California ISO and MISO Experiences and Prospective Operational Challenges for the New York ISO

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Topics

- California ISO and MISO Operational Challenges
- California ISO and MISO Evolution
- Conclusions

Appended

- Additional Detail
- References

Operational Challenges Overview

The California ISO and MISO have encountered a number of challenges in accommodating high levels of intermittent resources over the past several years. Two that will likely impact future New York ISO operations will be discussed today:

- Ramp constraints causing power balance violations in the real-time dispatch;
- Insufficient regulation to balance load and generation within the time frame of the real-time dispatch.

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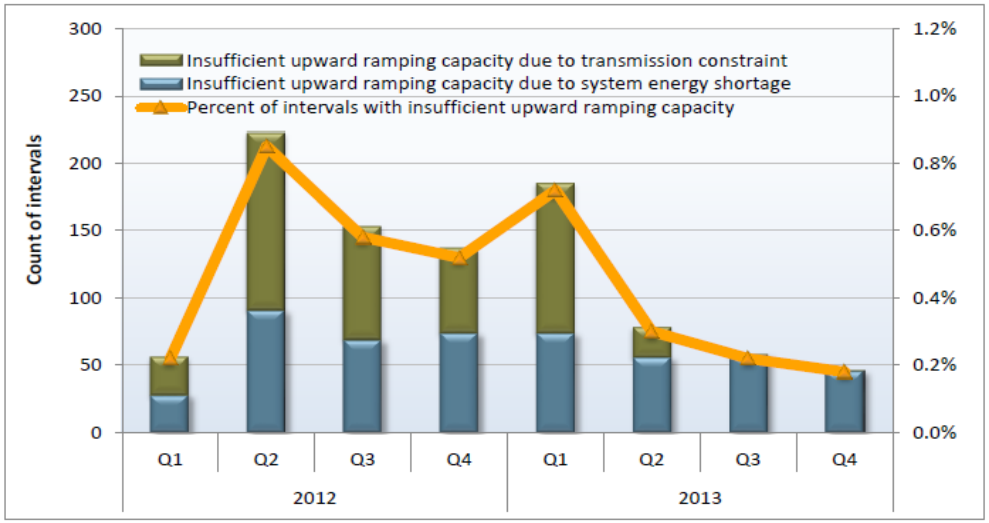
Power Balance Violations Due to Ramp Constraints

Operational Challenges — Ramp

The California ISO has had issues with ramp constraints causing power balance violations (an inability to increase generation output fast enough to balance net load) in the real-time dispatch. These power balance violations continued at a high level in 2012 despite the California ISO implementing a forward looking commitment for ramp capability at the end of 2011.

Power Balance Violations in RTD due to Insufficient Upward Ramp Capability
California ISO 2012-2013



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Source: 2013 Annual Report on Market Issues & Performance, California ISO, Department of Market Monitoring, April 2014 figure 3.1 page 86. Data for power balance violations over 2010-2011 and 2014-2015 is appended.

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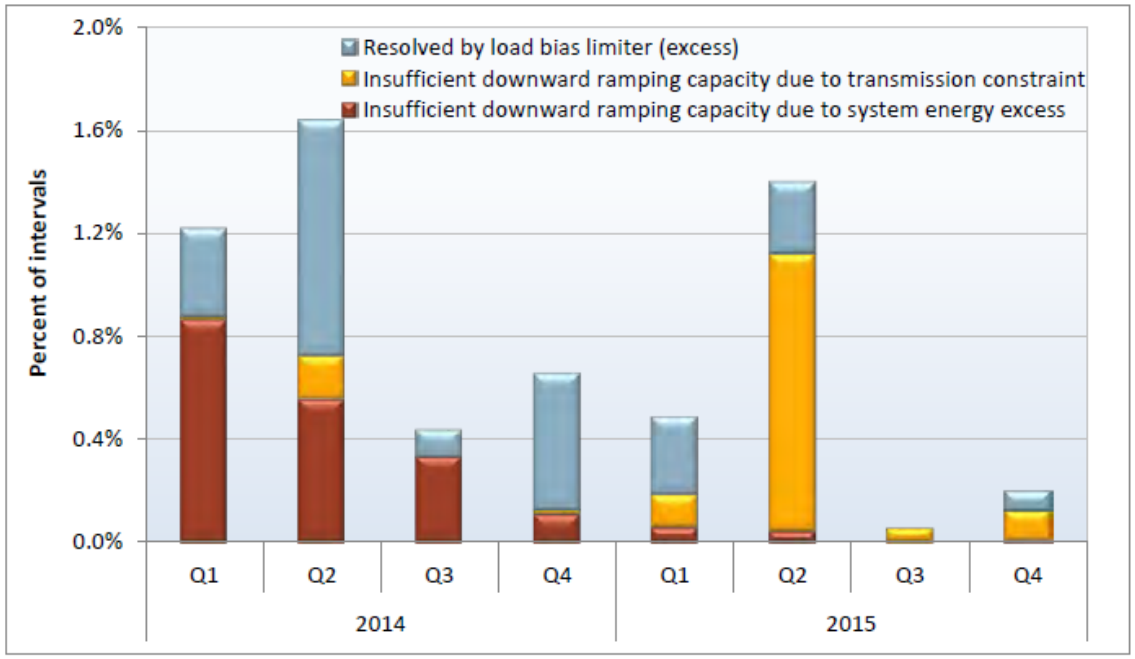
There has also been a converse problem of insufficient downward ramp capability leading to downward power balance violations in the real-time dispatch.

Power Balance Violations in RTD due to Insufficient Downward Ramp Capability
California ISO 2014-2015



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Source: 2015 Annual Report on Market Issues & Performance, California ISO, Department of Market Monitoring, May 2016 figure 3.9 page 81.

Insufficient Regulation to Balance Load and Generation

Operational Challenges — Regulation

In early 2016 the California ISO encountered problems balancing load and generation in real-time because its historical regulation requirement proved insufficient to balance load and generation within the time frame of the real-time dispatch.

- The California ISO has provided a detailed public discussion of the operational problems it encountered on an illustrative day, January 31, 2016.

- The problems on this day appear to have been a result of a combination of large near-term forecast errors for intermittent resource output, lags in the adjustment of the net load forecast, and perhaps elements of the way in which the AGC and real-time dispatch were designed to operate.

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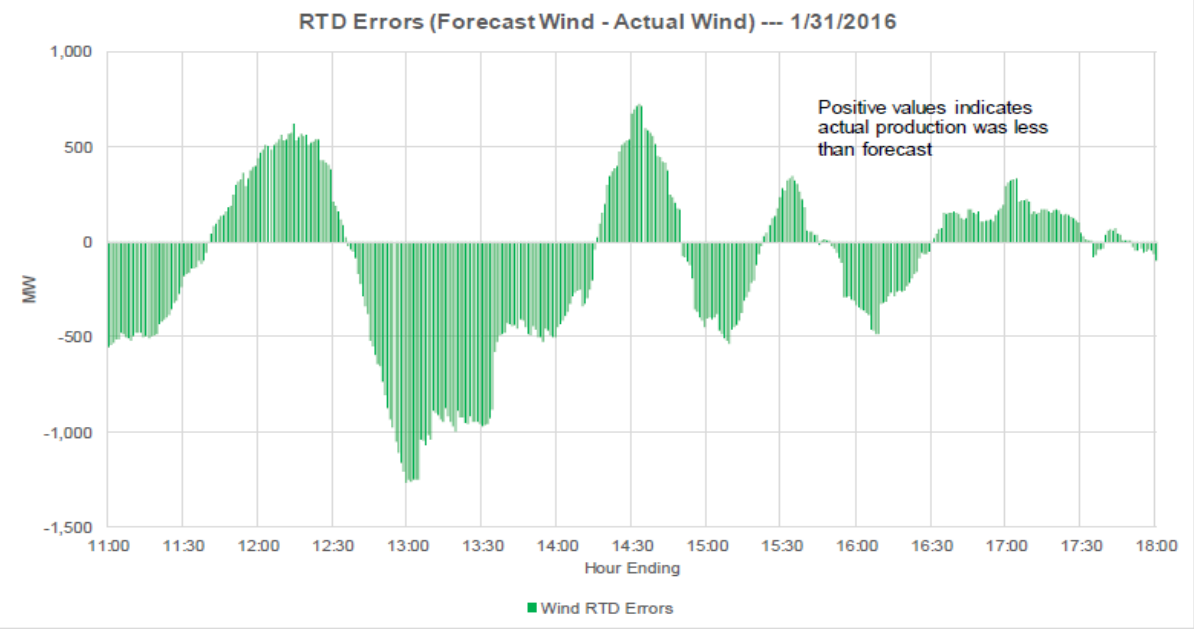
One source of these problems were large forecast errors of wind output within the time frame of the real-time dispatch.

California ISO RTD Wind Forecast Error

January 31, 2016



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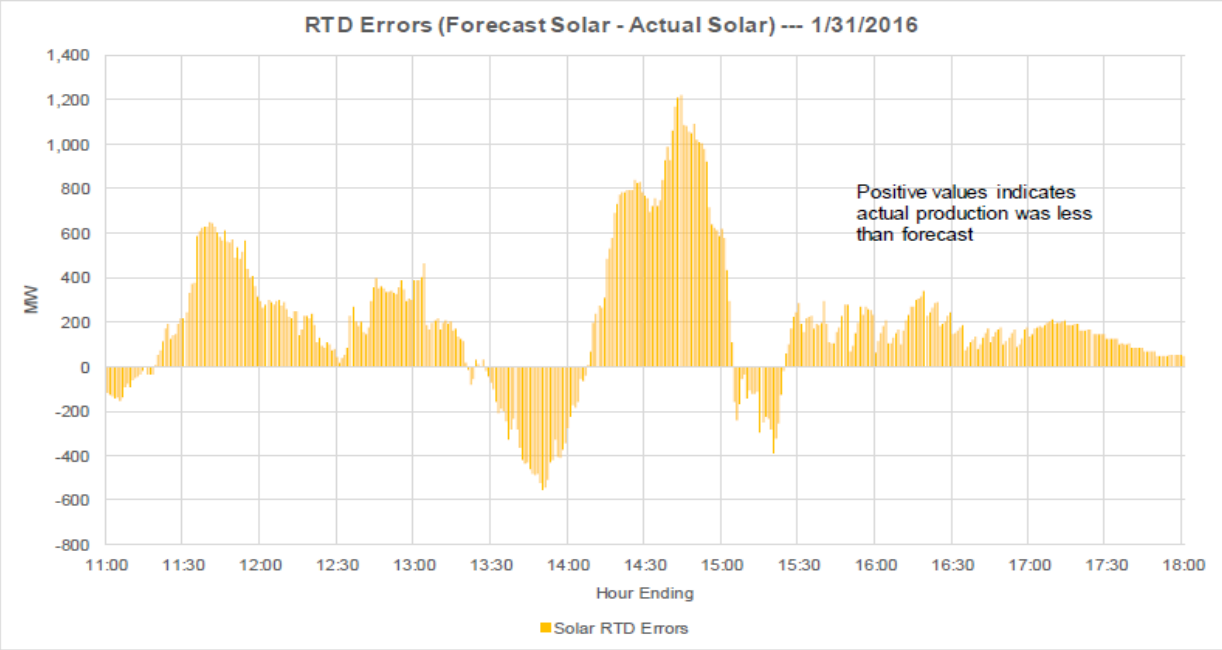
Source: California ISO, Market Performance and Planning Forum, July 21, 2016 p. 44.

Another source of problems were similar large forecast errors for solar generation output within the time frame of the real-time dispatch.

