Opinion on
Flexible Ramping Product

by

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I. Introduction

The increasing reliance of the California ISO (CAISO) on the output of intermittent resources to meet load has prompted the CAISO to take steps to ensure that sufficient flexible capacity will be able to balance load and generation in real time. This concern is addressed in the long run by the CAISO analyzing future needs for flexible capacity and informing the local regulatory authorities and load serving entities of these needs so they can contract for a mix of resources with the flexibility needed to meet load.[1] In addition, however, it is necessary to take steps to ensure that sufficient flexible capacity is available to balance generation and load in the time frame of the real-time dispatch.

We have previously recommended that the CAISO's short-term markets be the primary source of economic incentives to provide flexibility to the CAISO system.[2] The reason for our recommendation is that short-term energy, reserves, and flexiramp markets reward resources for providing energy precisely when needed during periods when net load

[1]The CAISO is responsible for defining categories of flexible resources that reflect the attributes and capabilities of various generation, demand-side, storage, import, and other resources that can be used to the meet the system's needs, and for defining how they would be operationally utilized. To fulfill that responsibility, the CAISO has recently implemented Phase I of its FRACMOO initiative (CAISO, "Flexible Resource Adequacy Criteria and Must-Offer Obligation", Revised Draft Final Proposal, March 7, 2014, www.caiso.com/Documents/RevisedDraftFinalProposal-FlexibleRACriteriaMustOfferObligation-Clean.pdf). Phase II is now under development (CAISO, "Flexible Resource Adequacy Criteria and Must-Offer Obligation—Phase 2", Straw Proposal, Dec. 11, 2015, www.caiso.com/Documents/StrawProposal-FlexibleResourceAdequacyCriteria-MustOfferObligationPhase2.pdf).

[2] J. Bushnell, S. Harvey, B.F. Hobbs, and S.O. Oren, Opinion on Flexible Resource Adequacy Criteria and Must-Offer Obligation, CAISO Market Surveillance Committee, March 11, 2014, p. 17, www.caiso.com/Documents/FinalOpinion-FlexibleResourceAdequacyCriteriaMustOfferObligation.pdf

is steeply ramping, and thereby avoid the very serious conceptual and practical problems of trying to accurately evaluate the contribution of imports, storage, start-limits, energy-limits, and other attributes in resource adequacy markets. We noted that there are several changes that have recently being made or could be made to the CAISO day-ahead and real-time markets to ensure that flexible resources are appropriately incented. These include creation of a flexible ramping product, which is the subject of the present initiative; the CAISO's separation of day-ahead and real-time bid cost recovery (implemented in 2014); the move to 15 minute markets for interchanges under FERC Order No. 764 (implemented in 2014); the on-going geographic expansion of the energy imbalance market (EIM); decreasing the use of out-of-market dispatch; and expanding scarcity pricing through appropriate reflection of energy imbalance and other constraint violation penalties in locational marginal prices.

The CAISO took an initial step to address the need to ensure that sufficient flexible capacity is available in the time frame of the real-time dispatch by implementing the flexible ramping constraint in December 2011.[3] The flexible ramping constraint implemented a ramp target in the CAISO's 15 minute real-time pre-dispatch (RTPD) that causes additional flexible capacity to be committed if RTPD anticipates that insufficient flexible capacity will be available to meet the ramp target.[4] While this design has helped reduce the frequency of shortages of ramp capability in the real-time dispatch, and thereby also reduced the frequency of power balance violations, it also has limitations. A significant limitation with the flexible ramping constraint is that the calculation of the available ramp in RTPD at times assumes that actions will be taken in real-time that are in fact not taken. For example, the calculations in RTPD assume that generation will be dispatched downward out of merit in the current 5 minute real-time dispatch (RTD) interval in order to make more ramp capability available in future dispatch intervals. At present, however, this out-of-merit dispatch does not actually occur in RTD, so that the system can be left with inadequate ramp to meet the possible variations in net load that the flexiramp constraint is intended to accommodate.[5]

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[3]See California ISO October 7, 2011 filing in FERC Docket ER12-50 and the MSC opinion of August 16, 2011 (www.caiso.com/Documents/FinalOpinion_Payment_Provision_FlexibleRamping.pdf).

