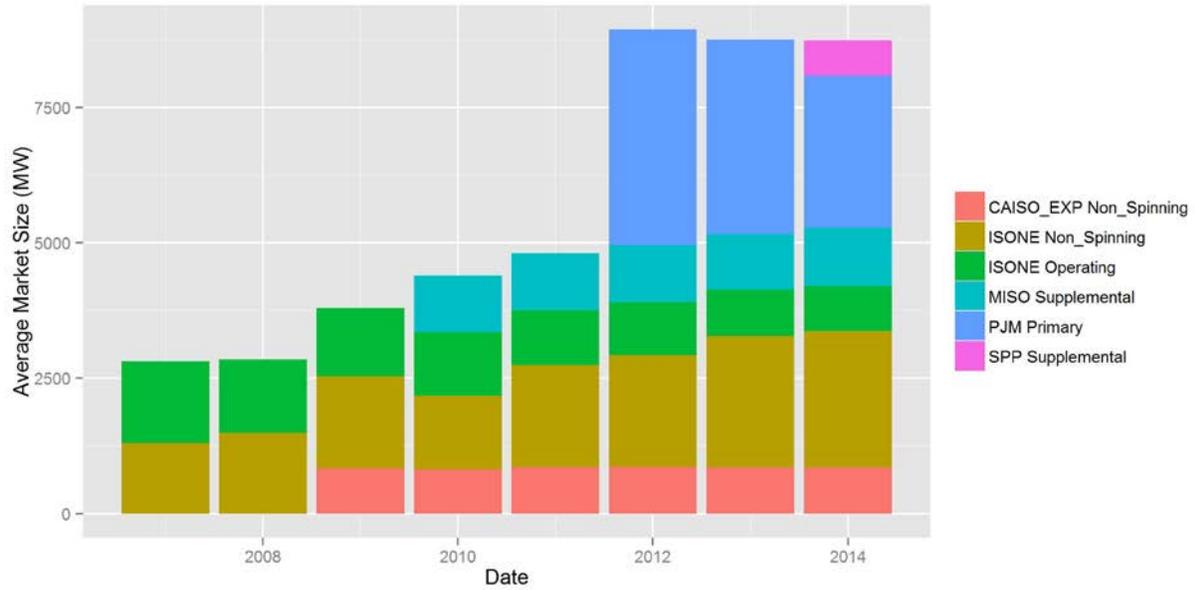


Figure 9-12 Total market size (in terms of average capacity) in each Non-spinning Reserves market

#### 9.4 Annual Data Summaries

Each of the tables in this section presents summary data on the prices and market size of each ancillary service in each ISO/RTO over a single calendar year.

Survey of U.S. Ancillary Services Markets

| 2014 Summary Data   |                 |                         |                        |                        |                      |                              |                              |                                |  |
|---------------------|-----------------|-------------------------|------------------------|------------------------|----------------------|------------------------------|------------------------------|--------------------------------|--|
| Region              | Product         | Mean Price<br>(\$/MW-h) | Min Price<br>(\$/MW-h) | Max Price<br>(\$/MW-h) | St. Dev<br>(\$/MW-h) | Median<br>Price<br>(\$/MW-h) | % Hours<br>With \$0<br>Price | Average<br>Market Size<br>(MW) | Annual Market<br>Revenue<br>(million \$) |
| <b>Regulation</b>   |                 |                         |                        |                        |                      |                              |                              |                                |  |
| CAISO_EXP           | Regulation_Up   | 5.41                    | 0.09                   | 50.01                  | 5.50                 | 3.26                         | 0.0%                         | 343.57                         | 16.12                                    |
| CAISO_EXP           | Regulation_Down | 3.90                    | -                      | 59.55                  | 2.62                 | 3.52                         | 4.4%                         | 328.09                         | 11.30                                    |
| ERCOT               | Regulation_Up   | 12.48                   | 1.00                   | 4,999.00               | 61.95                | 6.39                         | 0.0%                         | NA                             | NA                                       |
| ERCOT               | Regulation_Down | 9.77                    | 0.50                   | 310.08                 | 13.23                | 7.00                         | 0.0%                         | NA                             | NA                                       |
| MISO                | Regulation      | 11.24                   | 2.50                   | 202.39                 | 6.43                 | 10.26                        | 0.0%                         | 443.79                         | 43.38                                    |
| NYISO_East          | Regulation      | 13.76                   | 0.71                   | 408.13                 | 26.08                | 7.96                         | 0.0%                         | NA                             | NA                                       |
| NYISO_West          | Regulation      | 13.76                   | 0.71                   | 408.13                 | 26.08                | 7.96                         | 0.0%                         | NA                             | NA                                       |
| PJM                 | Regulation      | 43.70                   | 0.01                   | 3,303.87               | 104.07               | 22.28                        | 0.0%                         | 662.95                         | 256.93                                   |
| SPP                 | Regulation_Up   | 14.88                   | 1.36                   | 125.95                 | 8.42                 | 13.64                        | 0.0%                         | 351.54                         | 37.75                                    |
| SPP                 | Regulation_Down | 7.70                    | 0.07                   | 294.09                 | 6.05                 | 8.00                         | 0.0%                         | 334.51                         | 18.51                                    |
| <b>Spinning</b>     |                 |                         |                        |                        |                      |                              |                              |                                |  |
| CAISO_EXP           | Spinning        | 3.34                    | 0.09                   | 46.29                  | 5.13                 | 0.26                         | 0.0%                         | 849.33                         | 28.66                                    |
| ERCOT               | Spinning        | 14.15                   | 2.00                   | 1,285.73               | 31.82                | 8.61                         | 0.0%                         | NA                             | NA                                       |
| MISO                | Spinning        | 2.58                    | 0.45                   | 88.62                  | 3.31                 | 2.00                         | 0.0%                         | 923.37                         | 22.33                                    |
| ISONE               | Spinning        | 2.53                    | -                      | 1,000.00               | 22.57                | -                            | 82.7%                        | 921.26                         | 15.46                                    |
| NYISO_East          | Spinning        | 6.49                    | -                      | 964.31                 | 33.45                | -                            | 69.3%                        | NA                             | NA                                       |
| NYISO_West          | Spinning        | 4.07                    | -                      | 650.78                 | 23.21                | -                            | 87.6%                        | NA                             | NA                                       |
| PJM                 | Synchronized    | 4.21                    | -                      | 1,142.35               | 32.55                | -                            | 62.6%                        | 2,080.56                       | 54.38                                    |
| SPP                 | Spinning        | 7.46                    | 0.01                   | 103.72                 | 6.67                 | 5.48                         | 0.0%                         | 663.31                         | 33.79                                    |
| <b>Non-spinning</b> |                 |                         |                        |                        |                      |                              |                              |                                |  |
| CAISO_EXP           | Non_Spinning    | 0.14                    | 0.08                   | 23.06                  | 0.61                 | 0.09                         | 0.0%                         | 849.93                         | 1.24                                     |
| ERCOT               | Non_Spinning    | 5.48                    | 0.77                   | 435.70                 | 14.03                | 1.98                         | 0.0%                         | NA                             | NA                                       |
| MISO                | Supplemental    | 1.35                    | 0.45                   | 87.95                  | 2.96                 | 0.70                         | 0.0%                         | 1,073.22                       | 11.83                                    |
| ISONE               | Non_Spinning    | 1.62                    | -                      | 1,000.00               | 21.99                | -                            | 97.8%                        | 2,519.98                       | 17.43                                    |
| ISONE               | Operating       | 1.60                    | -                      | 1,000.00               | 20.62                | -                            | 97.8%                        | 825.12                         | 6.92                                     |
| NYISO_East          | Non_Spinning    | 1.75                    | -                      | 891.03                 | 24.13                | -                            | 98.2%                        | NA                             | NA                                       |
| NYISO_West          | Non_Spinning    | 0.49                    | -                      | 445.34                 | 10.62                | -                            | 99.5%                        | NA                             | NA                                       |
| NYISO_East          | Reserve_30      | 0.12                    | -                      | 246.98                 | 4.37                 | -                            | 99.9%                        | NA                             | NA                                       |
| NYISO_West          | Reserve_30      | 0.10                    | -                      | 234.40                 | 3.89                 | -                            | 99.9%                        | NA                             | NA                                       |
| PJM                 | Primary         | 0.95                    | -                      | 400.00                 | 13.32                | -                            | 95.5%                        | 2,816.22                       | 15.21                                    |
| SPP                 | Supplemental    | 1.82                    | 0.01                   | 98.00                  | 2.20                 | 1.65                         | 0.0%                         | 652.38                         | 8.33                                     |