California ISO RTD Solar Forecast Error

January 31, 2016



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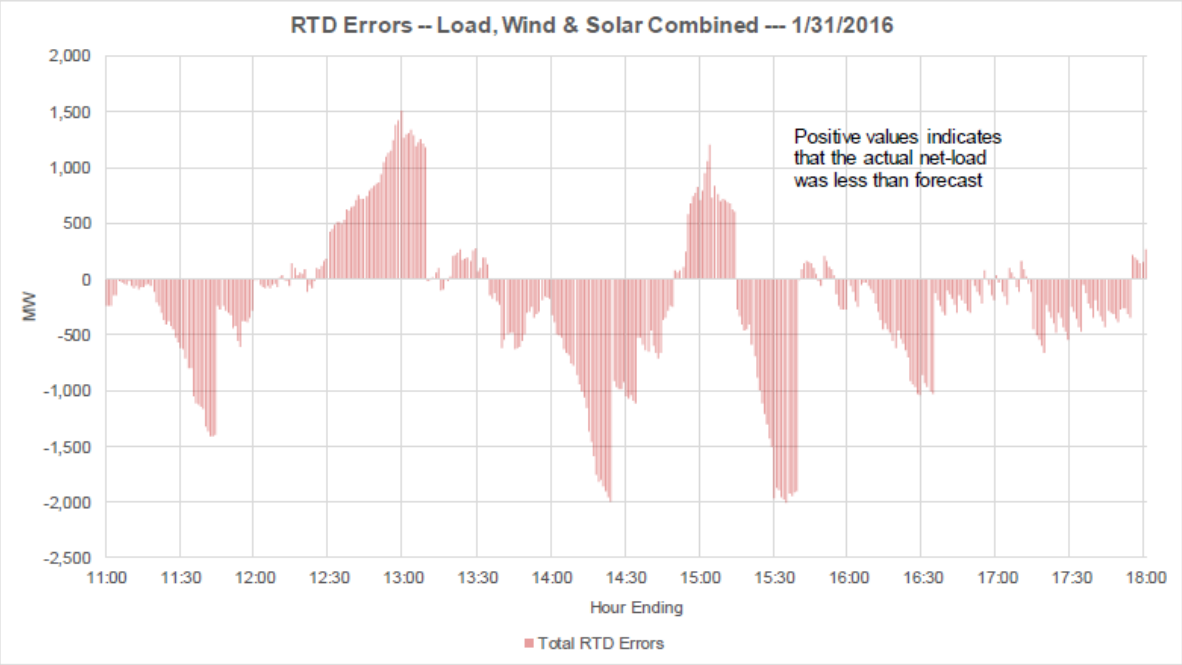
Source: California ISO, Market Performance and Planning Forum, July 21, 2016 p. 45.

While the forecast errors for wind and solar output and gross load offset at times, they combined to produce larger errors at other times that persisted for a number of dispatch intervals.

California ISO RTD Combined Net Load Forecast Error

January 31, 2016



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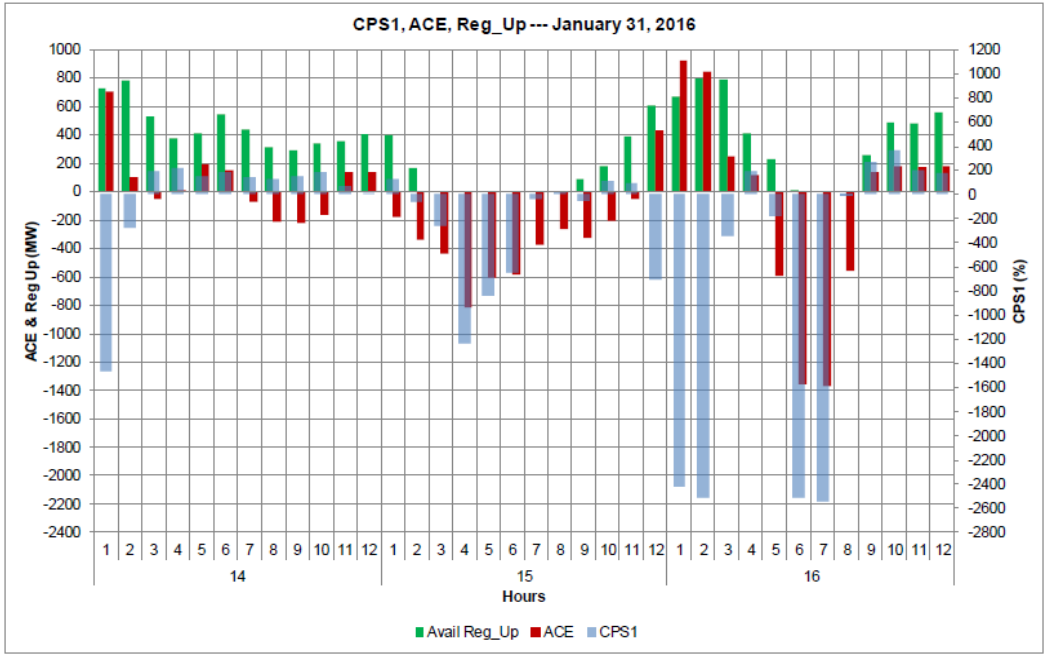
Source: California ISO, Market Performance and Planning Forum, July 21, 2016 p. 46.

The result of these forecasting errors was that the real-time dispatch instructions did not balance load and generation and the imbalance was too large to be met with the normal regulation requirement.

California ISO Available Regulation Up and ACE

January 31, 2016



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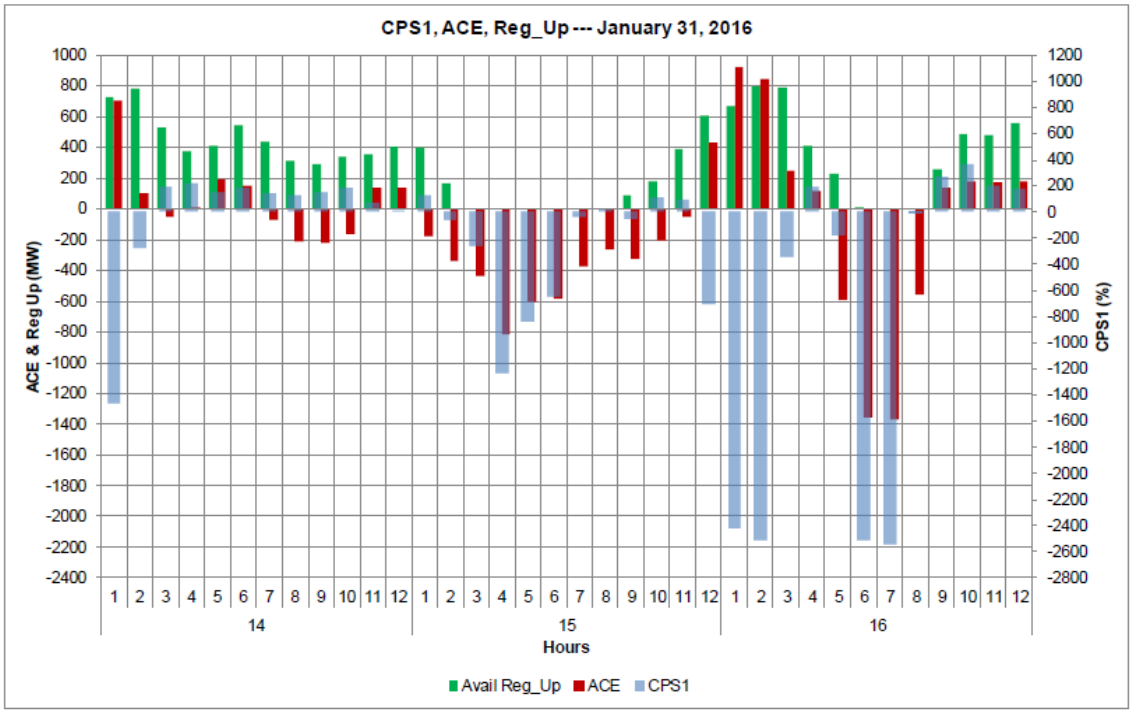
Source: California ISO, Market Performance and Planning Forum, July 21, 2016 p. 51.

It is noteworthy that the forecast errors were so large that no regulation Up was available for long periods of time, not just single intervals.

California ISO Available Regulation Up and ACE

January 31, 2016



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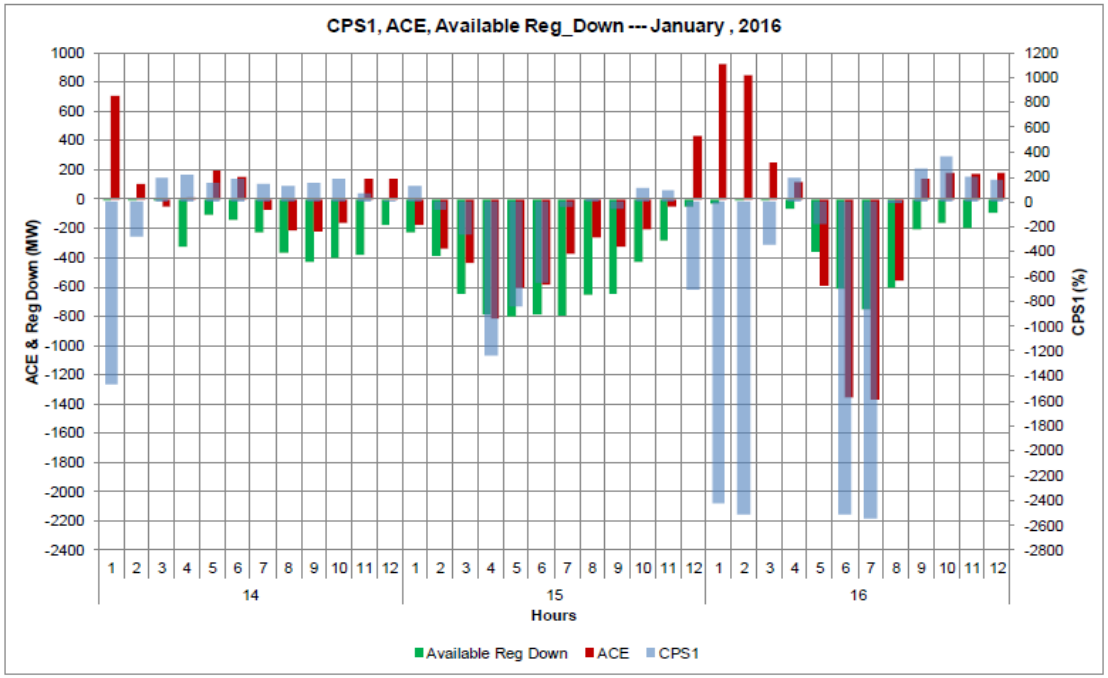
Source: California ISO, Market Performance and Planning Forum, July 21, 2016 p. 51.

The problems on this day were not just insufficient regulation Up, there were also periods when the dispatch was so far in excess of load that there was insufficient down regulation to balance load and generation within the time frame of the real-time dispatch.