[4]With implementation of the FERC Order No. 764 scheduling design, ramp could also be obtained by scheduling additional 15 minute interchange in RTPD. This has not been as big a factor as it could be because of the limited amount of imports presently being offered on a 15 minute basis.

[5] RTD may, however, dispatch generation out-of-merit to efficiently meet the forecast changes in load in the second and subsequent intervals. This is because RTD is a multi-interval optimization design, but the multi-interval optimization only accounts for forecast changes in load and does not account for the possibility that load will be higher or lower than the forecast. The essence of the flexiramp design is that it attempts to take account of the full uncertainty associated with net load forecasts in this multi-interval optimization.

One consequence of this aspect of the current implementation is that the amount of ramp capability that is calculated to be available in RTPD will often be larger than the amount that will actually be available in RTD. This overstatement of ramp capability in RTPD has been referred to by the CAISO as "phantom ramp" during the present CAISO initiative to develop a flexible ramping (or "flexiramp") product. While it would require a substantial effort to calculate exactly how much phantom ramp is typically present in RTPD under the current approach, some amount of phantom ramp is present any time there is a shadow price of ramp in RTPD that is not set by the penalty value.[6] This is because if the price of flexiramp is positive but not set by the penalty value, then this implies that the target amount of ramp capability was scheduled in RTPD.[7] In that case, the positive shadow price indicates that out-of-merit schedules in RTPD were required in order to provide the target amount of ramp capability for future periods, but in the current design RTD will likely fail to preserve the flexiramp thus scheduled by RTPD.

Therefore, as a result of this limitation of the current design, the ramp capability available in real-time will periodically be less than the target, even when the target amount of ramp capability was calculated to be available in RTPD. An indirect effect of this overstatement is that CAISO operators need to compensate for it by setting a higher ramp target in RTPD than they otherwise would. The higher target is more likely to cause additional units to be committed in RTPD and can thereby increase the amount of ramp capability that is actually available in real-time. These inflated rate capability targets in RTPD, however, tend to raise uplift costs because the units committed as a result of the higher target for the flexiramp constraint will often turn out to not be needed, or economic, in real-time operation. Thus, this flaw in the ramping constraint design, and the operator's ad hoc response to the flaw, has created periods of both over- and under-supply of ramping capability, at additional cost. Although the expense of the flexible ramping constraint has declined significantly since its implementation,[8] due to reductions in the amount of

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[6] See California ISO, Department of Market Monitoring, 3Q 2015 Report on Market Issues and Performance, November 16, 2015 p. 36, which reports the following information. In the 3rd quarter of 2015, DMM reported that the RTPD flexiramp constraint was binding in 4% of all fifteen minute intervals, with the price set by the penalty value in 0.3% of all intervals. In reality, there was a procurement shortfall in all of the intervals in which the constraint was binding, because the out-of-merit dispatch that provided some of the ramp capability needed to meet the ramp target in the other 3.7% of the hours did not actually occur in RTD, reducing the supply of ramp capability below the target. DMM similarly reported that the flexiramp constraint bound in 6% of all intervals in the 2nd quarter of 2015, with the price set by the penalty value in 0.8% of all intervals. Hence, there was a procurement shortfall in an additional 5.2% of all hours in the second quarter, because the out-of-merit dispatch that occurred in RTPD when the constraint bound did not actually occur in RTD.

[7] If the price of flexiramp is set by the penalty value it is likely that there will be some amount of phantom ramp but this is not necessarily the case.

[8] According to the market performance reports of the CAISO Department of Market Monitoring (www.caiso.com/market/Pages/MarketMonitoring/MarketIssuesPerfomanceReports/Default.aspx), in the first three months of implementation (Dec. 2011-Feb. 2012), payments to generators for capacity devoted to meeting the flexible ramping constraint were twice as large as

flexiramp procured and reductions in the penalty price for shortages (from $247 to $60 in January 2015)[9], those expenses are likely larger than necessary because of ramp targets that are inflated to compensate for phantom ramp.