Survey of U.S. Ancillary Services Markets

| 2013 Summary Data   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
|---------------------|-----------------|-------------------------|------------------------|------------------------|----------------------|------------------------------|------------------------------|--------------------------------|------------------------------------|
| Region              | Product         | Mean Price<br>(\$/MW-h) | Min Price<br>(\$/MW-h) | Max Price<br>(\$/MW-h) | St. Dev<br>(\$/MW-h) | Median<br>Price<br>(\$/MW-h) | % Hours<br>With \$0<br>Price | Average<br>Market Size<br>(MW) | Annual Market<br>Size (million \$) |
| <b>Regulation</b>   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Regulation_Up   | 4.56                    | 0.08                   | 119.97                 | 5.11                 | 2.88                         | 0.0%                         | 341.42                         | 13.58                              |
| CAISO_EXP           | Regulation_Down | 3.25                    | -                      | 23.30                  | 1.82                 | 3.03                         | 2.7%                         | 326.19                         | 9.43                               |
| ERCOT               | Regulation_Up   | 8.57                    | 0.01                   | 3,000.50               | 34.53                | 5.60                         | 0.0%                         | NA                             | NA                                 |
| ERCOT               | Regulation_Down | 4.89                    | 0.01                   | 150.00                 | 5.17                 | 3.25                         | 0.0%                         | NA                             | NA                                 |
| MISO                | Regulation      | 9.10                    | 1.51                   | 49.11                  | 5.11                 | 8.02                         | 0.0%                         | 448.14                         | 35.44                              |
| NYISO_East          | Regulation      | 9.70                    | -                      | 474.24                 | 22.21                | 5.32                         | 0.1%                         | NA                             | NA                                 |
| NYISO_West          | Regulation      | 9.70                    | -                      | 474.24                 | 22.21                | 5.32                         | 0.1%                         | NA                             | NA                                 |
| PJM                 | Regulation      | 28.14                   | -                      | 764.59                 | 32.68                | 21.31                        | 0.1%                         | 682.65                         | 182.39                             |
| SPP                 | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| SPP                 | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| <b>Spinning</b>     |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Spinning        | 2.74                    | 0.08                   | 119.87                 | 4.84                 | 0.41                         | 0.0%                         | 867.58                         | 23.65                              |
| ERCOT               | Spinning        | 9.77                    | 0.84                   | 3,000.00               | 34.83                | 7.00                         | 0.0%                         | NA                             | NA                                 |
| MISO                | Spinning        | 3.24                    | 0.25                   | 42.90                  | 3.57                 | 1.56                         | 0.0%                         | 963.05                         | 27.50                              |
| ISONE               | Spinning        | 2.97                    | -                      | 972.61                 | 27.47                | -                            | 91.5%                        | 882.61                         | 18.03                              |
| NYISO_East          | Spinning        | 6.77                    | -                      | 791.53                 | 35.65                | -                            | 61.2%                        | NA                             | NA                                 |
| NYISO_West          | Spinning        | 2.61                    | -                      | 461.50                 | 20.72                | -                            | 91.0%                        | NA                             | NA                                 |
| PJM                 | Synchronized    | 0.75                    | -                      | 105.66                 | 2.94                 | -                            | 85.4%                        | 3,231.27                       | 12.19                              |
| SPP                 | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| <b>Non-spinning</b> |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Non_Spinning    | 0.20                    | 0.05                   | 115.39                 | 2.29                 | 0.10                         | 0.0%                         | 846.79                         | 1.98                               |
| ERCOT               | Non_Spinning    | 3.47                    | 0.90                   | 3,000.00               | 32.99                | 1.00                         | 0.0%                         | NA                             | NA                                 |
| MISO                | Supplemental    | 1.75                    | 0.25                   | 42.90                  | 2.86                 | 0.70                         | 0.0%                         | 1,029.19                       | 15.45                              |
| ISONE               | Non_Spinning    | 2.45                    | -                      | 972.61                 | 26.89                | -                            | 97.6%                        | 2,433.78                       | 25.78                              |
| ISONE               | Operating       | 2.29                    | -                      | 500.00                 | 23.64                | -                            | 97.7%                        | 853.72                         | 10.01                              |
| NYISO_East          | Non_Spinning    | 2.77                    | -                      | 716.49                 | 28.01                | -                            | 97.0%                        | NA                             | NA                                 |
| NYISO_West          | Non_Spinning    | 0.66                    | -                      | 423.81                 | 13.29                | -                            | 99.5%                        | NA                             | NA                                 |
| NYISO_East          | Reserve_30      | 0.66                    | -                      | 429.40                 | 14.45                | -                            | 99.7%                        | NA                             | NA                                 |
| NYISO_West          | Reserve_30      | 0.38                    | -                      | 423.81                 | 10.94                | -                            | 99.8%                        | NA                             | NA                                 |
| PJM                 | Primary         | 0.02                    | -                      | 9.40                   | 0.25                 | -                            | 99.2%                        | 3,593.57                       | 0.29                               |
| SPP                 | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |

Survey of U.S. Ancillary Services Markets

| 2012 Summary Data   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
|---------------------|-----------------|-------------------------|------------------------|------------------------|----------------------|------------------------------|------------------------------|--------------------------------|------------------------------------|
| Region              | Product         | Mean Price<br>(\$/MW-h) | Min Price<br>(\$/MW-h) | Max Price<br>(\$/MW-h) | St. Dev<br>(\$/MW-h) | Median<br>Price<br>(\$/MW-h) | % Hours<br>With \$0<br>Price | Average<br>Market Size<br>(MW) | Annual Market<br>Size (million \$) |
| <b>Regulation</b>   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Regulation_Up   | 5.64                    | -                      | 129.74                 | 6.35                 | 3.66                         | 0.0%                         | 333.51                         | 16.68                              |
| CAISO_EXP           | Regulation_Down | 4.39                    | -                      | 25.61                  | 2.13                 | 3.87                         | 0.1%                         | 351.38                         | 14.04                              |
| ERCOT               | Regulation_Up   | 8.95                    | 0.01                   | 1,456.49               | 37.45                | 4.96                         | 0.0%                         | NA                             | NA                                 |
| ERCOT               | Regulation_Down | 4.23                    | 0.01                   | 150.00                 | 3.23                 | 4.00                         | 0.0%                         | NA                             | NA                                 |
| MISO                | Regulation      | 7.79                    | 1.27                   | 145.02                 | 4.97                 | 6.65                         | 0.0%                         | 397.92                         | 27.63                              |
| NYISO_East          | Regulation      | 8.73                    | 0.63                   | 311.43                 | 14.65                | 5.50                         | 0.0%                         | NA                             | NA                                 |
| NYISO_West          | Regulation      | 8.73                    | 0.63                   | 311.43                 | 14.65                | 5.50                         | 0.0%                         | NA                             | NA                                 |
| PJM                 | Regulation      | 35.59                   | 0.83                   | 386.91                 | 31.35                | 26.65                        | 0.0%                         | 686.27                         | 55.07                              |
| SPP                 | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| SPP                 | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| <b>Spinning</b>     |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Spinning        | 3.27                    | -                      | 129.73                 | 6.14                 | 1.00                         | 0.0%                         | 893.32                         | 29.90                              |
| ERCOT               | Spinning        | 9.76                    | 0.45                   | 1,461.06               | 37.81                | 5.24                         | 0.0%                         | NA                             | NA                                 |
| MISO                | Spinning        | 2.26                    | 0.32                   | 131.87                 | 3.70                 | 1.05                         | 0.0%                         | 982.84                         | 19.74                              |
| ISONE               | Spinning        | 1.67                    | -                      | 313.50                 | 12.30                | -                            | 90.1%                        | 984.96                         | 11.49                              |
| NYISO_East          | Spinning        | 5.74                    | -                      | 965.28                 | 32.67                | -                            | 67.6%                        | NA                             | NA                                 |
| NYISO_West          | Spinning        | 2.04                    | -                      | 508.28                 | 12.50                | -                            | 87.8%                        | NA                             | NA                                 |
| PJM                 | Synchronized    | 0.09                    | -                      | 29.16                  | 1.16                 | -                            | 97.9%                        | 3,612.11                       | 0.35                               |
| SPP                 | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| <b>Non-spinning</b> |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Non_Spinning    | 0.94                    | -                      | 129.73                 | 5.26                 | 0.10                         | 0.0%                         | 863.24                         | 10.25                              |
| ERCOT               | Non_Spinning    | 3.67                    | 0.01                   | 1,310.54               | 20.73                | 1.00                         | 0.0%                         | NA                             | NA                                 |
| MISO                | Supplemental    | 1.39                    | 0.32                   | 131.87                 | 3.49                 | 0.70                         | 0.0%                         | 1,059.58                       | 12.56                              |
| ISONE               | Non_Spinning    | 1.01                    | -                      | 288.50                 | 11.02                | -                            | 98.3%                        | 2,063.24                       | 12.26                              |
| ISONE               | Operating       | 1.04                    | -                      | 278.86                 | 11.12                | -                            | 98.4%                        | 968.67                         | 6.28                               |
| NYISO_East          | Non_Spinning    | 2.72                    | -                      | 842.71                 | 30.25                | -                            | 96.5%                        | NA                             | NA                                 |
| NYISO_West          | Non_Spinning    | 0.31                    | -                      | 385.71                 | 7.73                 | -                            | 99.5%                        | NA                             | NA                                 |
| NYISO_East          | Reserve_30      | 0.21                    | -                      | 487.72                 | 7.79                 | -                            | 99.8%                        | NA                             | NA                                 |
| NYISO_West          | Reserve_30      | 0.05                    | -                      | 115.25                 | 1.76                 | -                            | 99.9%                        | NA                             | NA                                 |
| PJM                 | Primary         | 0.02                    | -                      | 19.85                  | 0.58                 | -                            | 99.9%                        | 3,984.44                       | 0.09                               |
| SPP                 | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |

Survey of U.S. Ancillary Services Markets

| 2011 Summary Data   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
|---------------------|-----------------|-------------------------|------------------------|------------------------|----------------------|------------------------------|------------------------------|--------------------------------|------------------------------------|
| Region              | Product         | Mean Price<br>(\$/MW-h) | Min Price<br>(\$/MW-h) | Max Price<br>(\$/MW-h) | St. Dev<br>(\$/MW-h) | Median<br>Price<br>(\$/MW-h) | % Hours<br>With \$0<br>Price | Average<br>Market Size<br>(MW) | Annual Market<br>Size (million \$) |
| <b>Regulation</b>   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Regulation_Up   | 9.21                    | -                      | 90.81                  | 8.48                 | 6.86                         | 0.0%                         | 355.05                         | 29.69                              |
| CAISO_EXP           | Regulation_Down | 6.93                    | -                      | 79.55                  | 5.68                 | 5.29                         | 0.1%                         | 346.46                         | 22.17                              |
| ERCOT               | Regulation_Up   | 22.67                   | 0.47                   | 2,584.94               | 125.63               | 8.02                         | 0.0%                         | NA                             | NA                                 |
| ERCOT               | Regulation_Down | 8.58                    | 0.14                   | 593.00                 | 12.26                | 7.00                         | 0.0%                         | NA                             | NA                                 |
| MISO                | Regulation      | 11.16                   | 3.24                   | 101.64                 | 5.85                 | 9.47                         | 0.0%                         | 395.96                         | 39.21                              |
| NYISO_East          | Regulation      | 14.34                   | 2.21                   | 445.11                 | 19.31                | 9.43                         | 0.0%                         | NA                             | NA                                 |
| NYISO_West          | Regulation      | 14.34                   | 2.21                   | 445.11                 | 19.31                | 9.43                         | 0.0%                         | NA                             | NA                                 |
| PJM                 | Regulation      | █ #N/A                  | █ #N/A                 | █ #N/A                 | █ #N/A               | █ #N/A                       | █ #N/A                       | █ #N/A                         | █ #N/A                             |
| SPP                 | Regulation_Up   | █ #N/A                  | █ #N/A                 | █ #N/A                 | █ #N/A               | █ #N/A                       | █ #N/A                       | █ #N/A                         | █ #N/A                             |
| SPP                 | Regulation_Down | █ #N/A                  | █ #N/A                 | █ #N/A                 | █ #N/A               | █ #N/A                       | █ #N/A                       | █ #N/A                         | █ #N/A                             |
| <b>Spinning</b>     |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Spinning        | 7.23                    | -                      | 47.96                  | 7.20                 | 5.00                         | 0.0%                         | 849.92                         | 56.60                              |
| ERCOT               | Spinning        | 22.93                   | 0.67                   | 2,605.75               | 127.28               | 8.05                         | 0.0%                         | NA                             | NA                                 |
| MISO                | Spinning        | 2.84                    | 0.50                   | 28.85                  | 2.89                 | 1.46                         | 0.0%                         | 986.32                         | 23.84                              |
| ISONE               | Spinning        | 1.05                    | -                      | 418.31                 | 9.18                 | -                            | 88.5%                        | 956.27                         | 5.99                               |
| NYISO_East          | Spinning        | 4.64                    | -                      | 797.02                 | 29.46                | -                            | 80.9%                        | NA                             | NA                                 |
| NYISO_West          | Spinning        | 2.41                    | -                      | 416.22                 | 15.51                | -                            | 89.4%                        | NA                             | NA                                 |
| PJM                 | Synchronized    | █ #N/A                  | █ #N/A                 | █ #N/A                 | █ #N/A               | █ #N/A                       | █ #N/A                       | █ #N/A                         | █ #N/A                             |
| SPP                 | Spinning        | █ #N/A                  | █ #N/A                 | █ #N/A                 | █ #N/A               | █ #N/A                       | █ #N/A                       | █ #N/A                         | █ #N/A                             |
| <b>Non-spinning</b> |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Non_Spinning    | 0.98                    | -                      | 35.01                  | 2.48                 | 0.46                         | 0.0%                         | 852.66                         | 8.72                               |
| ERCOT               | Non_Spinning    | 11.77                   | 0.01                   | 1,500.00               | 62.23                | 3.08                         | 0.0%                         | NA                             | NA                                 |
| MISO                | Supplemental    | 1.22                    | 0.45                   | 27.27                  | 1.24                 | 0.90                         | 0.0%                         | 1,055.98                       | 11.33                              |
| ISONE               | Non_Spinning    | 0.40                    | -                      | 418.31                 | 8.30                 | -                            | 98.9%                        | 1,882.40                       | 2.43                               |
| ISONE               | Operating       | 0.28                    | -                      | 135.50                 | 4.32                 | -                            | 99.0%                        | 1,013.68                       | 1.20                               |
| NYISO_East          | Non_Spinning    | 2.06                    | -                      | 662.63                 | 24.83                | -                            | 97.1%                        | NA                             | NA                                 |
| NYISO_West          | Non_Spinning    | 0.38                    | -                      | 256.85                 | 7.63                 | -                            | 99.5%                        | NA                             | NA                                 |
| NYISO_East          | Reserve_30      | 0.31                    | -                      | 474.11                 | 9.26                 | -                            | 99.7%                        | NA                             | NA                                 |
| NYISO_West          | Reserve_30      | 0.20                    | -                      | 221.22                 | 5.09                 | -                            | 99.7%                        | NA                             | NA                                 |
| PJM                 | Primary         | █ #N/A                  | █ #N/A                 | █ #N/A                 | █ #N/A               | █ #N/A                       | █ #N/A                       | █ #N/A                         | █ #N/A                             |
| SPP                 | Supplemental    | █ #N/A                  | █ #N/A                 | █ #N/A                 | █ #N/A               | █ #N/A                       | █ #N/A                       | █ #N/A                         | █ #N/A                             |