California ISO Available Regulation Down and ACE

January 31, 2016



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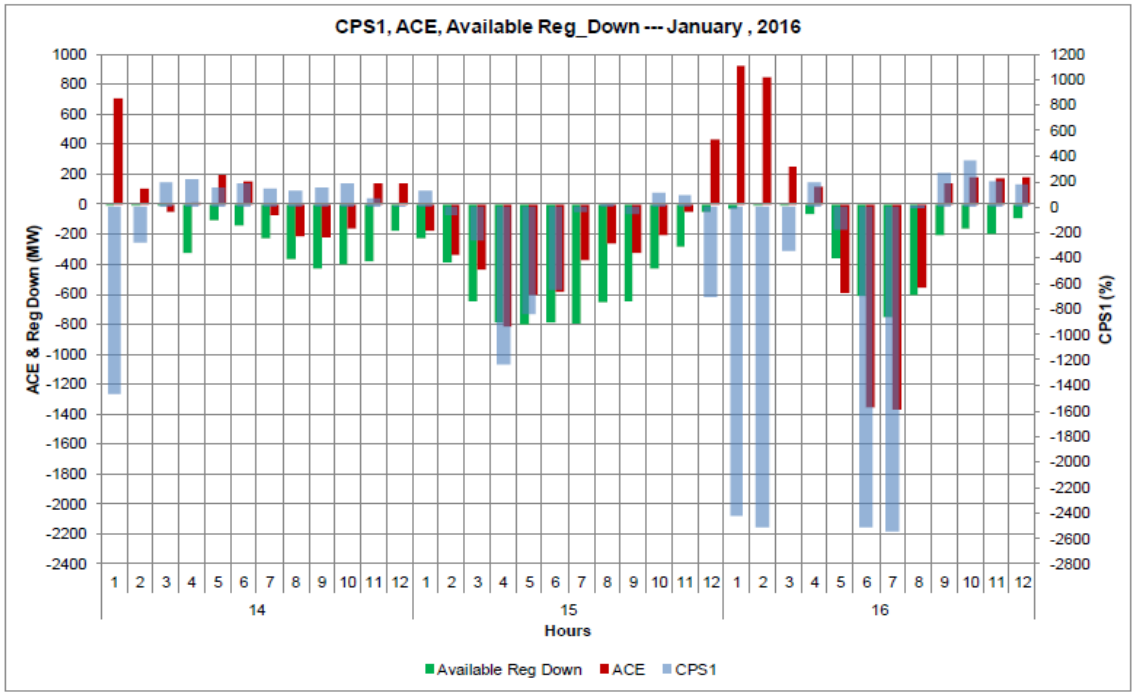
Source: California ISO, Market Performance and Planning Forum, July 21, 2016 p. 52.

Some of these periods with little or no regulation Down available also persisted for multiple intervals.

California ISO Available Regulation Down and ACE

January 31, 2016



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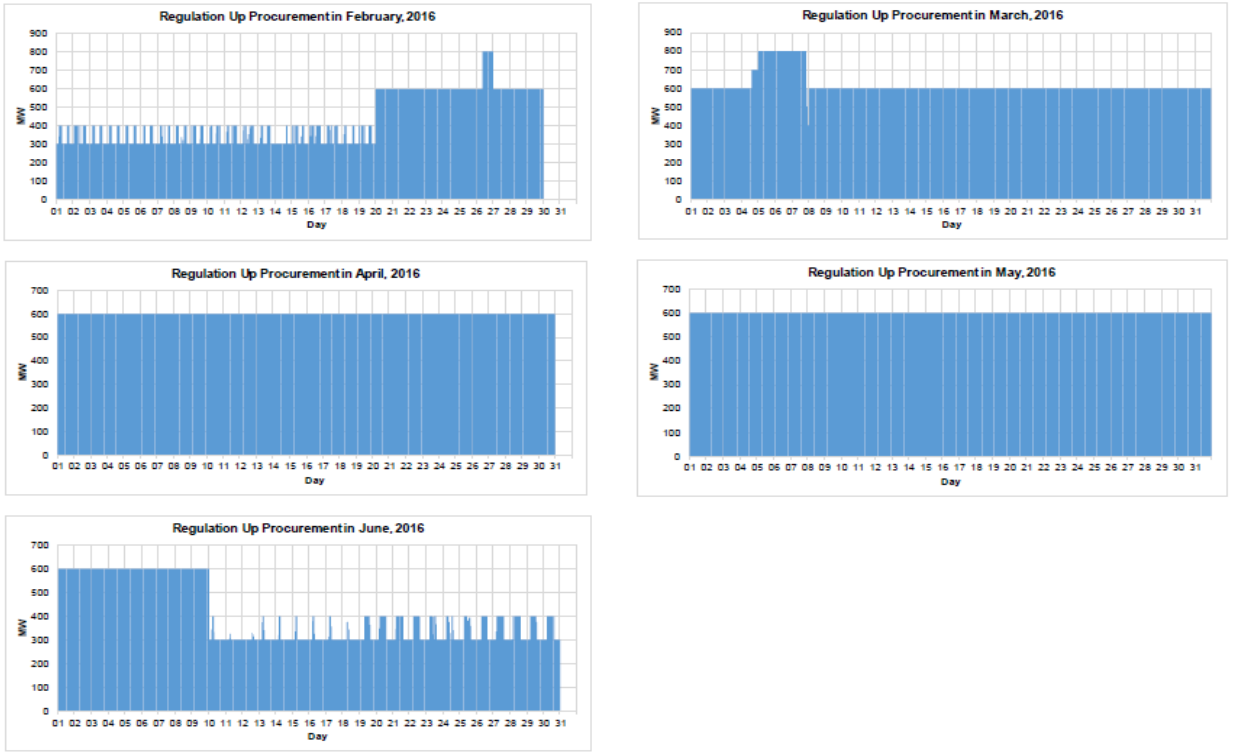
Source: California ISO, Market Performance and Planning Forum, July 21, 2016 p. 52.

These operational problems in January and February led California ISO operations to implement a large increase in the regulation requirement on February 20, 2016.

California ISO Regulation Requirements



Source: California ISO, Market Performance and Planning Forum, July 21, 2016 p. 55.

California and MISO Operating and Market Evolution

The California ISO and MISO have been evaluating, developing, and refining a number of market design and performance changes in order to address the challenges outlined above.

- Increase participation in economic dispatch;
- Implement ramp capability unit commitment;
- Implement ramp capability dispatch;
- Increase regulation depth or modify structure;
- Expand the scope of the ISO dispatch;
- Extend the time frame of intra-day unit commitment evaluations;
- Evolve the structure of the day-ahead market;
- Provide efficient incentives for the development and continued operation of low emitting flexible supply resources.

Full participation of physically dispatchable resources in the ISO economic dispatch is important for an ISO's ability to accommodate upward variations in intermittent resource output without adversely impacting overall grid reliability.

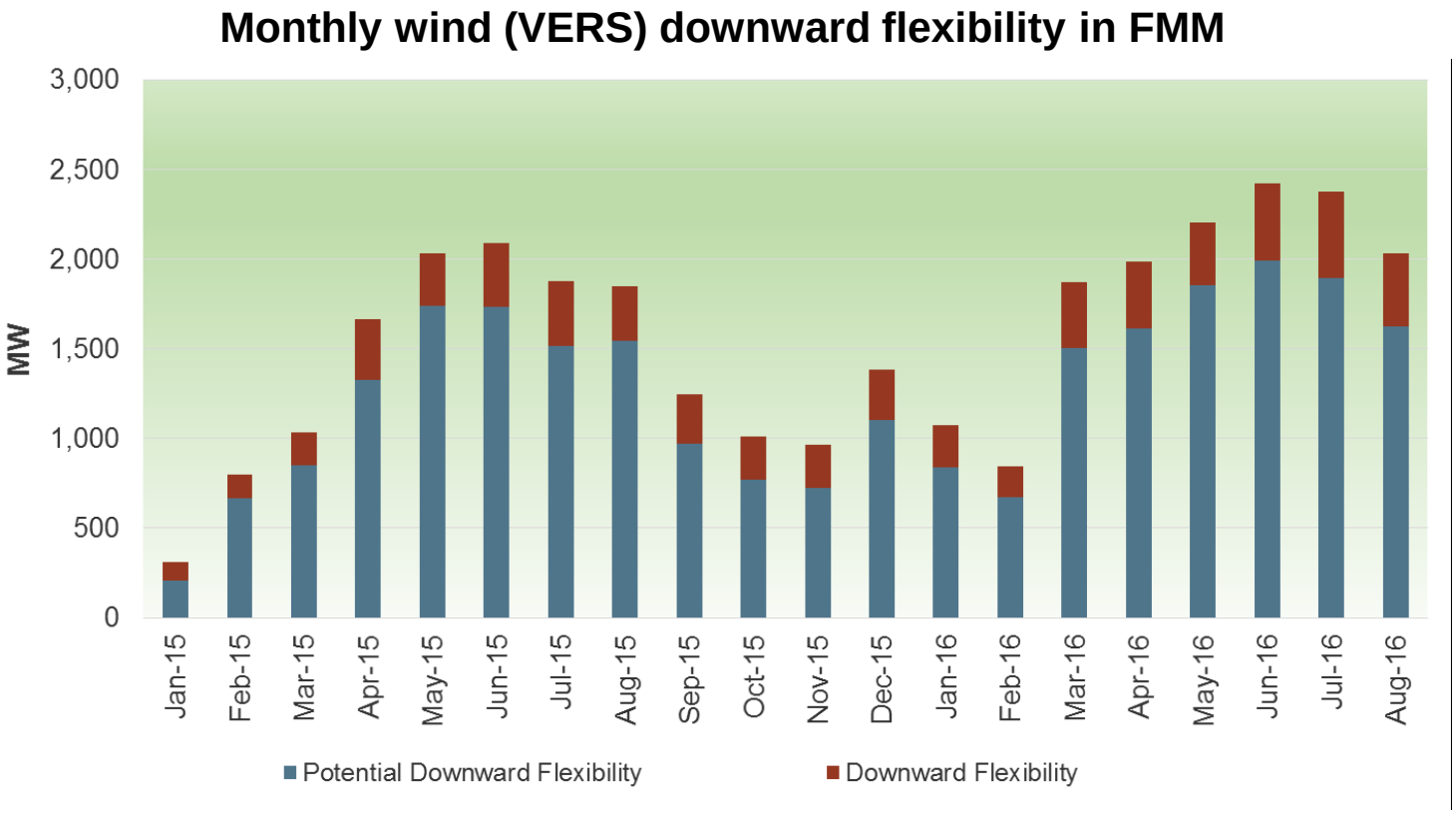
- The California ISO has made multiple changes in the design of its bid production cost guarantees over the past five years in order to remove disincentives for thermal resources to participate in the real-time economic dispatch. [1]

- The California ISO reduced its bid floor from -$30 to -$150 in May 2014 to encourage economic offers in place of self-schedules. [2]

- The California ISO is evaluating further changes in uplift allocation rules in order to remove incentives for load serving entities to self-schedule resources rather than participating in the economic dispatch. [3]

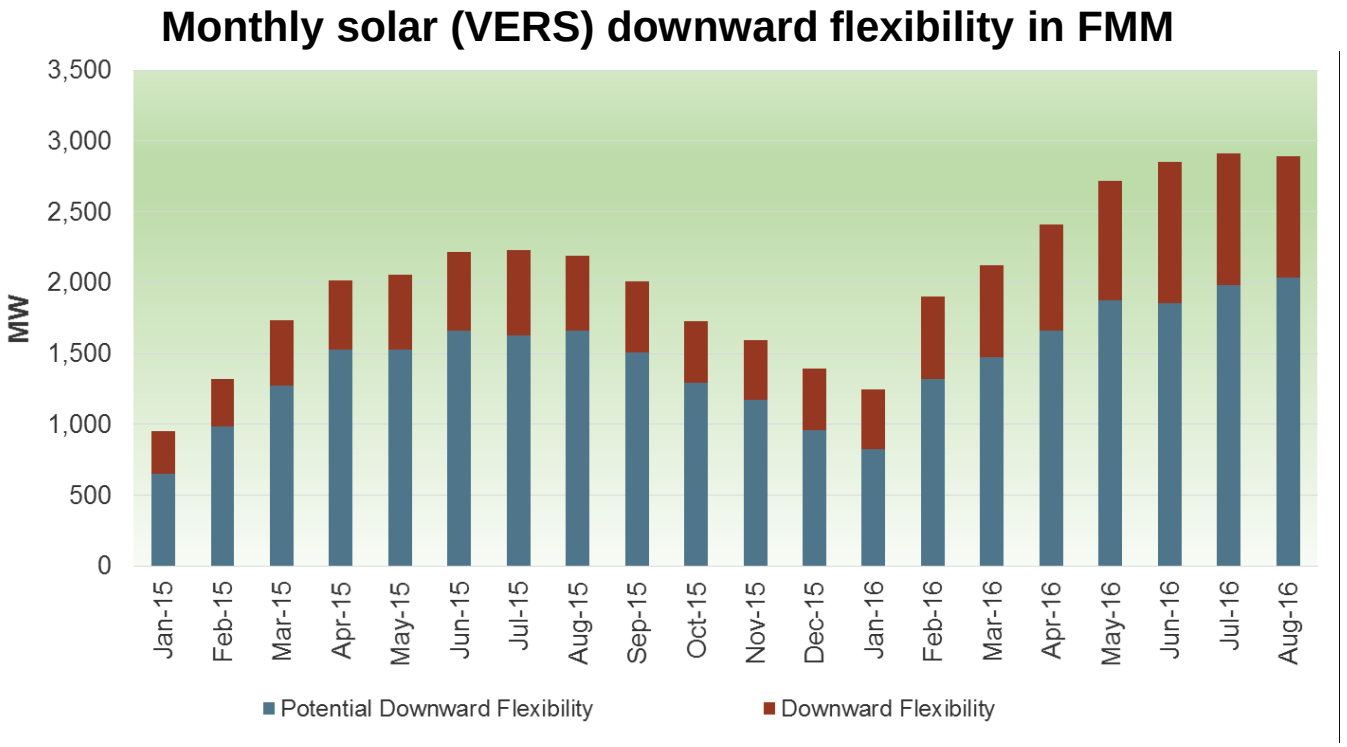
1 See Docket ER13-2452
2 See Docket ER13-2452
3 see http://www.caiso.com/informed/Pages/StakeholderProcesses/SelfSchedulesBidCostRecoveryAllocation_BidFloor.aspx

Nevertheless, only a small portion of wind generation output participates in the California ISO's economic dispatch.