The out-of-merit schedules that the flexiramp constraint induces in RTPD tend to increase RTPD prices relative to RTD prices because the RTD does not include a similar constraint. However the lack of the additional ramp capability in RTD can also increase RTD prices relative to RTPD prices to the extent that the lack of ramp capability in RTD causes more frequent load balance violations and the associated price spikes in RTD. In 2015, average monthly RTPD and RTD prices do not exhibit systematic differences. This could imply that the price effects of phantom ramp are modest, or could imply that the offsetting biases in prices are masked in monthly averages.[10] It is possible that higher RTD prices experienced in the early evening in Q3 2015 might be in part due to lack of ramp capability. Although the Department of Market Monitoring does not explicitly attribute the RTD price spikes to lack of ramp capability,[11] we strongly suspect that ramp constraint violations are to blame when these higher RTD arise because of power balance violations, as those high prices were not due to overall reserve shortages.[12]

This incomplete implementation of the flexiramp constraint has remained in place longer than originally intended because of competing demands on CAISO resources that arose with FERC Order No. 764 and EIM implementation. However, it is important to correct the limitations of the current flexiramp design before they become a bigger hindrance to the efficient development of CAISO markets, the EIM, and the expansion of the CAISO.

The Market Surveillance Committee (MSC) has considered various elements of the flexiramp product design in a long series of public MSC meetings beginning in March 30,

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payments for spinning reserves. In 2012 as a whole, $20 million was paid for the flexiramp constraint (cf. $35 million for spinning reserve), while in 2014 only $6.5 million in flexiramp payments were made. The first three quarters of 2015 saw flexiramp payments fall to $2.5 million, with the constraint binding in about 5% of 15 minute intervals.

[9] See CAISO, Department of Market Monitoring, "3Q 2015 Report on Market Issues and Performance," November 16, 2015, p. 34, Footnote 33, www.caiso.com/Documents/2015ThirdQuarterReport-MarketIssuesandPerformance-November2015.pdf.

[10] DMM data indicate that differences between RTPD and RTD monthly average prices are very minor (generally less than $2/MWh in each of the first months of 2015 and well below $1/MWh averaged across months), with RTPD prices being slightly lower in most months (ibid, p. 3,). Differences are somewhat larger in peak hours than at other times, especially in the early evening hours, when RTD prices were 50% or more greater than RTPD prices in the third quarter of 2015. In contrast, RTPD prices are higher in the morning hours (6-10), although not as dramatically so (ibid., p. 10) {which could be due to down spikes in RTD}.

[11] Ibid.

[12] Ibid., Figure 2.4 shows that the evening hours with higher RTD prices are the hours in which the flexiramp constraint was mostly likely to bind.

2012, then May 25, 2012, August 14, 2012, October 19, 2012, August 22, 2014, October 15, 2014, December 16, 2014, July 15, 2015, October 20, 2015 and December 11, 2015. These issues have also been discussed in many meetings between CAISO staff and individual MSC members over the past several years. In this Opinion, we review the CAISO's flexible ramping product proposal.[13] In the next section, we summarize the changes that the CAISO proposes in the present flexible ramping constraint-based system. Then in Section III, we outline what we consider to be key issues in the design of the product. These include issues concerning:

- flexiramp requirement forecasting;
- locational constraints;
- day-ahead acquisition;
- bidding by providers of the product;
- impacts on convergence of day-ahead and real-time prices and interactions with virtual bidding; and
- cost allocation.

Section IV summarizes our conclusions about the present proposal, and future revisions that could be desirable.

II. Key Changes Implemented with Proposed Flexiramp Product Design

In addition to the most important change, that of implementing the flexiramp constraint in RTD in addition to RTPD, the CAISO flexiramp product design also implements several other desirable but less fundamental improvements.

1. Compensation

When the flexiramp product is implemented, the compensation to resources providing ramp capability in RTPD and RTD will be more directly related to the incremental cost of providing flexiramp, providing improved incentives for resources to make investments or operating practice changes that would enable them to supply more ramp capability. Resources providing flexiramp under the current flexiramp constraint design are compensated, but the compensation under Section 3.2 of the settlement agreement at times reduces the compensation for the supply of ramp capability to a value below the shadow price of the ramping constraint.[14]

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[13] CAISO, "Flexible Ramping Product, Revised Draft Final Proposal," Dec. 17, 2015, www.caiso.com/Documents/RevisedDraftFinalProposal-FlexibleRampingProduct-2015.pdf