Survey of U.S. Ancillary Services Markets

| 2010 Summary Data   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
|---------------------|-----------------|-------------------------|------------------------|------------------------|----------------------|------------------------------|------------------------------|--------------------------------|------------------------------------|
| Region              | Product         | Mean Price<br>(\$/MW-h) | Min Price<br>(\$/MW-h) | Max Price<br>(\$/MW-h) | St. Dev<br>(\$/MW-h) | Median<br>Price<br>(\$/MW-h) | % Hours<br>With \$0<br>Price | Average<br>Market Size<br>(MW) | Annual Market<br>Size (million \$) |
| <b>Regulation</b>   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Regulation_Up   | 6.08                    | -                      | 66.37                  | 5.75                 | 4.23                         | 0.0%                         | 385.55                         | 24.05                              |
| CAISO_EXP           | Regulation_Down | 5.30                    | -                      | 74.75                  | 4.60                 | 4.00                         | 0.2%                         | 340.19                         | 18.48                              |
| ERCOT               | Regulation_Up   | 9.81                    | 1.10                   | 112.57                 | 8.55                 | 7.04                         | 0.0%                         | NA                             | NA                                 |
| ERCOT               | Regulation_Down | 8.27                    | 1.50                   | 498.50                 | 12.12                | 6.19                         | 0.0%                         | NA                             | NA                                 |
| MISO                | Regulation      | 12.67                   | 2.94                   | 101.90                 | 6.50                 | 10.78                        | 0.0%                         | 395.71                         | 44.56                              |
| NYISO_East          | Regulation      | 26.70                   | 1.10                   | 300.00                 | 20.54                | 27.67                        | 0.0%                         | NA                             | NA                                 |
| NYISO_West          | Regulation      | 26.70                   | 1.10                   | 300.00                 | 20.54                | 27.67                        | 0.0%                         | NA                             | NA                                 |
| PJM                 | Regulation      | █ #N/A                  | █ #N/A                 | █ #N/A                 | █ #N/A               | █ #N/A                       | █ #N/A                       | █ #N/A                         | █ #N/A                             |
| SPP                 | Regulation_Up   | █ #N/A                  | █ #N/A                 | █ #N/A                 | █ #N/A               | █ #N/A                       | █ #N/A                       | █ #N/A                         | █ #N/A                             |
| SPP                 | Regulation_Down | █ #N/A                  | █ #N/A                 | █ #N/A                 | █ #N/A               | █ #N/A                       | █ #N/A                       | █ #N/A                         | █ #N/A                             |
| <b>Spinning</b>     |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Spinning        | 4.50                    | -                      | 66.37                  | 5.21                 | 2.51                         | 0.0%                         | 799.95                         | 36.68                              |
| ERCOT               | Spinning        | 9.09                    | 1.01                   | 124.51                 | 7.93                 | 6.37                         | 0.0%                         | NA                             | NA                                 |
| MISO                | Spinning        | 4.02                    | 0.18                   | 33.65                  | 4.46                 | 2.43                         | 0.0%                         | 998.80                         | 33.18                              |
| ISONE               | Spinning        | 1.77                    | -                      | 637.68                 | 13.72                | -                            | 86.6%                        | 954.36                         | 10.17                              |
| NYISO_East          | Spinning        | 4.17                    | -                      | 713.26                 | 23.75                | -                            | 80.5%                        | NA                             | NA                                 |
| NYISO_West          | Spinning        | 2.55                    | -                      | 302.20                 | 14.60                | -                            | 90.5%                        | NA                             | NA                                 |
| PJM                 | Synchronized    | █ #N/A                  | █ #N/A                 | █ #N/A                 | █ #N/A               | █ #N/A                       | █ #N/A                       | █ #N/A                         | █ #N/A                             |
| SPP                 | Spinning        | █ #N/A                  | █ #N/A                 | █ #N/A                 | █ #N/A               | █ #N/A                       | █ #N/A                       | █ #N/A                         | █ #N/A                             |
| <b>Non-spinning</b> |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Non_Spinning    | 0.58                    | -                      | 66.37                  | 2.36                 | 0.30                         | 0.2%                         | 813.82                         | 5.32                               |
| ERCOT               | Non_Spinning    | 4.25                    | 0.01                   | 295.92                 | 11.07                | 1.80                         | 0.0%                         | NA                             | NA                                 |
| MISO                | Supplemental    | 1.46                    | 0.18                   | 9.00                   | 1.37                 | 0.75                         | 0.0%                         | 1,042.91                       | 13.73                              |
| ISONE               | Non_Spinning    | 1.17                    | -                      | 637.50                 | 12.97                | -                            | 96.5%                        | 1,357.99                       | 7.12                               |
| ISONE               | Operating       | 0.43                    | -                      | 111.61                 | 5.00                 | -                            | 98.6%                        | 1,176.98                       | 1.93                               |
| NYISO_East          | Non_Spinning    | 1.08                    | -                      | 580.20                 | 17.41                | -                            | 98.9%                        | NA                             | NA                                 |
| NYISO_West          | Non_Spinning    | 0.12                    | -                      | 245.24                 | 3.81                 | -                            | 99.7%                        | NA                             | NA                                 |
| NYISO_East          | Reserve_30      | 0.03                    | -                      | 100.31                 | 1.31                 | -                            | 99.8%                        | NA                             | NA                                 |
| NYISO_West          | Reserve_30      | 0.03                    | -                      | 100.31                 | 1.31                 | -                            | 99.8%                        | NA                             | NA                                 |
| PJM                 | Primary         | █ #N/A                  | █ #N/A                 | █ #N/A                 | █ #N/A               | █ #N/A                       | █ #N/A                       | █ #N/A                         | █ #N/A                             |
| SPP                 | Supplemental    | █ #N/A                  | █ #N/A                 | █ #N/A                 | █ #N/A               | █ #N/A                       | █ #N/A                       | █ #N/A                         | █ #N/A                             |

Survey of U.S. Ancillary Services Markets

| 2009 Summary Data   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
|---------------------|-----------------|-------------------------|------------------------|------------------------|----------------------|------------------------------|------------------------------|--------------------------------|------------------------------------|
| Region              | Product         | Mean Price<br>(\$/MW-h) | Min Price<br>(\$/MW-h) | Max Price<br>(\$/MW-h) | St. Dev<br>(\$/MW-h) | Median<br>Price<br>(\$/MW-h) | % Hours<br>With \$0<br>Price | Average<br>Market Size<br>(MW) | Annual Market<br>Size (million \$) |
| <b>Regulation</b>   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Regulation_Up   | 5.32                    | 0.60                   | 416.94                 | 7.81                 | 4.23                         | 0.0%                         | 385.79                         | 14.05                              |
| CAISO_EXP           | Regulation_Down | 5.02                    | -                      | 64.80                  | 4.44                 | 3.81                         | 0.7%                         | 378.18                         | 12.96                              |
| ERCOT               | Regulation_Up   | 9.70                    | 1.14                   | 300.01                 | 12.34                | 6.03                         | 0.0%                         | NA                             | NA                                 |
| ERCOT               | Regulation_Down | 7.25                    | 1.21                   | 500.00                 | 10.26                | 5.01                         | 0.0%                         | NA                             | NA                                 |
| MISO                | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| NYISO_East          | Regulation      | 39.14                   | 9.08                   | 300.00                 | 21.73                | 32.00                        | 0.0%                         | NA                             | NA                                 |
| NYISO_West          | Regulation      | 39.14                   | 9.08                   | 300.00                 | 21.73                | 32.00                        | 0.0%                         | NA                             | NA                                 |
| PJM                 | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| SPP                 | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| SPP                 | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| <b>Spinning</b>     |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Spinning        | 3.73                    | 0.59                   | 416.37                 | 7.72                 | 1.79                         | 0.0%                         | 834.78                         | 22.30                              |
| ERCOT               | Spinning        | 9.96                    | 0.01                   | 185.11                 | 10.79                | 6.40                         | 0.0%                         | NA                             | NA                                 |
| MISO                | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| ISONE               | Spinning        | 0.72                    | -                      | 120.52                 | 5.87                 | -                            | 92.5%                        | 924.48                         | 4.29                               |
| NYISO_East          | Spinning        | 2.60                    | -                      | 382.32                 | 13.97                | -                            | 86.8%                        | NA                             | NA                                 |
| NYISO_West          | Spinning        | 2.20                    | -                      | 293.44                 | 11.87                | -                            | 88.5%                        | NA                             | NA                                 |
| PJM                 | Synchronized    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| SPP                 | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| <b>Non-spinning</b> |                 |                         |                        |                        |                      |                              |                              |                                |                                    |
| CAISO_EXP           | Non_Spinning    | 1.44                    | -                      | 416.33                 | 7.20                 | 0.75                         | 0.2%                         | 832.62                         | 9.30                               |
| ERCOT               | Non_Spinning    | 2.31                    | -                      | 175.00                 | 6.99                 | 0.83                         | 7.0%                         | NA                             | NA                                 |
| MISO                | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| ISONE               | Non_Spinning    | 0.48                    | -                      | 113.84                 | 5.30                 | -                            | 97.6%                        | 1,701.13                       | 3.10                               |
| ISONE               | Operating       | 0.09                    | -                      | 75.28                  | 1.97                 | -                            | 99.4%                        | 1,258.26                       | 0.52                               |
| NYISO_East          | Non_Spinning    | 0.29                    | -                      | 317.55                 | 6.95                 | -                            | 99.7%                        | NA                             | NA                                 |
| NYISO_West          | Non_Spinning    | 0.03                    | -                      | 150.00                 | 1.69                 | -                            | 99.9%                        | NA                             | NA                                 |
| NYISO_East          | Reserve_30      | -                       | -                      | -                      | -                    | -                            | 100.0%                       | NA                             | NA                                 |
| NYISO_West          | Reserve_30      | -                       | -                      | -                      | -                    | -                            | 100.0%                       | NA                             | NA                                 |
| PJM                 | Primary         | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |
| SPP                 | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |

Survey of U.S. Ancillary Services Markets

| 2008 Summary Data   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
|---------------------|-----------------|-------------------------|------------------------|------------------------|----------------------|------------------------------|------------------------------|--------------------------------|------------------------------------|--|
| Region              | Product         | Mean Price<br>(\$/MW-h) | Min Price<br>(\$/MW-h) | Max Price<br>(\$/MW-h) | St. Dev<br>(\$/MW-h) | Median<br>Price<br>(\$/MW-h) | % Hours<br>With \$0<br>Price | Average<br>Market Size<br>(MW) | Annual Market<br>Size (million \$) |  |
| <b>Regulation</b>   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| CAISO_EXP           | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Regulation_Up   | 22.71                   | 1.66                   | 500.03                 | 24.64                | 15.30                        | 0.0%                         | NA                             | NA                                 |  |
| ERCOT               | Regulation_Down | 19.52                   | 0.78                   | 500.00                 | 15.05                | 16.80                        | 0.0%                         | NA                             | NA                                 |  |
| MISO                | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Regulation      | 56.98                   | 8.00                   | 300.00                 | 25.95                | 50.00                        | 0.0%                         | NA                             | NA                                 |  |
| NYISO_West          | Regulation      | 56.98                   | 8.00                   | 300.00                 | 25.95                | 50.00                        | 0.0%                         | NA                             | NA                                 |  |
| PJM                 | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Spinning</b>     |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Spinning        | 27.04                   | 2.50                   | 2,000.02               | 38.88                | 20.00                        | 0.0%                         | NA                             | NA                                 |  |
| MISO                | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Spinning        | 1.68                    | -                      | 715.92                 | 16.15                | -                            | 90.4%                        | 944.58                         | 9.33                               |  |
| NYISO_East          | Spinning        | 5.35                    | -                      | 836.04                 | 29.20                | -                            | 80.9%                        | NA                             | NA                                 |  |
| NYISO_West          | Spinning        | 3.52                    | -                      | 393.15                 | 16.25                | -                            | 85.7%                        | NA                             | NA                                 |  |
| PJM                 | Synchronized    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Non-spinning</b> |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Non_Spinning    | 4.11                    | -                      | 2,000.00               | 37.90                | 0.05                         | 48.4%                        | NA                             | NA                                 |  |
| MISO                | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Non_Spinning    | 1.21                    | -                      | 715.92                 | 15.64                | -                            | 95.8%                        | 1,480.73                       | 6.48                               |  |
| ISONE               | Operating       | 0.10                    | -                      | 91.01                  | 2.08                 | -                            | 99.4%                        | 1,356.20                       | 0.57                               |  |
| NYISO_East          | Non_Spinning    | 1.60                    | -                      | 650.00                 | 23.98                | -                            | 98.8%                        | NA                             | NA                                 |  |
| NYISO_West          | Non_Spinning    | 0.29                    | -                      | 156.15                 | 5.64                 | -                            | 99.5%                        | NA                             | NA                                 |  |
| NYISO_East          | Reserve_30      | 0.02                    | -                      | 61.54                  | 0.86                 | -                            | 99.9%                        | NA                             | NA                                 |  |
| NYISO_West          | Reserve_30      | 0.02                    | -                      | 61.54                  | 0.86                 | -                            | 99.9%                        | NA                             | NA                                 |  |
| PJM                 | Primary         | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |

Survey of U.S. Ancillary Services Markets

| 2007 Summary Data   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
|---------------------|-----------------|-------------------------|------------------------|------------------------|----------------------|------------------------------|------------------------------|--------------------------------|------------------------------------|--|
| Region              | Product         | Mean Price<br>(\$/MW-h) | Min Price<br>(\$/MW-h) | Max Price<br>(\$/MW-h) | St. Dev<br>(\$/MW-h) | Median<br>Price<br>(\$/MW-h) | % Hours<br>With \$0<br>Price | Average<br>Market Size<br>(MW) | Annual Market<br>Size (million \$) |  |
| <b>Regulation</b>   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| CAISO_EXP           | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Regulation_Up   | 13.14                   | 0.01                   | 298.00                 | 12.04                | 9.89                         | 0.0%                         | NA                             | NA                                 |  |
| ERCOT               | Regulation_Down | 8.30                    | 0.27                   | 70.00                  | 5.09                 | 7.26                         | 0.0%                         | NA                             | NA                                 |  |
| MISO                | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Regulation      | 57.85                   | 7.80                   | 300.00                 | 25.98                | 50.00                        | 0.0%                         | NA                             | NA                                 |  |
| NYISO_West          | Regulation      | 57.85                   | 7.80                   | 300.00                 | 25.98                | 50.00                        | 0.0%                         | NA                             | NA                                 |  |
| PJM                 | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Spinning</b>     |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Spinning        | 12.61                   | 0.86                   | 100.00                 | 9.91                 | 9.90                         | 0.0%                         | NA                             | NA                                 |  |
| MISO                | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Spinning        | 0.43                    | -                      | 183.59                 | 5.09                 | -                            | 94.8%                        | 1,258.92                       | 2.76                               |  |
| NYISO_East          | Spinning        | 5.22                    | -                      | 1,222.50               | 36.54                | -                            | 83.3%                        | NA                             | NA                                 |  |
| NYISO_West          | Spinning        | 3.25                    | -                      | 720.00                 | 19.22                | -                            | 87.2%                        | NA                             | NA                                 |  |
| PJM                 | Synchronized    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Non-spinning</b> |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Non_Spinning    | 3.01                    | -                      | 180.00                 | 6.59                 | -                            | 50.7%                        | NA                             | NA                                 |  |
| MISO                | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Non_Spinning    | 0.39                    | -                      | 157.73                 | 4.89                 | -                            | 96.7%                        | 1,294.70                       | 2.17                               |  |
| ISONE               | Operating       | 0.21                    | -                      | 122.90                 | 3.04                 | -                            | 97.8%                        | 1,509.89                       | 1.37                               |  |
| NYISO_East          | Non_Spinning    | 2.19                    | -                      | 867.31                 | 30.69                | -                            | 98.6%                        | NA                             | NA                                 |  |
| NYISO_West          | Non_Spinning    | 0.64                    | -                      | 350.00                 | 11.22                | -                            | 99.4%                        | NA                             | NA                                 |  |
| NYISO_East          | Reserve_30      | 0.23                    | -                      | 225.00                 | 5.57                 | -                            | 99.7%                        | NA                             | NA                                 |  |
| NYISO_West          | Reserve_30      | 0.21                    | -                      | 200.00                 | 5.26                 | -                            | 99.7%                        | NA                             | NA                                 |  |
| PJM                 | Primary         | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |

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| 2006 Summary Data   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
|---------------------|-----------------|-------------------------|------------------------|------------------------|----------------------|------------------------------|------------------------------|--------------------------------|------------------------------------|--|
| Region              | Product         | Mean Price<br>(\$/MW-h) | Min Price<br>(\$/MW-h) | Max Price<br>(\$/MW-h) | St. Dev<br>(\$/MW-h) | Median<br>Price<br>(\$/MW-h) | % Hours<br>With \$0<br>Price | Average<br>Market Size<br>(MW) | Annual Market<br>Size (million \$) |  |
| <b>Regulation</b>   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| CAISO_EXP           | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Regulation_Up   | 15.24                   | 1.00                   | 219.41                 | 14.71                | 11.55                        | 0.0%                         | NA                             | NA                                 |  |
| ERCOT               | Regulation_Down | 7.96                    | 0.01                   | 331.16                 | 8.81                 | 6.19                         | 0.0%                         | NA                             | NA                                 |  |
| MISO                | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Regulation      | 56.31                   | 25.20                  | 559.50                 | 32.90                | 43.00                        | 0.0%                         | NA                             | NA                                 |  |
| NYISO_West          | Regulation      | 56.31                   | 25.20                  | 559.50                 | 32.90                | 43.00                        | 0.0%                         | NA                             | NA                                 |  |
| PJM                 | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Spinning</b>     |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Spinning        | 12.93                   | 1.02                   | 168.78                 | 13.33                | 9.00                         | 0.0%                         | NA                             | NA                                 |  |
| MISO                | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Spinning        | 6.40                    | -                      | 961.31                 | 40.99                | -                            | 77.6%                        | NA                             | NA                                 |  |
| NYISO_West          | Spinning        | 3.33                    | -                      | 457.94                 | 16.82                | -                            | 83.3%                        | NA                             | NA                                 |  |
| PJM                 | Synchronized    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Non-spinning</b> |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Non_Spinning    | 8.98                    | -                      | 314.55                 | 20.42                | -                            | 59.5%                        | NA                             | NA                                 |  |
| MISO                | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Operating       | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Non_Spinning    | 2.92                    | -                      | 854.68                 | 35.47                | -                            | 98.5%                        | NA                             | NA                                 |  |
| NYISO_West          | Non_Spinning    | 0.43                    | -                      | 339.12                 | 8.93                 | -                            | 99.3%                        | NA                             | NA                                 |  |
| NYISO_East          | Reserve_30      | 0.61                    | -                      | 685.56                 | 14.88                | -                            | 99.5%                        | NA                             | NA                                 |  |
| NYISO_West          | Reserve_30      | 0.17                    | -                      | 199.84                 | 4.37                 | -                            | 99.6%                        | NA                             | NA                                 |  |
| PJM                 | Primary         | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |

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| 2005 Summary Data   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
|---------------------|-----------------|-------------------------|------------------------|------------------------|----------------------|------------------------------|------------------------------|--------------------------------|------------------------------------|--|
| Region              | Product         | Mean Price<br>(\$/MW-h) | Min Price<br>(\$/MW-h) | Max Price<br>(\$/MW-h) | St. Dev<br>(\$/MW-h) | Median<br>Price<br>(\$/MW-h) | % Hours<br>With \$0<br>Price | Average<br>Market Size<br>(MW) | Annual Market<br>Size (million \$) |  |
| <b>Regulation</b>   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| CAISO_EXP           | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Regulation_Up   | 18.54                   | 1.67                   | 322.45                 | 17.37                | 14.43                        | 0.0%                         | NA                             | NA                                 |  |
| ERCOT               | Regulation_Down | 19.53                   | 1.98                   | 700.00                 | 27.50                | 13.50                        | 0.0%                         | NA                             | NA                                 |  |
| MISO                | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Regulation      | 48.92                   | 8.91                   | 428.51                 | 43.83                | 33.58                        | 0.0%                         | NA                             | NA                                 |  |
| NYISO_West          | Regulation      | 48.92                   | 8.91                   | 428.51                 | 43.83                | 33.58                        | 0.0%                         | NA                             | NA                                 |  |
| PJM                 | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Spinning</b>     |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Spinning        | 16.61                   | 0.01                   | 731.32                 | 22.13                | 11.91                        | 0.0%                         | NA                             | NA                                 |  |
| MISO                | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Spinning        | 6.38                    | -                      | 1,383.33               | 37.03                | -                            | 77.4%                        | NA                             | NA                                 |  |
| NYISO_West          | Spinning        | 3.39                    | -                      | 850.00                 | 19.76                | -                            | 84.6%                        | NA                             | NA                                 |  |
| PJM                 | Synchronized    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Non-spinning</b> |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Non_Spinning    | 5.97                    | -                      | 510.00                 | 17.19                | -                            | 76.7%                        | NA                             | NA                                 |  |
| MISO                | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Operating       | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Non_Spinning    | 2.75                    | -                      | 875.00                 | 30.32                | -                            | 96.9%                        | NA                             | NA                                 |  |
| NYISO_West          | Non_Spinning    | 0.57                    | -                      | 350.00                 | 9.59                 | -                            | 98.7%                        | NA                             | NA                                 |  |
| NYISO_East          | Reserve_30      | 0.28                    | -                      | 446.03                 | 6.90                 | -                            | 99.1%                        | NA                             | NA                                 |  |
| NYISO_West          | Reserve_30      | 0.19                    | -                      | 200.00                 | 4.24                 | -                            | 99.3%                        | NA                             | NA                                 |  |
| PJM                 | Primary         | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |

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| 2004 Summary Data   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
|---------------------|-----------------|-------------------------|------------------------|------------------------|----------------------|------------------------------|------------------------------|--------------------------------|------------------------------------|--|
| Region              | Product         | Mean Price<br>(\$/MW-h) | Min Price<br>(\$/MW-h) | Max Price<br>(\$/MW-h) | St. Dev<br>(\$/MW-h) | Median<br>Price<br>(\$/MW-h) | % Hours<br>With \$0<br>Price | Average<br>Market Size<br>(MW) | Annual Market<br>Size (million \$) |  |
| <b>Regulation</b>   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| CAISO_EXP           | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Regulation_Up   | 11.52                   | 2.00                   | 64.74                  | 8.47                 | 9.00                         | 0.0%                         | NA                             | NA                                 |  |
| ERCOT               | Regulation_Down | 11.13                   | 0.01                   | 101.02                 | 10.73                | 7.99                         | 0.0%                         | NA                             | NA                                 |  |
| MISO                | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| PJM                 | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Spinning</b>     |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Spinning        | 8.32                    | 0.01                   | 51.03                  | 6.59                 | 6.99                         | 0.0%                         | NA                             | NA                                 |  |
| MISO                | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| PJM                 | Synchronized    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Non-spinning</b> |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Non_Spinning    | 1.87                    | -                      | 399.98                 | 8.60                 | -                            | 75.2%                        | NA                             | NA                                 |  |
| MISO                | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Operating       | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Reserve_30      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Reserve_30      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| PJM                 | Primary         | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |

Survey of U.S. Ancillary Services Markets

| 2003 Summary Data   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
|---------------------|-----------------|-------------------------|------------------------|------------------------|----------------------|------------------------------|------------------------------|--------------------------------|------------------------------------|--|
| Region              | Product         | Mean Price<br>(\$/MW-h) | Min Price<br>(\$/MW-h) | Max Price<br>(\$/MW-h) | St. Dev<br>(\$/MW-h) | Median<br>Price<br>(\$/MW-h) | % Hours<br>With \$0<br>Price | Average<br>Market Size<br>(MW) | Annual Market<br>Size (million \$) |  |
| <b>Regulation</b>   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| CAISO_EXP           | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Regulation_Up   | 12.11                   | -                      | 999.00                 | 44.88                | 8.05                         | 0.2%                         | NA                             | NA                                 |  |
| ERCOT               | Regulation_Down | 7.76                    | 0.19                   | 70.00                  | 5.54                 | 6.24                         | 0.0%                         | NA                             | NA                                 |  |
| MISO                | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| PJM                 | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Spinning</b>     |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Spinning        | 11.00                   | -                      | 999.00                 | 50.96                | 7.00                         | 0.0%                         | NA                             | NA                                 |  |
| MISO                | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| PJM                 | Synchronized    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Non-spinning</b> |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Non_Spinning    | 2.64                    | -                      | 200.00                 | 8.45                 | -                            | 74.7%                        | NA                             | NA                                 |  |
| MISO                | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Operating       | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Reserve_30      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Reserve_30      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| PJM                 | Primary         | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |

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| 2002 Summary Data   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
|---------------------|-----------------|-------------------------|------------------------|------------------------|----------------------|------------------------------|------------------------------|--------------------------------|------------------------------------|--|
| Region              | Product         | Mean Price<br>(\$/MW-h) | Min Price<br>(\$/MW-h) | Max Price<br>(\$/MW-h) | St. Dev<br>(\$/MW-h) | Median<br>Price<br>(\$/MW-h) | % Hours<br>With \$0<br>Price | Average<br>Market Size<br>(MW) | Annual Market<br>Size (million \$) |  |
| <b>Regulation</b>   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| CAISO_EXP           | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Regulation_Up   | 6.52                    | -                      | 55.00                  | 4.05                 | 5.79                         | 0.1%                         | NA                             | NA                                 |  |
| ERCOT               | Regulation_Down | 5.08                    | -                      | 171.93                 | 4.81                 | 3.99                         | 0.1%                         | NA                             | NA                                 |  |
| MISO                | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| PJM                 | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Spinning</b>     |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Spinning        | 6.56                    | -                      | 119.19                 | 5.77                 | 5.00                         | 0.1%                         | NA                             | NA                                 |  |
| MISO                | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| PJM                 | Synchronized    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Non-spinning</b> |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Non_Spinning    | 2.73                    | -                      | 999.00                 | 38.83                | -                            | 82.2%                        | NA                             | NA                                 |  |
| MISO                | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Operating       | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Reserve_30      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Reserve_30      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| PJM                 | Primary         | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |

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| 2001 Summary Data   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
|---------------------|-----------------|-------------------------|------------------------|------------------------|----------------------|------------------------------|------------------------------|--------------------------------|------------------------------------|--|
| Region              | Product         | Mean Price<br>(\$/MW-h) | Min Price<br>(\$/MW-h) | Max Price<br>(\$/MW-h) | St. Dev<br>(\$/MW-h) | Median<br>Price<br>(\$/MW-h) | % Hours<br>With \$0<br>Price | Average<br>Market Size<br>(MW) | Annual Market<br>Size (million \$) |  |
| <b>Regulation</b>   |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| CAISO_EXP           | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Regulation_Up   | 10.93                   | -                      | 500.00                 | 43.07                | 6.50                         | 0.0%                         | NA                             | NA                                 |  |
| ERCOT               | Regulation_Down | 7.96                    | 0.50                   | 500.00                 | 34.50                | 2.85                         | 0.0%                         | NA                             | NA                                 |  |
| MISO                | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| PJM                 | Regulation      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Up   | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Regulation_Down | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Spinning</b>     |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Spinning        | 7.34                    | 0.50                   | 1,000.00               | 34.38                | 3.99                         | 0.0%                         | NA                             | NA                                 |  |
| MISO                | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| PJM                 | Synchronized    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Spinning        | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| <b>Non-spinning</b> |                 |                         |                        |                        |                      |                              |                              |                                |                                    |  |
| CAISO_EXP           | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ERCOT               | Non_Spinning    | 4.60                    | -                      | 1,000.00               | 61.72                | -                            | 85.0%                        | NA                             | NA                                 |  |
| MISO                | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| ISONE               | Operating       | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Non_Spinning    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_East          | Reserve_30      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| NYISO_West          | Reserve_30      | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| PJM                 | Primary         | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |
| SPP                 | Supplemental    | #N/A                    | #N/A                   | #N/A                   | #N/A                 | #N/A                         | #N/A                         | #N/A                           | #N/A                               |  |



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