Source: California ISO, Market Performance and Planning Forum, September 20, 2016 p. 33. "FMM" is the California ISO's 15 minute market.

A larger proportion of solar generation is typically dispatchable than is the case for wind, but less than 1/3 of solar output is dispatchable on average.



Source: California ISO, Market Performance and Planning Forum, September 20, 2016 p. 34.

A continuing problem in achieving higher levels of dispatchability, particularly in California, are contract structures that discourage participation in the economic dispatch.

- There have been suggestions that contract provisions that treat curtailed output differently than economically dispatched output has incented self-scheduling by buyers to avoid paying the contract price for curtailed output.
- The source of this problem is contract provisions that pay high prices for power delivered at times when the power has a substantially negative economic value.
- These incentive issues not only involve the structure of solar and wind generation contracts but also the structure of contracts for cogeneration facility output.
- Contract structures that require economic bids but incent the submission of highly negative offer prices can also create operational challenges through their impact on the unit commitment.

Implement ramp capability unit commitment

- The MISO began taking ramp capability (headroom) into account in operator intra-day unit commitment decisions back in 2008, both to aid in managing variations in wind generation output and to manage unpredictable variations in net interchange.
- The MISO began developing a look–ahead unit commitment tool analogous to RTC in 2009 and implemented it in April 2012. [1]
- The California ISO implemented a look-ahead unit commitment model (RTPD) that is very similar to the NYISO's RTC in April 2009.
- In December 2011, the California ISO modified the RTPD design to take account of projected ramp capability in future periods and included an explicit ramp capability target in determining whether to commit generation and schedule interchange in RTPD. [2]

1. **Filed in docket ER12-923 January 27, 2012**
2. **Filed in docket ER12-50, October 7, 2011.**

While these efforts provide valuable learning experiences for the New York ISO to draw upon, these efforts highlight the complexity of the problem:

- Implementing a ramp capability target in the forward looking commitment tool but not in the real-time dispatch has lead to what appear to be substantial amounts of “phantom ramp” in the California ISO look-ahead unit commitment ramp evaluation.

- The California ISO has found it necessary modify the penalty values used for ramp procurement a number of times, with a new design planned for implementation in November 2016.

- Moreover, the California ISO is still struggling to set cost effective ramp procurement targets close to five years after the design was initially implemented.

Implement ramp capability dispatch

- Both the MISO and California ISO have been developing and are now implementing a new dispatch concept which it is hoped will increase the ramp capability that will be available from existing resources to manage variations in intermittent resource output.

- The MISO implemented its design on May 1, 2016 [1] and the California ISO plans to implement its design on November 1, 2016 following final FERC approval. [2]

1. **1. See https://www.misoenergy.org/WhatWeDo/MarketEnhancements/Pages/RampManagement.aspx filed in docket ER14-2156**
2. **2. See http://www.caiso.com/informed/Pages/StakeholderProcesses/FlexibleRampingProduct.aspx, filed in docket ER16-2023.**

The implementation of these ramp capability designs is only the first step in utilizing ramp based dispatch to better accommodate variations in intermittent resource output.

- The ability of these designs to achieve cost effective increases in ramp capability depends on the ability of the ISO to select appropriate values for key parameters in the optimization such as the ramp target for each period and the penalty price for ramp capability shortfalls.

- It will take time to assess how the initial parameter choices are performing and make necessary adjustments, which will be complicated by continuing changes in the resource mix and market conditions.

Until practical operating experience is available with these design it is also be uncertain whether these initial dispatch designs will need to modified to manage distinct ramp targets in each forward time interval in order to achieve the intended benefits.

- The New York ISO will be able to benefit from observing the operation of the initial MISO and California ISO designs.
- Unfortunately, one possible lesson could be that these designs are not effective enough in procuring additional ramp capability on a cost effective basis to help the New York ISO manage higher levels of intermittent resource output.

Increase regulation depth or modify regulation and dispatch designs.

- The California ISO's problems in early 2016 with large real-time load forecast errors and a consequent inability to balance load and generation caused the California ISO to roughly double the regulation requirement in many hours was discussed above.

- This increase lead to a rough quintupling of regulation costs and appears to have also driven up spinning reserve and ramp capability prices because the other ancillary services compete for the same ramp capability needed to provide regulation. [1]

1. **The California ISO department of market monitoring calculated that the total cost of regulation rose from less than $90,000 a day prior to the increase, to an average of around $470,000 a day while the higher requirements were in effect, See California ISO Department of Market Monitoring, Q2 2016 Report on Market Issues and Performance, p. 73**

Alternatives to increases in regulation requirements could be:

- improved real-time net load forecasting methods;
  - -- improved accuracy
  - -- higher solution speed/reduced time lag

- Changes to the way regulation ranges are defined relative to the RTD dispatch and actual generator operating points.

Expand the geographic scope of the ISO dispatch.

- The MISO was already substantially larger than the New York ISO when it added Entergy and other utilities in MISO south in late 2013, increasing installed summer capacity from 107,714 megawatts in 2013 to 143,610 megawatts in 2014. [1]

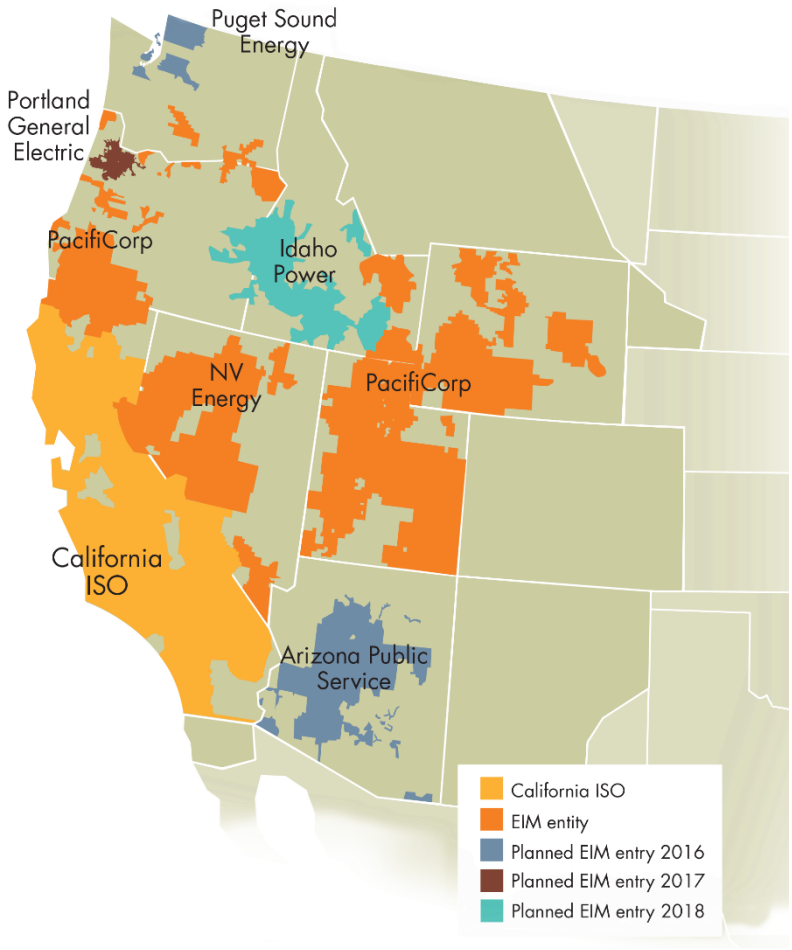
- The California ISO's peak load is around 50% larger than that of the New York ISO (47,257 megawatts) yet the California ISO has still found it desirable to expand its geographic scope through the energy imbalance market (adding around 26,000 megawatts of generation to date and more than 33, 000 by 2018) to better manage variations in the output of intermittent resources.

1. **See Potomac Economics, MISO 2014 State of the Market Report p. 5.**

California ISO and Miso Evolution

Scope

The Western EIM already covers a broad footprint in WECC, and that footprint will expand substantially in the next few years.



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It will be difficult for the New York ISO to expand the geographic scope of its real-time dispatch in the same way the MISO and California ISO have done.

- The New York ISO's efforts to implement 15 minute interchange scheduling and coordinated interchange scheduling are ways to achieve some of the benefits of a larger geographic scope in managing higher levels of intermittent resource output.

- One of the challenges for the New York ISO will be to work with the Ontario IESO and ISO New England to improve coordination of real-time interchange scheduling among the three Northeast ISOs.

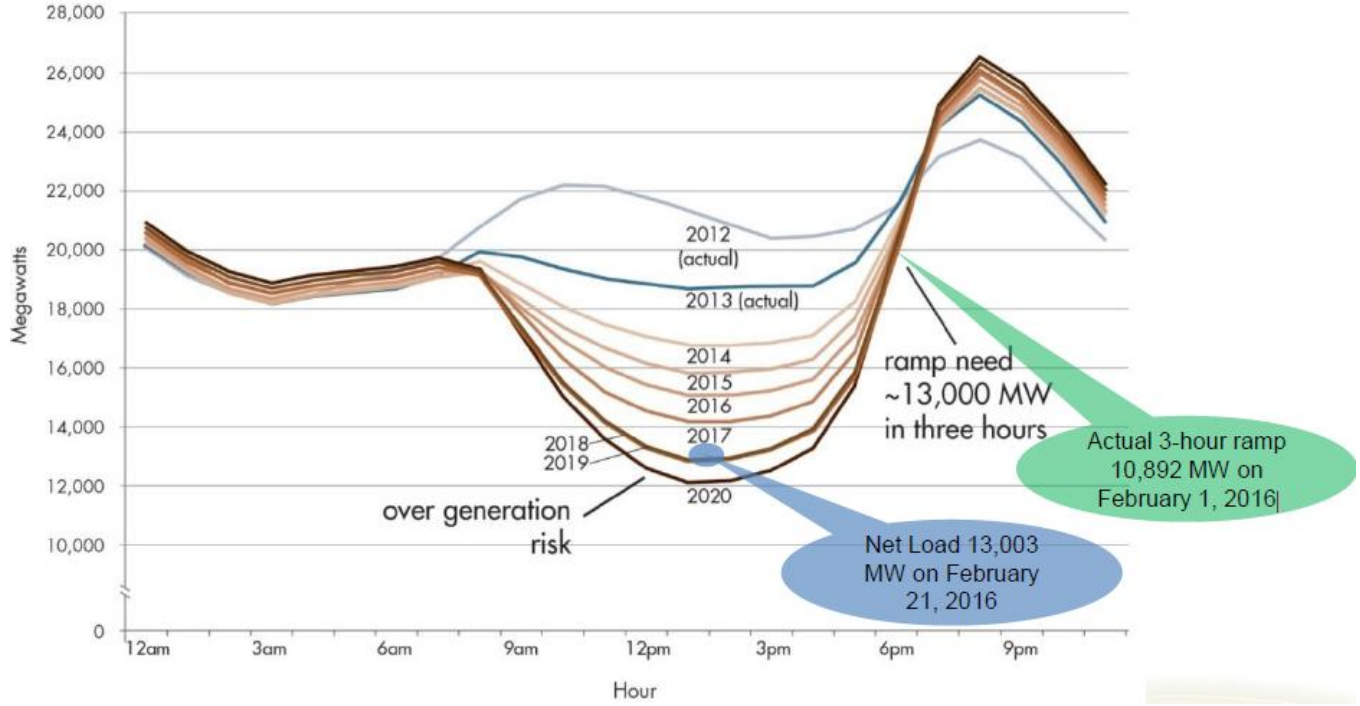
Extend the time frame of intra-day unit commitment evaluations.