[14] See California ISO July 27, 2012 filing of settlement agreement in Docket ER12-50-000. It is also possible that resources could at times be dispatched out-of-merit in RTD under the current design in order to manage a ramp that is forecast to occur in RTD in the multi-interval optimization but was for some reason not projected in RTPD and hence not compensated by the flexiramp mechanism under the current flexiramp constraint design. In some circumstances such resources

2. Down Ramp Capability

Under the proposed flexiramp product design, a target would be implemented for the procurement of down ramp capability (as opposed to only upward capability in the current flexiramp constraint design) in both RTPD and RTD. Compensation would be provided for the supply of this downward ramp capability at times when it is scarce, based on the opportunity cost of dispatching generation out of merit to create additional down ramp capability. This out-of-merit dispatch could simply mean scheduling fewer imports in hours when flexible generation has been dispatched down close to its minimum, while at the same time cost savings from scheduling incremental imports would be very small if the net load forecast is correct.

3. Compensation for Ramp Provided in RTPD

The compensation design would be extended to resources and schedules providing ramp in the RTPD, even if the resources are not dispatchable in RTD. Schedules that lessen the need for flexiramp will be paid the flexiramp price per unit of ramp, while those that exacerbate the need will pay that price. As discussed at the MSC meeting on July 15, 2015, the existence of both 15 minute and 5 minute ramp capacity requirements in RTPD (either 15 minute or 5 minute ramp capability to meet forecast ramp needs and 5 minute ramp capability to meet the uncertain component of ramp needs) creates a possibility that the shadow price of 15 minute ramp used to meet forecasted net load in RTPD would be less than the shadow price of 5 minute ramp used to meet the uncertain portion of net load.

Because it should be possible for the optimization in RTPD to create additional 5 minute ramp capability by increasing or decreasing 15 minute energy schedules, there is reason to expect that the two shadow prices will not diverge and hence that this possibility will not have any material impact in practice, The potential for such a divergence will need to be reviewed when the details of the implementation have been developed and testing will have either confirmed the expectation that the shadow prices will not diverge in practice or identified the circumstances in which this may occur and any potential impacts can be assessed at that time.

4. Demand Curve for Flexiramp Procurement

The flexiramp product design would implement a demand curve for the portion of the ramp scheduled to meet potential errors in the net load forecast, i.e., a cost sensitive procurement target, for ramp capability up and down in both RTPD and RTD, as opposed to

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might still be compensated in later iterations of RTD if the forecast ramp is realized in subsequent settlement intervals and the resources can be dispatched to a higher output than would otherwise be the case. Under the proposed flexiramp product design, resources dispatched down out of merit would always be compensated for their opportunity costs.

the single penalty factor used in the current design.[15] The parameters of that curve will be based upon estimates of the effects of incremental flexiramp supply upon the probability of power balance violations, and the penalties associated with that violation. This design should result in a more cost-effective procurement of ramp, reducing uplift because the design would not commit generation at a high out-of-merit cost to eliminate small shortages of ramp capability relative to the target.

III. Key Issues

While it is our perception that most stakeholders support the four core changes described above, there are a number of details of the design on which there is less consensus. The main issues that have been raised by stakeholders, the DMM and the MSC are the following.

1. The Need for Improved Forecasting of Ramp Needs

A critical element of the overall flexiramp constraint and product design is the determination of the amount of ramp capability that RTPD and RTD attempt to procure. If this target is set too high relative to potential ramp requirements, the increase in costs from the out-of-merit dispatch needed to create incremental ramp capability in one interval will exceed the benefits in subsequent intervals from avoiding power balance violations and/or avoiding the need to dispatch very high cost generation resources up or very low cost generation down. The potentially significant cost of overestimating the amount of ramp capability needed is evident in the steady reduction in flexiramp constraint costs since its implementation in 2011, in large measure due to reductions in the amounts required.[16]

Greatly complicating the task of setting this target is the reality that ramp needs are likely to vary by time of day, by season, and with system conditions. The CAISO has taken a number of approaches to setting the ramp procurement target for the flexiramp constraint since its implementation in December 2011. The above noted reductions in flexiramp procurement and payments have not been accompanied by large increases in power balance violations due to ramp shortages, indicating either that the methods for specifying the target have improved substantially since 2011 or that the flexiramp constraint has not contributed much to reducing the frequency of price spikes, perhaps because of the amount of phantom ramp procured. Beginning in March 2015 the CAISO began using a tool to automatically calculate the ramp target for RTPD based on the amount required to

[15] A single high penalty price will be used for the procurement of the ramp capability needed to meet the forecast change in net load.

[16] See Footnote 8, infra.

cover 95% of the variation in net load in the same interval in the prior 40 instances, calculated separately for weekends and weekdays.[17]

The DMM has pointed out that the methodology initially used to calculate the amount of ramp capability needed resulted in rather extreme hour to hour variability in the estimated ramp needs, with the target often set at the floor or ceiling.[18] We concur with the DMM critique of the performance of the initial ramp need forecasting tool. Cost-effective choices regarding the amount of ramp procured at different times of day and year are critical to the cost effective performance of the flexiramp design.

The fundamental difficulty with the CAISO's initial approach used for the current implementation of the flexible ramping constraint of estimating ramp needs based on the 95th percentile of net load variability in the prior 40 intervals is that this is a very small amount of data with which to estimate the tail of the distribution of net load variation, leading to large sample errors and variations in the estimates. With 40 data points, the 95th percentile of the distribution is defined by 2 extreme data points which is much too small a sample to reliably estimate the variability of the distribution. A similar approach based on the 95th percentile of the variation in net load in that hour over the prior month was proposed for calculating the ramp capability target for the flexiramp product.[19] While this would slightly expand the sample size for the weekdays to around 84 to 92 data points, this would still be a small number of data points to rely on for reliable estimates of the shape of the tail of the distribution of net load outcomes and would likely not do much to improve the predictions relative to the current method.

The CAISO has mentioned the possibility of grouping similar hours to improve the predictions which could expand the sample size enough to permit more reliable estimates of the variability of net load. However, while it will not be simple to develop good forecasts, the CAISO has historical data that can be used to test and refine alternative approaches before they are implemented in the real-time market. The important thing is for the CAISO to carry out this testing prior to implementing the flexiramp product. While the CAISO has to balance implementation complexity with improved predictions, the accuracy of the CAISO's estimates of ramp capability needs is critical to the design's ability to achieve cost savings.

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[17]See California ISO, Department of Market Monitoring, 3Q 2015 Report on Market Issues and Performance, November 16, 2015 p. 36

[18] See most recently, California ISO, Department of Market Monitoring, "3Q 2015 Report on Market Issues and Performance," November 16, 2015, pp. 34-36 and a slightly longer discussion in California ISO, Department of Market Monitoring, "2Q 2015 Report on Market Issues and Performance," August 17, 2015, pp. 41-46, particularly Figure 2.4.

[19]See California ISO, Flexible Ramping Product, Revised Draft Final Proposal, December 17, 2015 p. 12, and California ISO, Flexible Ramping Product, Draft Final Technical Appendix, December 17, 2015 p. 12.

The CAISO needs to have the flexibility to adjust the forecasting methodology to improve performance without long delays. But the CAISO also needs to thoroughly analyze the performance of the forecasting tool before it is implemented. It then needs to track the performance of the methodology used to calculate ramp requirements after implementation and correct elements of the methodology that lead to poor projections of flexiramp needs without long lags.

2. Locational Constraints

The current proposal will implement locational constraints on flexiramp procurement between balancing authority areas across the EIM footprint, but will not impose any locational constraints on the location at which flexible capacity would be scheduled within the CAISO or an EIM entity balancing authority area. This is consistent with the current procurement design for the flexiramp constraint in RTPD which can, and has in the past, led to the procurement of flexiramp capacity in regions in which it cannot be dispatched to avoid power balance violations because of transmission constraints.[20] It may therefore turn out at some point to be desirable to implement additional locational targets within the CAISO, i.e., in addition to those for the EIM regions. It is not possible to accurately assess whether this will be an important need, and which locational targets would be appropriate, until the CAISO gains some experience with operation of the flexiramp product and with the expansion of the EIM footprint that will occur over the next few years.

3. Integration of Flexiramp Procurement into the Day-Ahead Market

It is possible that the optimal procurement of flexiramp in RTPD will turn out to be facilitated by making some changes in the structure of the day-ahead market that take into account the amount of ramp capability up and down provided by the resources committed in the day-ahead market and their day-ahead market schedules. Because the core element of the flexiramp product design is that generating resources will be dispatched in RTD so as to make additional ramp capability available from on-line units, the implementation of the flexiramp product will not directly lead to the commitment of any additional capacity in real-time, compared to what is currently being committed in RTPD under the present flexiramp constraint.