- One of the emerging problems in managing high levels of intermittent resource output is the mismatch between the look-ahead horizon of the current look-ahead unit commitment programs and the horizon needed to manage variations in net load over the day on a system with substantial solar generation.
- The California ISO RTPD/RTUC program looks out 1 to 1.25 hours in 15 minute increments. [1]
- The MISO look-ahead unit commitment tool looks out 3 hours in 15 and 30 minute increments. [2]
- The New York ISO RTC looks out 2.5 hours in 15 minute increments.

1. **See California ISO Business Practice Manual for Market Operations section 7.6.**
2. **See MISO April 30, 2012 filing letter in Docket ER12-923.**

The California duck curve reflects a net load peak in the early morning hours when solar generation output is low then an evening net load peak when the sun goes down.

Typical Spring Day Forecast from 2014



Source: California ISO, "Draft Flexible Capacity Needs Assessment for 2017," p. 21

None of the current intra-day unit commitment programs looks out far enough to take both the morning and evening net load peaks into account in making commitment and decommitment decisions.

- The MISO, California ISO and NYISO day-ahead markets all look out over the entire day in scheduling the day-ahead market but this optimization over the day can be undone in real-time by intra-day evaluations looking out only a few of hours.

- One way to better manage unit commitment over the duck curve would be to use an intra-day commitment evaluation that is able to look out over both of the daily net load peaks.

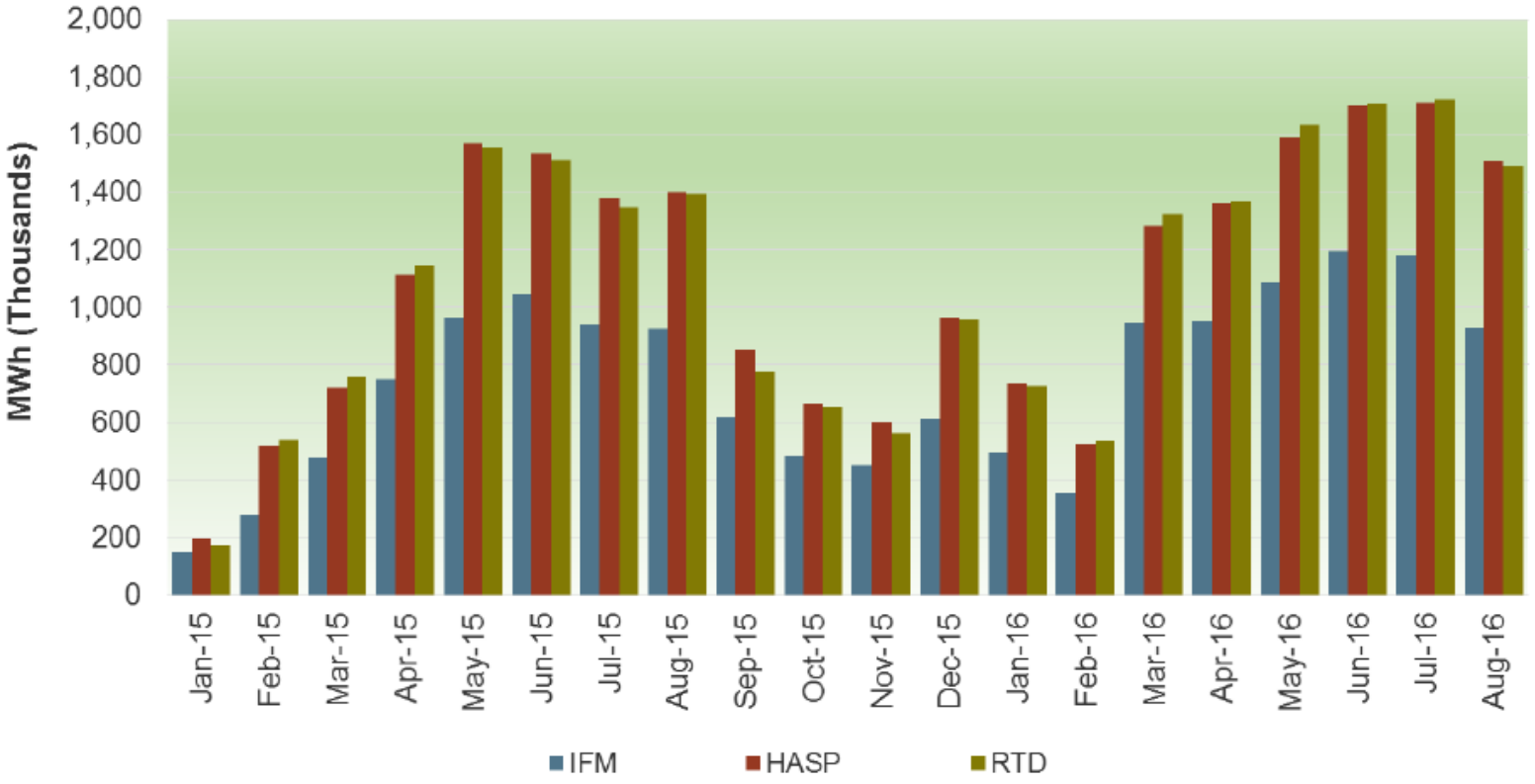
Evolve the structure of the day-ahead market.

The design of the MISO, California ISO and New York ISO day-ahead markets and reliability commitment processes was developed with historical load shapes, load forecast errors and resource outage rates in mind.

- Some elements of these designs operate differently if the resource mix includes a large amount of intermittent resource output.
- Accommodating these changes may require changes to the structure of the reliability commitment and/or further changes in the level and structure of reserve targets and reserve shortage values.

California ISO and MISO Evolution DAM

The California ISO has published data showing the average difference between wind resource output and day-ahead market schedules.



Source: California ISO, Market Performance and Planning Forum, September 16, 2016 p. 28

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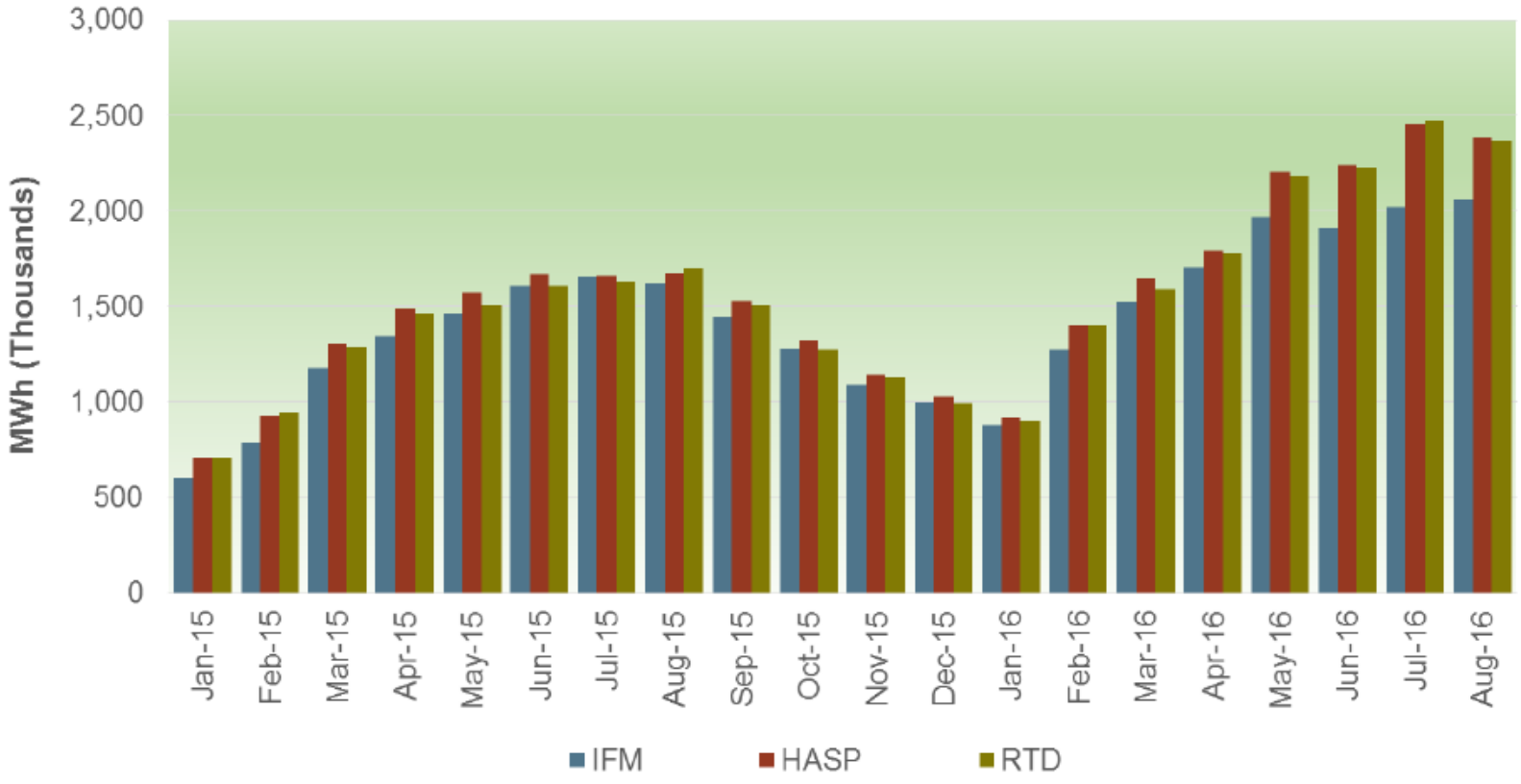
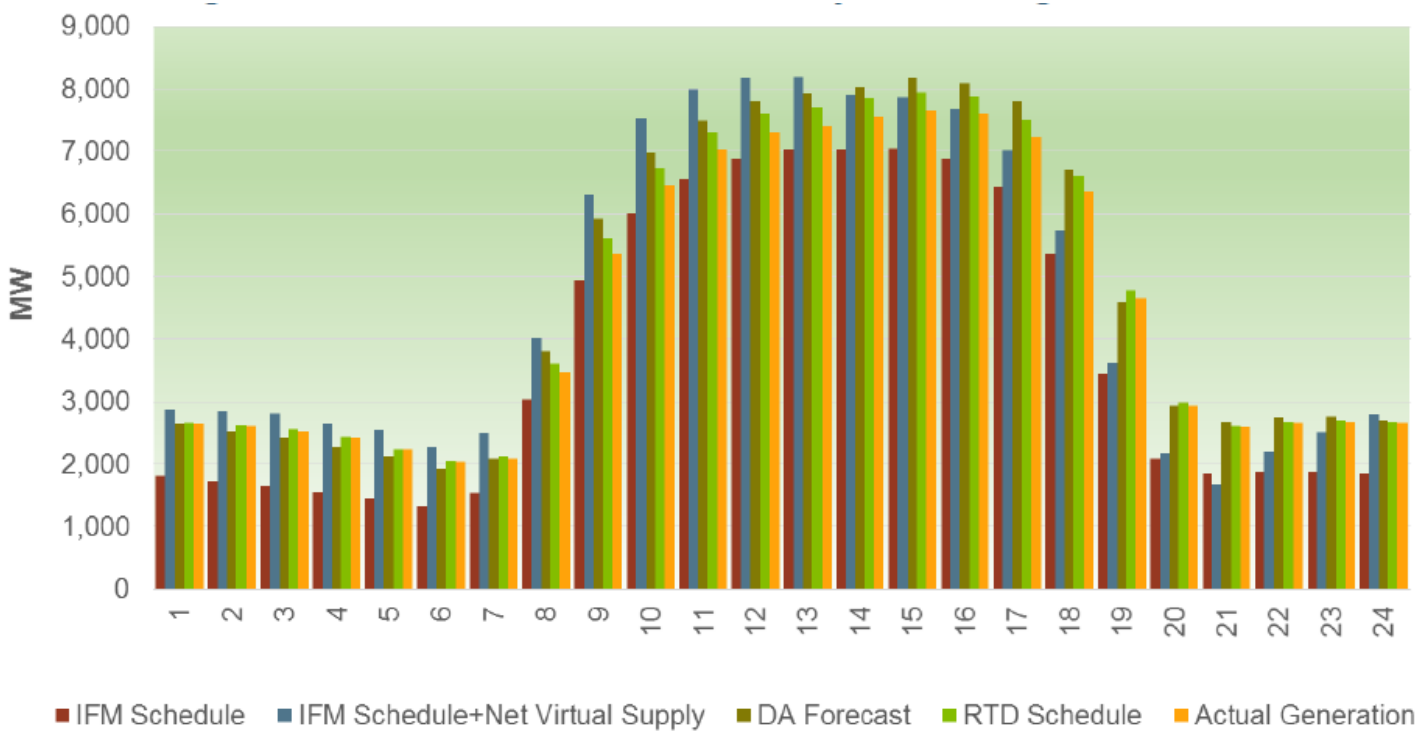
The California ISO has published similar data for solar generation output showing a somewhat smaller gap between day-ahead market schedules and real-time output.