If the flexiramp product design operates as intended, it will tend to enable the CAISO to set a lower target for procuring ramp capability in RTPD, because more of the ramp procured will actually be available for use in the real-time dispatch. This should lower the need for commitment and out-of-merit dispatch in RTPD to accommodate flexiramp needs and the associated procurement costs.

While the CAISO may eventually find it desirable to make changes in the integrated forward market to better optimize the availability of resources in real-time (in RTPD), the

[20] CAISO DMM, "2012 Annual Report on Market Issues and Performance," April 2013, p. 84, www.caiso.com/Documents/2012AnnualReport-MarketIssue-Performance.pdf.

implementation of the flexiramp product design does not directly impact either the day-ahead or real-time commitment. The most important change that will be implemented with the flexiramp product is that the CAISO will be dispatching the system in real-time to actually maintain the amount of ramp capability calculated in RTPD. Until this limitation of the current design is corrected and sufficient experience is gained operating under the new design, it would premature to consider or evaluate other possible future changes. Indeed, we doubt that the CAISO would even be able to assess what kind of changes might be desirable until it has accumulated experience operating with the flexiramp product design in place.

4. Bidding for Flexiramp

There was also discussion during the stakeholder process of whether the flexiramp product market design should provide for resources to submit bids to provide flexiramp. It was observed above in the discussion of the potential for flexiramp procurement in the day-ahead market that there would be no schedules for flexiramp established in the day ahead market in this initial design, hence there will be no costs incurred in the day-ahead time frame that need to be recovered in an offer price for providing flexiramp.

We have concluded in the course of discussions of bidding during the stakeholder process that resources scheduled to provide flexiramp in real-time, either in RTPD or RTD, would also not incur any costs that should be reflected in an offer price in order to achieve an efficient market outcome. In general, this is because the costs of providing flexiramp are entirely in the form of the opportunity costs of not selling energy or ancillary services within the CAISO real-time markets. These opportunity costs can be calculated from the resource energy offer and real-time prices and used to determine the real-time price of flexiramp.[21] With the implementation of the flexiramp product, these opportunity costs will be fully captured in the CAISO's co-optimization and pricing models for the RTPD and RTD markets.

In particular, units scheduled to provide flexiramp in RTPD or RTD would not incur any incremental O&M costs that could be reflected in an offer price because the units would be dispatched up and down for energy without regard to such an offer price for flexiramp, just as they are today. Moreover, real-time offer prices for flexiramp also would not enable resources to recover investments in increased ramp capability because, absent market power, the higher the offer price for ramp capability, the lower the returns to ramp capability would be (because the offer price would cause the resource to be scheduled less often to provide ramp in RTPD or RTD).

[21] This opportunity cost calculation will not take account of costs that are not reflected in a resource's offer price, but this would be a consequence of the failure to reflect the costs in those offers in the first place. Any design that calculates opportunity costs on the basis of something other than actual offer prices would inevitably create the opportunity for extremely inefficient bidding strategies that would reduce market efficiency and raise consumer costs.

Real-time offer prices for flexiramp are also not needed to reflect energy market opportunity costs in non-CAISO markets, because there are no such opportunity costs. CAISO market participants can purchase energy to support exports to non-CAISO markets in the fifteen minute market (FMM) without regard to how their generation within CAISO is dispatched and hence there are no outside-market opportunity costs. Conversely, real-time offer prices for flexiramp also would not enable resources to reflect the opportunity cost of providing ancillary services in real-time in markets external to the CAISO, as any such opportunity costs would be forgone when a resource is made available for dispatch in the CAISO's real-time market. No additional opportunity costs of providing ancillary services to other markets are forgone when a resource is scheduled to provide flexiramp.

While we and the CAISO were unable to identify any costs that should arguably be reflected in such an offer price for flexiramp, we identified a number of potential inefficiencies and inconsistencies that would arise from a design that allows flexiramp bidding. Adding bidding creates the potential to both unnecessarily complicate the implementation of the product, and lead to unintended consequences that would provide inefficient outcomes. In particular, there would be a potential for resources offering ramp with a positive bid price to not clear against the flexiramp target, despite the fact that their capacity and ramp capability would be available for dispatch in real-time, in both RTPD and RTD. When this occurred, the CAISO would either have to (1) not count the ramping capability on these resources as available in clearing the market despite the fact that it would actually be available, or (2) count the capacity and simply not pay the resources.

In the first instance, if the CAISO did not account for the capacity that did not clear in RTPD, it would potentially commit additional generation or schedule imports to provide additional ramp capability, even though adequate ramp was already available. Even if RTPD were programmed to do this, would operators be expected to confirm commitments that were inconsistent with the actual physical state of the system? How would operators determine which commitments inconsistent with the actual state of the system that they should allow or not allow?

If, on the other hand, the CAISO counted the capacity that did not clear but did not pay it, this approach would make the offer price meaningless, while if the CAISO did not count it but did pay it, that would provide a strong incentive for resources to submit high offer prices that would distort the clearing price.

All of these approaches would lead to problems that can readily be avoided by not providing for such offer prices in the real-time commitment and dispatch.

5. Impact on Virtual Bidding

Some stakeholders expressed a concern that the implementation of the flexiramp product without implementing a flexiramp procurement process in the day-ahead market would create opportunities for inefficient virtual bidding that would potentially inflate consumer costs. We have evaluated this concern and concluded that no such potential exists.

As discussed in Section I above, the flexiramp constraint is currently modeled in fifteen minute market. The modeling of the flexiramp constraint in the binding interval of FMM should have the effect of raising FMM prices for energy and ancillary services to the extent that it causes resources to be scheduled down out of merit to provide ramp in the binding interval, with other resources dispatched higher than they otherwise would be.

Conversely, however, the modeling of the flexiramp constraint in the advisory intervals can lower FMM prices during intervals with potential price spikes, by committing additional generation.

These effects are occurring today and have been impacting FMM prices since the implementation of the FMM market in early 2014. While the CAISO has generally been procuring less flexiramp since early 2014 than in the prior years, the flexiramp constraint still has a non-zero shadow price in many hours of the FMM.[22] These positive shadow prices reflect hours when the flexiramp constraint is raising both energy and ancillary service prices in FMM, relative to what they would otherwise be, given the unit commitment.

The impact of the flexiramp constraint on FMM prices relative to day-ahead market prices is complex to evaluate because the flexiramp constraint not only changes the schedules in the FMM in a way that raises FMM prices relative to the day-ahead market, it also potentially changes the unit commitment in a way that lowers FMM prices relative to the day-ahead market. The design is intended to reduce overall production costs, and generally also reduce FMM prices, but empirically assessing the overall net effect of the two offsetting effects would be difficult without a very detailed and resource-intensive analysis.

DMM data in its quarterly reports tend to show that there has been net virtual supply offers in the day-ahead market in the past year,[23] which would be consistent with FMM prices that are lower than day-ahead market prices.[24] This relationship between day-ahead and FMM prices could conceivably be a result of resources committed in RTPD to meet the flexiramp constraint, but it is more likely due to resources being committed through other processes, such as long start units in RUC.

Any such effects of the flexiramp constraint will be largely unimpacted by the introduction of the flexiramp product, which affects the modeling of the flexiramp constraint in RTD rather than in RTPD.

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18. See, for example, CAISO DMM, "Q3 2015 Report on Market Issues and Performance," op. cit., Table 2.4 p. 37.

19. See for example, ibid., Figure 1.14, p. 26.

20. See, for example, ibid., Figure E-1, p. 3, and Figures 1.1-1.3 pp. 9-10.

One potential impact of implementing the flexiramp constraint in RTD with the introduction of the flexiramp product is that it is possible that more ramp will be available in the binding interval of RTPD at lower cost than is the case in the current design because the initial positions of generation resources when RTPD initializes will reflect resources being dispatched down in RTD to provide the flexiramp product. We believe that this impact will likely be extremely small if not non-existent because RTPD initializes so far in advance of the binding interval.