Source: California ISO, Market Performance and Planning Forum, September 16, 2016 p. 27

Some of the unbid wind and solar output is likely reflected in virtual supply bids, some submitted by the utility that has contracted for the output of the resource but is not entitled to submit bids for the resource.



Source: California ISO, Market Performance and Planning Forum, September 16, 2016 p. 29

Current reliability commitment designs do not take account of virtual supply offers and some only take account of intermittent resource output that clears in the day ahead market.

- This approach may not be appropriate, and the reliability commitment may not operate as intended, if virtual supply offers reflect the actual expected output of intermittent resources.
- Moreover, as intermittent resource output becomes larger relative to ISO reserve targets, the reliability commitment may need to take explicit account of the likely minimum and maximum levels of intermittent resource output during each hour.
- Changes in the structure of the day-ahead market and reliability commitment could potentially take the form of an additional reserve target to cover variability in intermittent resource output.

California ISO and MISO Evolution DAM

The California ISO and MISO have begun to envision changes in the structure of their day-ahead markets to better accommodate the variability of intermittent resource output in real-time.

- The California ISO considered changes to the structure of its day-ahead market and reliability commitment in developing the flexi-ramp product and will likely consider changes again after it has experience with the operation of the flexi-ramp product. [1]

- The MISO implemented some changes in its day-ahead market this spring in conjunction with the implementation of its ramp capability product. [2]

1. **See California ISO, Flexible Ramping Products, Second Revised Draft Final Proposal, October, 24, 2012, section 2.5 and California ISO, Integrated Day-Ahead Market, Draft Technical Proposal, September 28, 2012.**
2. **See Testimony of Joe Gardner in docket ER2156 June 10, 2014, pp. 9, 17-18.**

Provide efficient incentives for the development and continued operation of low emitting flexible supply resources.

- Both the MISO and California ISO have implemented a variety of changes in their real-time market design in order to provide efficient incentives for the development of resources able to cost effectively manage variations in intermittent resource output.
- It is important to provide these incentives in market prices as uplift payments to keep existing resources in operation or on-line when they are needed but uneconomic do not provide incentives for the development of new lower cost or more flexible resources.

Some of the changes implemented by the MISO and California ISO over the past few years to in order to improve incentives in the real-time market to better accommodate variations in intermittent resource output include:

- Implementation of ramp capability pricing;
- Adjustment of real-time shortage pricing for spinning reserves (MISO)
- Reductions in the offer price floor (California ISO)

Conclusions

• As in California and the MISO, maintaining current levels of reliability with higher levels of intermittent output will likely require continuing evolution of NYISO operating practices and market design to incent the supply and effective operation of resources able to cost effectively balance variations in intermittent resource output.

•Experience in California and MISO has shown that contract structures for intermittent resources can have a material impact on the cost to consumers of balancing variations in intermittent resource output and can raise the cost to consumers of changes in market design needed to manage higher levels of intermittent resource output.

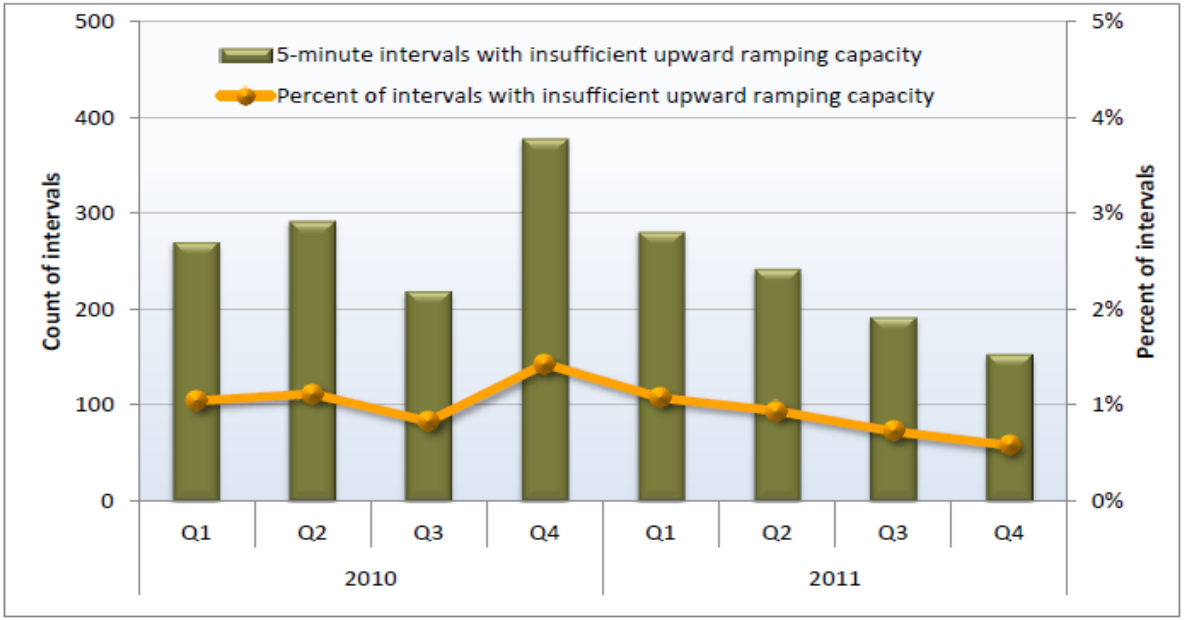
• While the approaches California and MISO are taking in managing higher levels of intermittent output should inform NYISO in adapting to similar changes, both California and MISO are still seeking better ways to effectively address some challenges, some of the approaches currently being used are still evolving, and their performance is still being evaluated.

Additional Detail

Operational Challenges

The California ISO has had issues with ramp constraints causing power balance violations in the real-time dispatch going back to 2010.

Power Balance Violations in RTD due to Insufficient Upward Ramp Capability
California ISO 2010-2011



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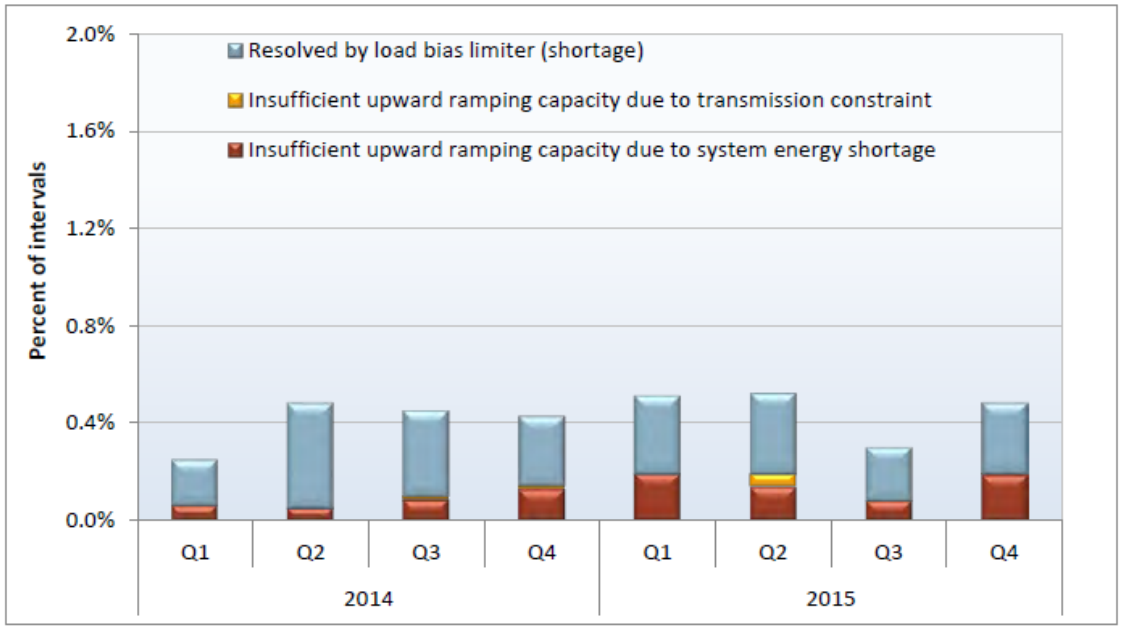
Source: 2011 Annual Report on Market Issues & Performance, California ISO, Department of Market Monitoring, April 2012 figure 3.2 page66.

The frequency with which these power balance violations impact real-time prices has been reduced in recent years but the underlying operational problems have continued.

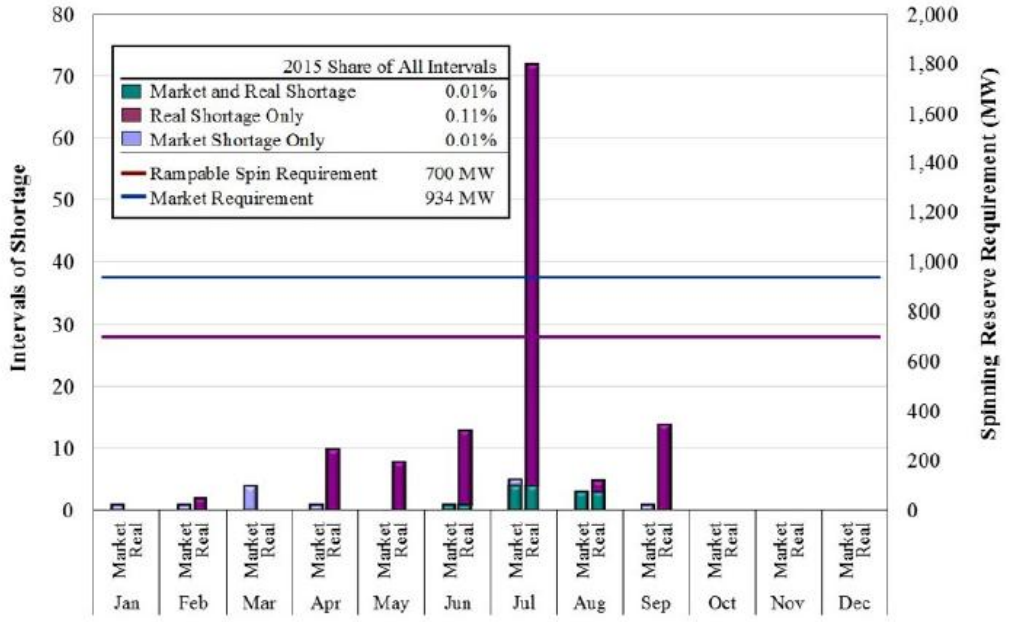
Power Balance Violations in RTD due to Insufficient Upward Ramp Capability
California ISO 2014-2015



Source: 2015 Annual Report on Market Issues & Performance, California ISO, Department of Market Monitoring, May 2016 figure 3.8 page 81.