However, these effects are difficult to fully evaluate because there may be features of the RTPD initialization based on the RTD solutions at *t*-42.5 that cause the effect of actual unit positions and dispatch instructions at *t*-42.5 to impact the RTPD solution when the system is ramp constrained, reducing both RTD and RTPD prices for a given ramp target. If this is the case, implementation of the flexiramp product may reduce the cost of ramp in RTPD and somewhat reduce FMM prices for energy and ancillary services, given the target and unit commitment.

Because the introduction of the flexiramp constraint in RTD will likely have little or no effect on FMM prices and schedules, it will not directly impact the level of virtual bidding, which depends on the difference between day-ahead market and FMM prices absent the virtual bids. Moreover, if the introduction of the flexiramp product somewhat impacts FMM prices by causing the FMM and real-time dispatch to operate more efficiently, that is a good thing, regardless of how it impacts of level of virtual bids.

The introduction of the flexiramp product is likely to somewhat raise RTD prices during non-price spike intervals but should more than offset this impact on average power prices by reducing the frequency of power balance violations in RTD, leading to a net reduction in RTD prices. RTD prices currently tend to exceed day-ahead and FMM prices during the hours ending 17-19, which are also the hours in which the flexiramp constraint tends to have a positive shadow price. That is, the constraint binds and schedules resources out of merit order to create ramp which is not actually available in real-time.[25]

Changes in the flexiramp target in RTPD will, however, have a potential impact on FMM prices. There are two factors that could cause the flexiramp target to change with implementation of the flexiramp product. First, better methods of estimating ramp needs could lead to improved targets. This would be independent of flexiramp product implementation. Second, as noted in the discussion in Section I, the implementation of the flexiramp product in RTD will mean that more ramp will actually be available in RTD, given the same target in RTPD, which should lower the need for flexiramp in RTPD and allow flexiramp targets to be set at a lower level while achieving the same reduction in power balance violations.

Overall, the implementation of the flexiramp product will not directly impact FMM prices. While the implementation of the flexiramp product might allow reductions in the

21. See, e.g., ibid. , Figure 1.3, p. 10 and Figure 2.4, p. 37.

flexiramp target that would reduce FMM prices given the unit commitment, such a reduction in the target would also reduce the need commit units to provide ramp, which would tend to raise FMM prices. Reducing the production cost of meeting load while prices do not materially rise or fall would tend to reduce uplift costs as well as production costs. . The bottom line is that implementation of the flexiramp product should reduce production costs and any impact on the level of virtual bidding would be an indirect impact attributable to increased market efficiency, which might either increase or decrease the level of virtual bids.

6. Cost Allocation and Settlement

The CAISO's cost allocation design for flexiramp product balances workability with an approximate allocation of flexiramp costs to the schedules that create the need for ramp capability. The design would implement a number of cost allocation changes that would improve the allocation of flexiramp costs to the sources of variability in net load that create the need for additional ramp capability. In particular, accounting for forecasted ramp in the design and cost allocation processes avoids some outcomes in which movements that reduce ramp requirements would be assigned flexiramp costs. The proposed allocation is a significant improvement over the present approach, because self-schedules that help the system by diminishing net load ramp are also rewarded, while self-schedules that exacerbate net load ramps pay for the additional ramp needs they create in the intervals they create them.

The cost allocation design with charges and payments for scheduled movement in the FMM and RTD in the normal billing cycle, and charges and payments for the uncertainty portion, is somewhat complex because some ramp capability receives compensation in the daily settlements while other capability is paid at the end of the month. However, this design appears to be a reasonable way to accommodate the multiple goals of a) a cost allocation design that recognizes that the CAISO cannot pay for flexiramp until it has been paid by those to whom the costs are allocated; b) avoiding resettlements of an initial cost allocation that would further complicate the billing and settlement process; and c) applying the cost allocation formula over a long enough to avoid anomalous outcomes.

IV. Conclusion

We conclude that the implementation of the flexiramp product design should improve the availability of ramp capability in the real-time dispatch and eliminate the inconsistencies in the current design that will hinder, if not preclude, other potential improvements in the design until these inconsistencies are addressed. It is possible that after the CAISO has accumulated some experience with the operation of the system with the flexiramp product in place it will identify further improvements that could be made relating to the day-ahead market or locational targets. But a necessary first step in moving towards such improvements is to address the inconsistencies in the current design which have already been in place too long and will create more problems the longer they are left unresolved.