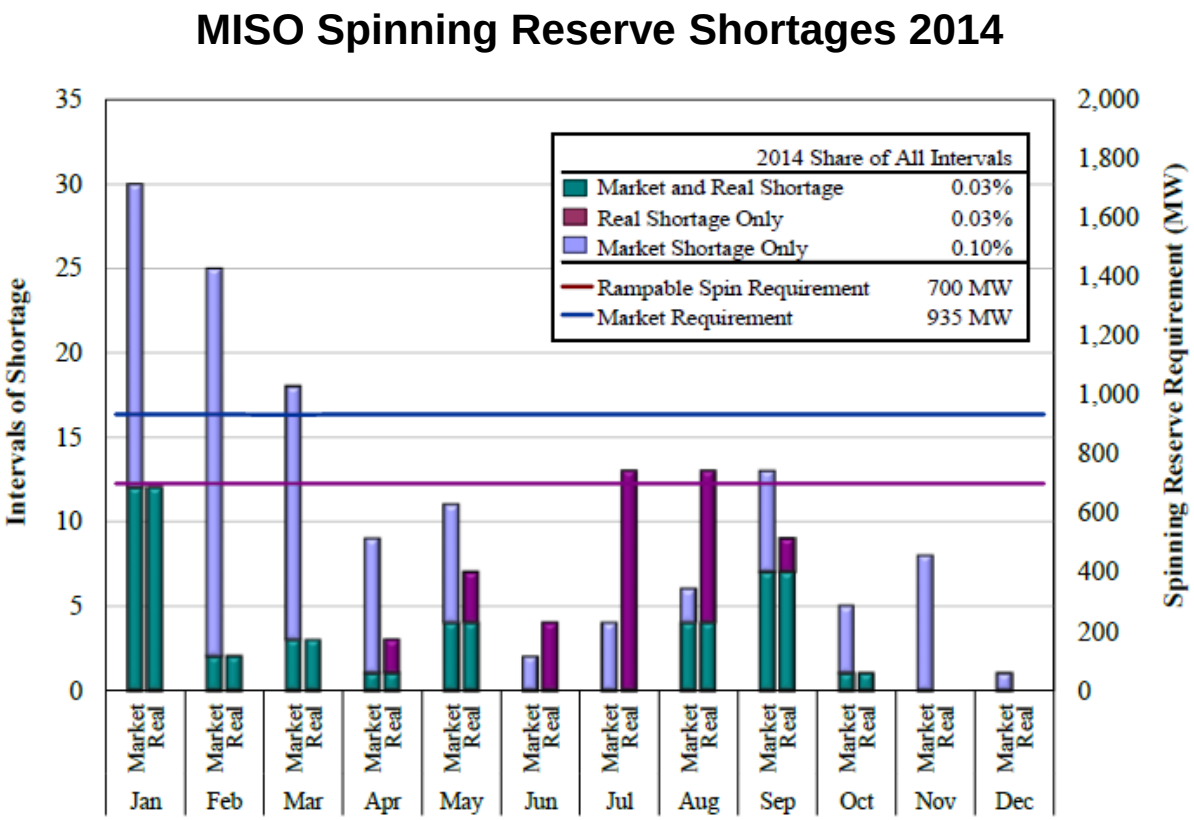
The MISO manages power balance violations in its real-time dispatch by utilizing a market spinning reserve target that is somewhat more than 200 megawatts in excess of its reliability requirement and dispatching spinning reserve to balance load and generation at specified penalty prices.

MISO Spinning Reserve Shortages 2015



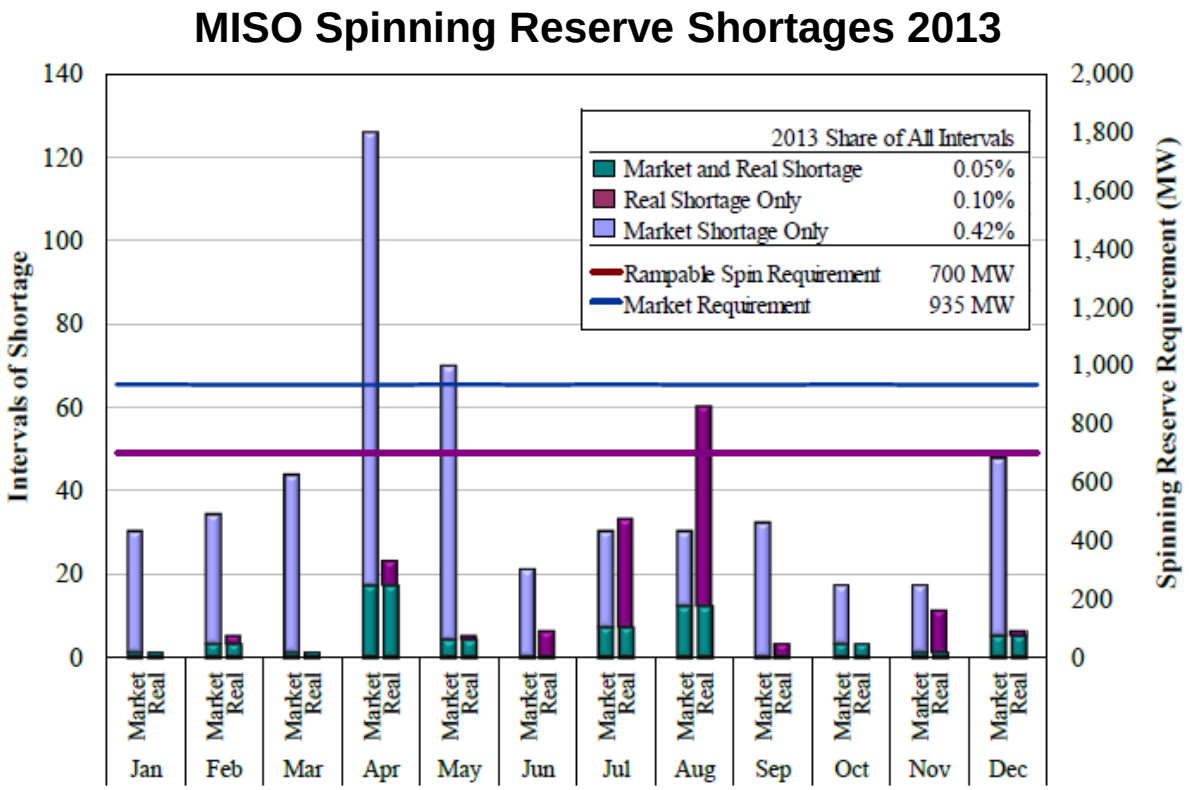
Source: Potomac Economics, 2015 State of the Market Report for the MISO Electricity Markets, Analytical Appendix, June 2016 Figure A-50, p. A-56.

The pattern of spin shortages over the year varies from year to year, with more of the shortages in the winter in 2014.



Source: Potomac Economics, 2014 State of the Market Report for the MISO Electricity Markets, Analytical Appendix, June 2015 Figure A49, p. A-52.

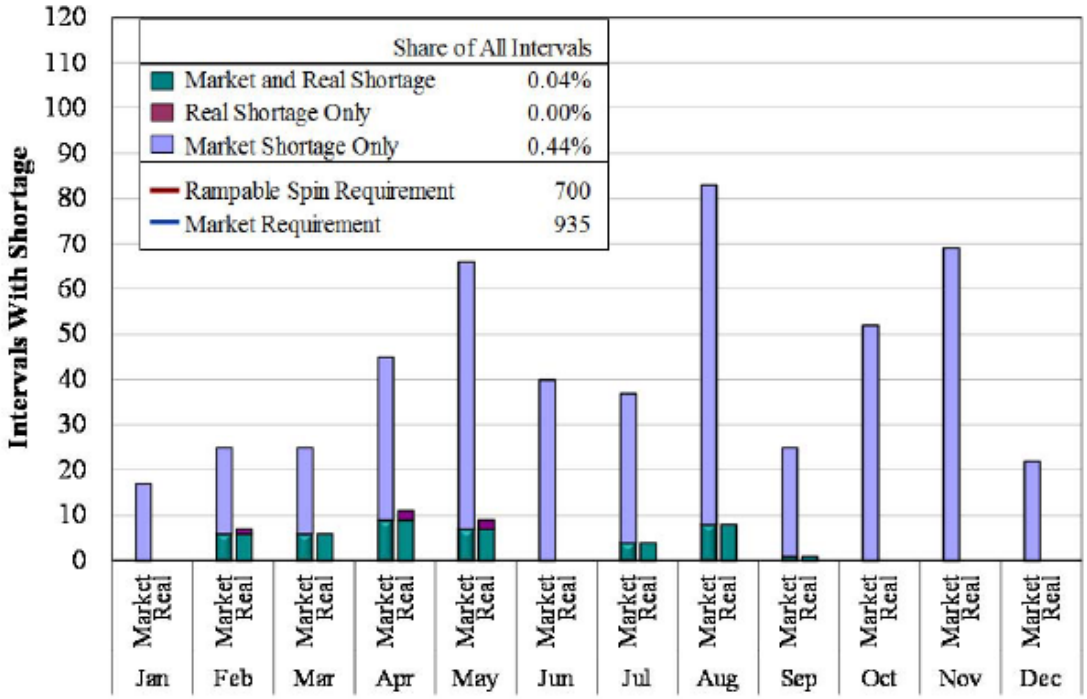
The level of spinning reserves shortages was much higher in the years prior to the formation of MISO south at the end of 2013.



Source: Potomac Economics, 2013 State of the Market Report for the MISO Electricity Markets, Analytical Appendix, June 2014 Figure A40, p. A-68.

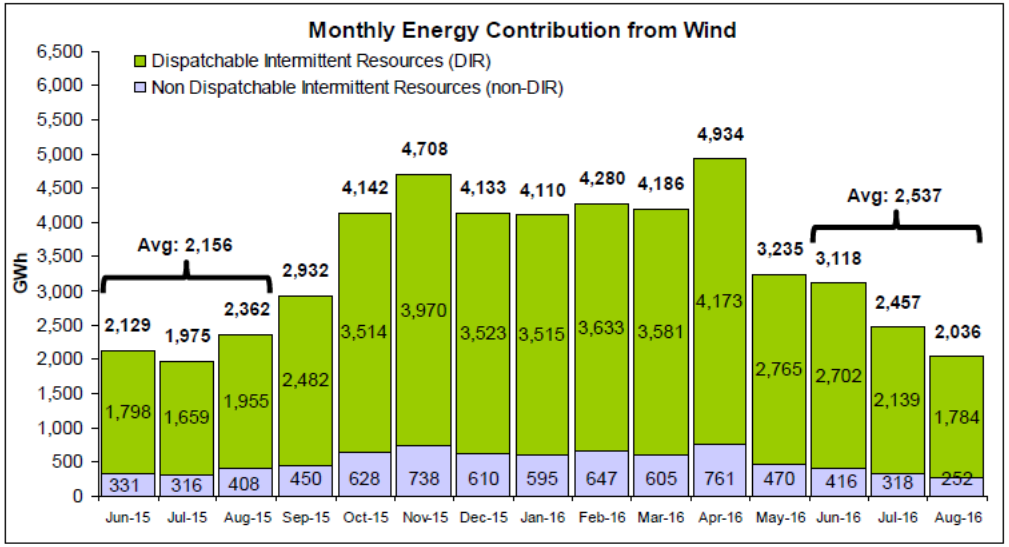
A similar higher level of spinning reserves shortages was seen in 2012.

MISO Spinning Reserve Shortages 2012



Source: Potomac Economics, 2012 State of the Market Report for the MISO Electricity Markets, Analytical Appendix, June 2013 Figure A46, p. A-66.

In the MISO a little over 84% of wind generation capacity participates in the MISO's economic dispatch (DIR or Dispatchable Intermittent Resources) and the proportion of actual wind output that is dispatchable is typically higher than this.

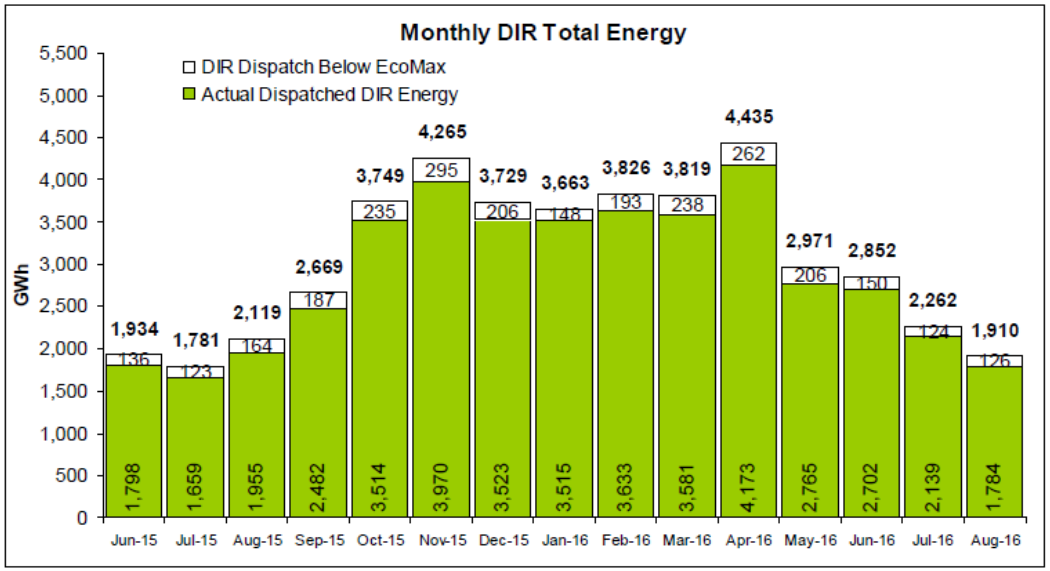


Wind Energy* as a Percentage of MISO Energy*	4.3%	5.9%	8.9%	10.3%	8.1%	7.5%	8.8%	8.8%	10.9%	7.0%	5.9%	4.3%	3.6%
DIR Energy as a Percent of Total Wind Energy*	82.7%	84.7%	84.8%	84.3%	85.2%	85.5%	84.9%	85.6%	84.6%	85.5%	86.7%	87.0%	87.6%

*Hourly State Estimator data.

Source: MISO Quarterly Operations Report for the Board of Directors Market Committee, September 2016 pp. 20, 22.

The MISO regularly makes use of its ability to dispatch wind generation in order to manage transmission congestion or balance overall load and generation.

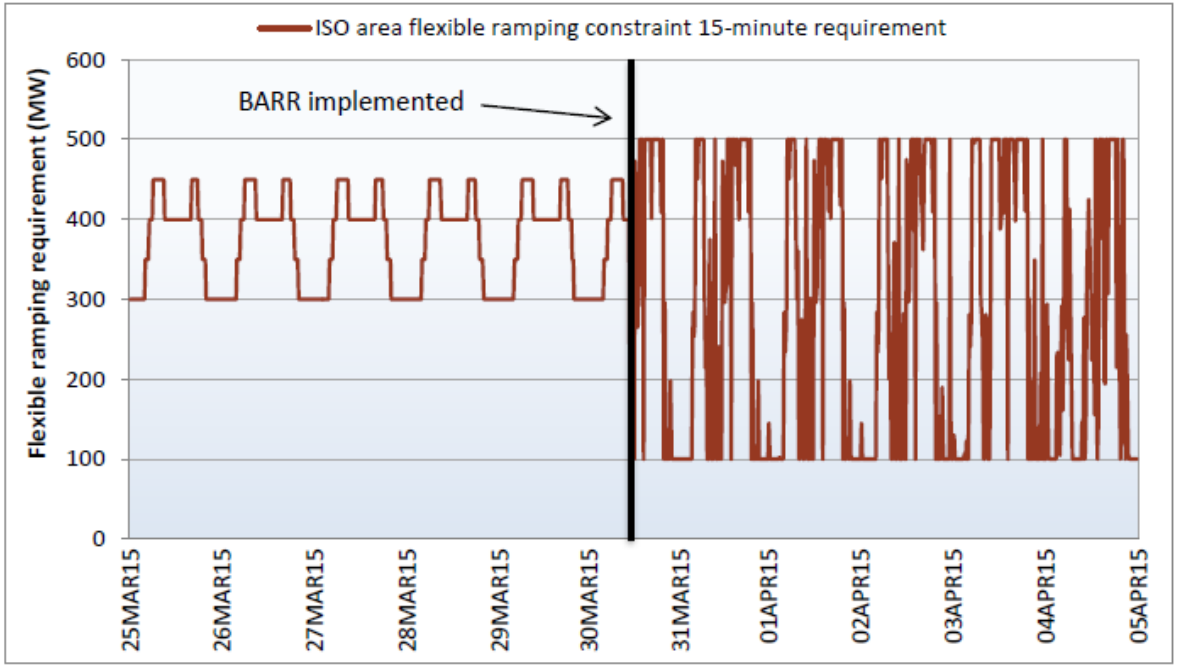


DIR Dispatch Below EcoMax as a Percent of Available DIR Energy*	7.7%	7.0%	6.3%	6.9%	5.5%	4.0%	5.0%	6.2%	5.9%	6.9%	5.3%	5.5%	6.6%

*Hourly State Estimator data.

Source: MISO Quarterly Operations Report for the Board of Directors Market Committee, September 2016 pp. 21.

The software implemented by the California ISO in spring 2015 that was intended to improve the determination of ramp capability procurement targets has in practice produced extremely erratic procurement targets. A new design will be implemented on November 1, 2016 but its performance remains to be seen.



Source: California ISO, Department of Market Monitoring, Q2 2015 Report on market Issues and Performance, August 17, 2015 Figure 2.4 p. 44.

The California ISO historically allowed the operators of start- or energy-limited resource owners to manage the limits by only making the resources available for commitment during projected high loads periods.

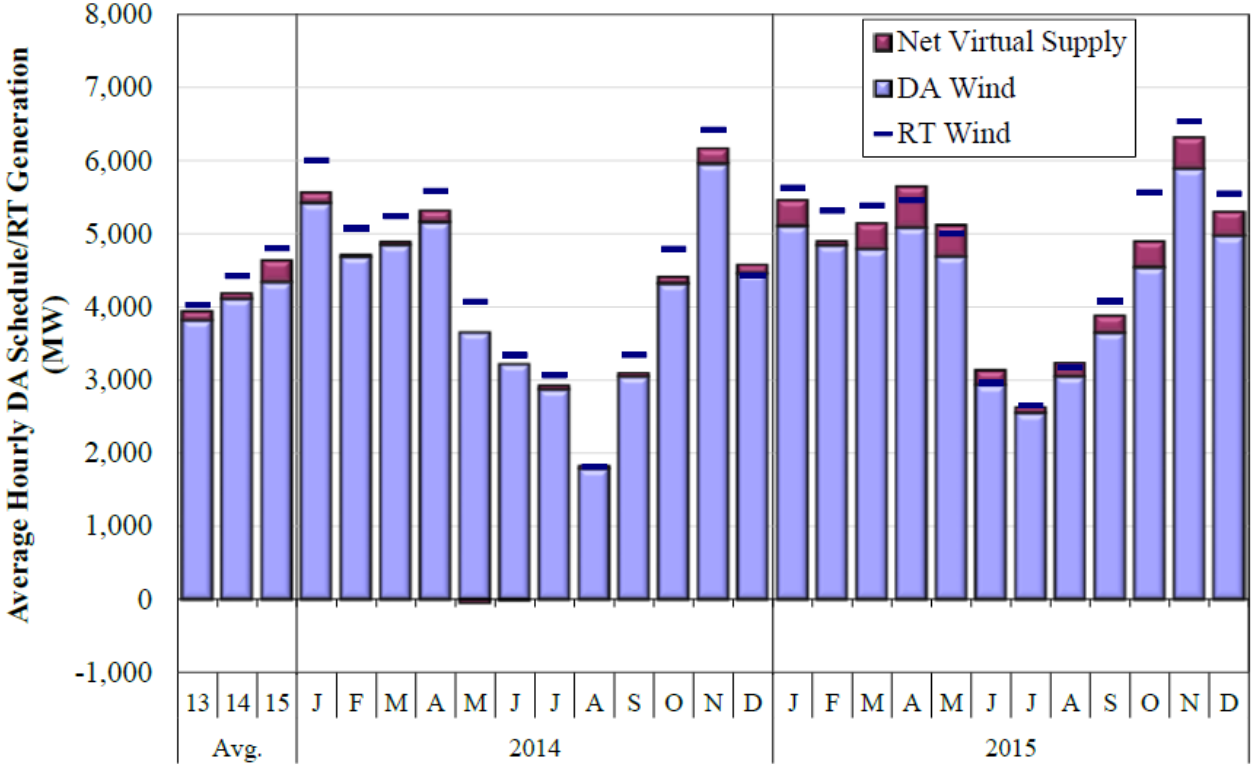
- This approach to managing the commitment of use limited units is very inefficient in a system with high levels of intermittent resource output in which it is impossible to predict periods of high net load.

- This inefficiency has motivated the California ISO to seek to make changes to the way that the commitment of these resources are managed in the dispatch/market so the resources are available at all times when their output is need to balance variations in intermittent resource output, while respecting the unit use limits.[1]

1. **See California ISO, Commitment Cost Enhancements Phase 3, Draft Final Proposal, February 17, 2016 p. 10; California ISO, Commitment Cost Enhancements Phase 2, Revised Straw Proposal, December 22, 2104 pp. 16-17.**

California ISO and MISO Evolution DAM

The same pattern of underbidding of wind output in the day-ahead market, partially offset by virtual supply bids, is seen in the MISO dav-ahead market.



Source: Potomac Economics, 2015 State of the Market Report for the MISO Electricity Markets, Figure p. 19 p. 47.

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New York ISO Market Design

The New York ISO market design has core design features that support the integration of substantial levels of renewable energy output in meeting New York load.

- A real-time economic dispatch that can increase and decrease generation output on a five minute basis to accommodate variations in intermittent resource output at least cost;
- The ability for intermittent resources to participate in the real-time economic dispatch;
- The ability to accommodate bids reflecting emission costs (CO2, NOx, SOx or other) in the economic dispatch;
- Day-ahead and real-time prices that provide transparent valuation of power consumption or output at each location, at each point in time over the day and year.

New York ISO Market Design

The New York ISO has been developing several new capabilities over the past several years in order to be able to accommodate larger amounts of intermittent resource output:

- 15 minute scheduling, implemented with Hydro Quebec in July 2011, and with PJM in July 2012;

- Coordinated interchange scheduling: implemented with PJM in November 2014 and with ISO New England in December 2015.

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